HEXAGON

engineering REALITY

Accelerate smart manufacturing

Volume XVII – Issue 2

Leading with sustainability

Issue focus: Supporting sustainability in manufacturing | Plus a range of exclusive customer stories and technical articles

Leadership

Leading with sustainability

By Josh Weiss, President,
Hexagon's Manufacturing Intelligence division

In today's rapidly evolving business landscape, sustainability is no longer a luxury; it is now an imperative. The pivotal role sustainability plays is at the heart of Hexagon's strategy as we underpin our commitment to consistently deliver transformational software and hardware solutions across every stage of the manufacturing process.

For us at Hexagon, championing sustainability goes beyond just embedding it in our operational procedures. Rather, it forms the core of our product development process, shaping the way we assist manufacturers across diverse industries. Supporting manufacturers on their journey to market success from design through to production, quality control, and reporting, requires that sustainability is integral to our strategic vision.

Sustainability begins at design

A sustainable future begins with design. The potential environmental impact of products can be lowered significantly during the design stage, in fact 80% of a product's environmental performance is locked in at this point. Hexagon approaches sustainability challenges with precision, infusing operations from conceptual design to engineered product with thoughtfully-crafted, software solutions that prioritise longevity, recyclability, and energy efficiency. Our tools empower designers to visualise life-cycle impacts and iterate virtually, reducing impact on resources while also identifying opportunities to improve efficiency and implement eco-friendly design early in the production process.

A sustainable approach to production

Hexagon believes that the key to achieving a resilient and sustainable economy lies in the shift towards lean and efficient manufacturing processes. It's a journey that we're not simply observing – we're leading. Our state-of-the-art hardware solutions are optimised for operational

energy efficiency, minimising waste without compromising productivity or quality. We champion manufacturing methods that utilise fewer resources, generate less waste, and can be rectified if errors occur. Investing in technologies like AI and machine learning also contribute to aiding intelligent decision-making, process optimisation and bridging the skills gap impacting many industries. Combined, these capabilities help manufacturers become more competitive, efficient and ultimately more sustainable.

The power of quality control

Sustainable manufacturing isn't just about the initial stages of design and production – it's an end-to-end commitment. Crucial to this commitment is quality control, often an undervalued aspect in the discourse around sustainable manufacturing. By utilising data-driven analytics to monitor and improve the quality of our products, we reduce both the rate of manufacturing errors and the need for costly, resource-intensive remediation processes. Our quality control measures contribute to our sustainability goals by reducing product failures and potential waste, ensuring a robust, efficient, and more importantly, a sustainable manufacturing process.

Transparent reporting: the backbone of sustainability

Transparency is the backbone of any sustainable business model. It fosters trust, enhances credibility, and nurtures stakeholder relations. Recognising this, Hexagon provides manufacturers with comprehensive and transparent reporting tools. Our software solutions allow manufacturers to track their sustainability progress, report on their green credentials, and ultimately evidence their commitment to the environment.

Leading into the future

Steering through the complexities and challenges of the manufacturing landscape today, Hexagon is a preferred technology partner for many top global manufacturers and we remain committed to embedding sustainability throughout our business. We lead the way in empowering makers across all industries operate more efficiently and with greater resilience for a more sustainable future. It is now time for businesses to transcend traditional boundaries and emerge with a forward-thinking perspective on sustainability.

We at Hexagon approach sustainability with great optimism, confident that change-making software and hardware solutions can fuel a future characterised by conscious manufacturing, sustainable developments, and an overall healthier global ecosystem. Our strategy, in essence, is not just about leading with sustainability, but advocating for it as a part of a transformative, global efficiency narrative that substantially contributes to the better future we collectively envision.

Letter from the **editor**

Welcome to the latest edition of Engineering Reality, the magazine that showcases the latest innovations and customer stories from Hexagon's Manufacturing Intelligence division.

In this issue, we're taking a closer look at Hexagon's commitment to supporting sustainability across the world of manufacturing. We've spoken with our sustainability experts to see exactly where Hexagon's efforts are being targeted, from eco-friendly product design and facilities upgrades to quantifying the emissions avoided through the integration of our solutions within manufacturing workflows.

This focus continues into the customer stories included in this issue. We have some interesting new case studies with a sustainability angle, from more sustainable production processes to specific solutions for sustainability-linked industry segments such as eMobility and electric propulsion.

It's great to have the opportunity to dive into these details of how our partners are using our solutions to meet their challenges, in terms of sustainability and beyond. We hope you enjoy reading this issue as much as we enjoyed putting it together.

Happy reading,

Dr Kaustubh (Keb) Nande, Vice President – Global Product Marketing, Hexagon's Manufacturing Intelligence division

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Hexagon's Manufacturing Intelligence division

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Sustainability

Navigating the path to sustainability: Understanding Hexagon's eco-driven missions with a focus on carbon footprint

By Adam Savage, Chief Operating Officer,
Hexagon's Manufacturing Intelligence division

Hexagon, aligned with the highest sustainability standards, is committed to pioneering a responsible and fair approach to environmental stewardship and organisational function. The company diligently supports and endorses the United Nations Global Compact (UNGC) principles pertaining to environment, labour, human rights and anti-corruption. Furthermore, Hexagon acknowledges the necessity of addressing environmental, social, and governance issues throughout every phase of the value chain, upholding the 2030 Agenda for Sustainable Development and the UN Sustainable Development Goals (SDGs).

Hexagon sustainability goals and commitments

Hexagon places importance on reducing greenhouse gas emissions in harmony with a net-zero trajectory, ensuring effective sustainable resource management and waste reduction in various industrial and office settings. Hexagon additionally governs its activities according to the strict chemical safety regulations, such as the EU Directive on REACH while also striving to minimise the environmental impact of its operations and supply chain, specifically on water purity and air quality.

Most importantly, Hexagon gives priority to sustainability integration in all their product designs, development, and production processes. This coincides with a commitment to fostering a culture of mutual respect and fairness among employees, positioning themselves as a corporate role model in handling environmental issues.

The environmental impact

Hexagon has made tangible strides in demonstrating its commitment. A principal testament to this is the company's alliance with the Business Ambition for 1.5°C, setting net-zero carbon emissions objectives that are presently being validated by the Science Based Targets initiative (SBTi). Illustrating significant progress, Hexagon has managed to increase its renewable electricity proportion to 46%.

Sustainability vision for the future

The future of Hexagon is hinged upon extensive sustainability plans. These entail employing an environmental management system compatible with the ISO 14001 certification in majority production facilities, aiming to incrementally grow its renewable energy mix to reach 100%. Hexagon also aims to define a meticulous water management program for sites in high-risk water areas and has set a bold goal to send no waste to landfills by 2030.

A roadmap to net-zero emissions

Hexagon is adamantly committed to achieving net-zero emissions, focusing on reducing total value chain emissions in compliance with a Net-Zero Standard by 2050. The company has plotted a solid plan to curb their Scope 1 and Scope 2 discharges by a striking 95% by 2030.

As part of their transparency, Hexagon has established the baseline emissions comprising Scope 1, Scope 2, and given categories of Scope 3 discharges for comparative assessments with future reductions. For the year 2022, the Total emissions stand at approximately 410,000 tons of CO2 equivalent (TCO2e).

Implementing the CO2 emission reduction pathway

Hexagon's approach toward CO2 emission reduction lies in the formulation of precise roadmaps for each facility, consistent with the 1.5°C scenario guided by the Net-Zero Standard. By 2030, Hexagon aims for a 95% reduction in Scope 1 & Scope 2 emissions, and a 25% cut in their full value chain, while only considering high-quality offsets beyond their net-zero or SBT.

In addressing the CO2 emission challenge, Hexagon has articulately defined four core action areas — product innovations optimised against sustainability criteria, enabling change by empowering stakeholders, improving value chain impact through specific Net-Zero Roadmaps and applicable Sustainable Procurement Programs, and fostering a culture of inclusion and performance driven by social responsibility.

Undoubtedly, Hexagon's dedication to environmental sustainability specifically towards CO2 emissions reduction is not only significant for their operations but sets an example for many businesses globally. Fully aware that sustainability is an ongoing journey, Hexagon continues to streamline its processes, empower its stakeholders, and integrate environmental considerations into its value chain to realise a sustainable future where business and environment coexist harmoniously.

Sustainability

Quantifying avoided emissions: The key to unlocking industrial decarbonisation

By Matthias Schlegel, Product Avoided Emissions Manager,
Hexagon's Manufacturing Intelligence division

As the world faces the urgent challenge of climate change, industries are under immense pressure to accelerate decarbonisation efforts. Manufacturing, automotive, aerospace, and other sectors play a crucial role in reducing greenhouse gas emissions and transitioning towards a net-zero future. However, achieving this ambitious goal requires a comprehensive approach that leverages a company's impact beyond reducing its own carbon footprint.

In this article, we'll explore decarbonisation and the concept of avoided emissions. Then, we'll discuss why quantification is so important and the way that Hexagon approaches it. Finally, we'll look ahead to what the future holds for Hexagon.

A multi-faceted undertaking

Hexagon has made tangible strides in demonstrating its commitment. Decarbonisation is a multi-faceted undertaking that involves a range of strategies and actions. Companies can contribute to a net-zero world in three primary ways.

Decarbonising their inventory by reducing their Scope 1, 2, and 3 emissions, including implementing measures to minimise direct emissions from their operations and indirect from purchased energy and throughout their value chain.

Introducing or financing solutions that contribute to global decarbonisation, generating avoided emissions.

Contributing to carbon sink development through direct removals, indirect removals, or financing of removals.

The concept of avoided emissions

”Avoided emissions” refers to greenhouse gas emissions that are prevented or reduced by implementing specific technologies, products, or solutions — emissions that would’ve occurred without such interventions. By quantifying avoided emissions, companies can gain a deeper understanding of their offerings’ positive environmental impact and make informed decisions that have an impact beyond its carbon footprint.

Quantifying avoided emissions sends a strong message to stakeholders. It demonstrates to customers that Hexagon is actively helping them reduce their environmental impact. For investors, it showcases that Hexagon’s product portfolio is future-proof and aligned with sustainability objectives. Management can leverage avoided emissions data to highlight areas for focused investment and future growth. And product developers gain insight into how their work contributes to the planet’s future and can prioritise solutions with the greatest potential for decarbonisation.

The importance of quantification

Quantifying avoided emissions is critical in supporting corporate accountability, driving innovation, and prioritising solutions that contribute to net-zero targets. Without accurate quantification, it becomes challenging for companies to assess the impact of decarbonisation initiatives and make strategic decisions that align with sustainability goals.

Enabling transparency and accountability

Quantified avoided emissions reporting fosters transparency and accountability toward external stakeholders, including customers, investors, and regulatory bodies. By providing tangible evidence of the environmental benefits of their products and solutions, companies can demonstrate their commitment to sustainability and build trust among stakeholders. This transparency allows stakeholders to make informed decisions and hold companies accountable for their decarbonisation efforts.

Guiding innovation and product development

Quantifying avoided emissions serves as a guiding metric for innovative processes and product development efforts. By identifying solutions with a high potential for avoiding emissions, companies can prioritise investments and allocate resources toward the most impactful products. A data-driven approach aligns research and development efforts with sustainability objectives, ensuring new products and solutions prioritise decarbonisation.

For example, Hexagon’s Manufacturing Intelligence (MI) portfolio focuses on two key areas: product design and manufacturing. In product design, solutions such as Emendate enable optimising products for weight. At the same time, Adams, VTD, and Simufact Forming allow companies to replace physical prototypes with digital twins and real-world tests with simulations. And Odyssee helps reduce computational efforts.

In manufacturing, Hexagon's solutions avoid emissions in several ways:

- Metrology devices and software minimise scrap and rework
- RADAN and ALPHACAM reduce waste
- Production software solutions optimise energy consumption
- NCSIMUL extends machine lifetimes
- ETQ Reliance enables paperless operations

By quantifying the avoided emissions associated with these solutions, Hexagon can prioritise our development and deployment to maximise our positive impact on societal emissions.

Informing strategic portfolio decisions

As companies strive to future-proof their product portfolios, quantifying avoided emissions becomes crucial for strategic decision-making. Solutions with a proven ability to contribute to global decarbonisation will likely experience increasing demand in a carbon-constrained world. By prioritising and scaling up these solutions, companies can position themselves for long-term success while actively supporting the transition to a net-zero economy.

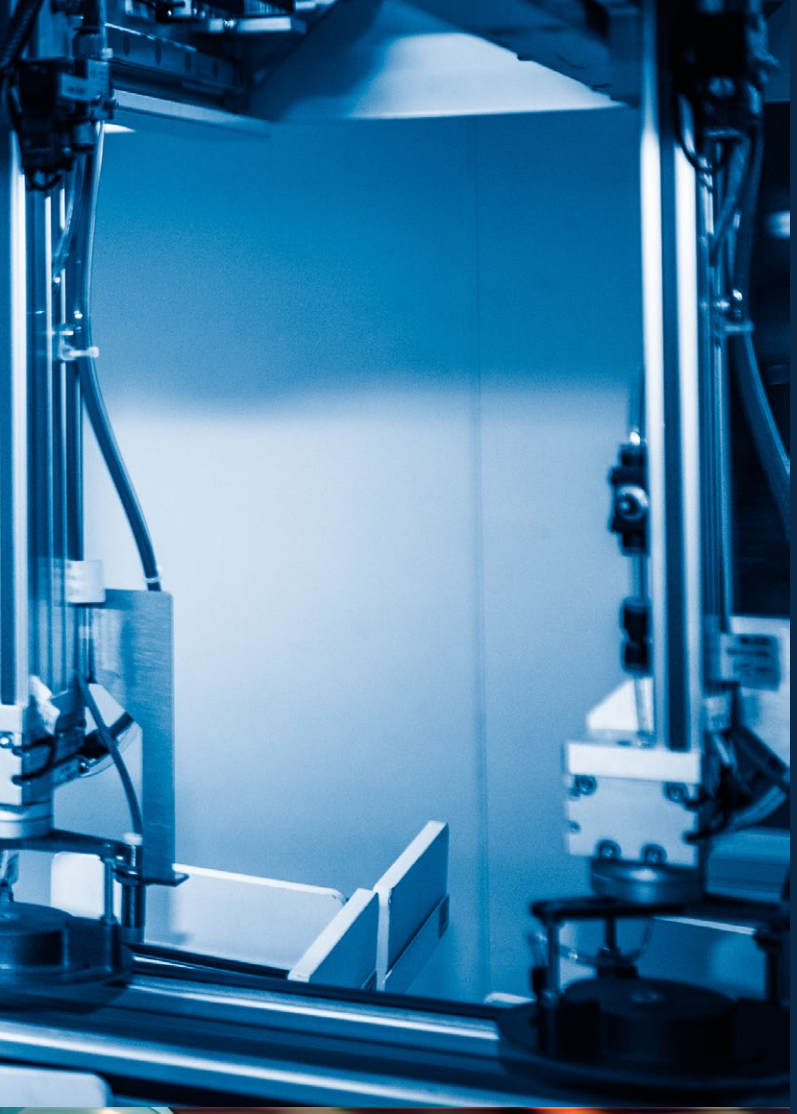
Hexagon has identified specific product lines and solutions with the greatest potential for providing customers with quantifiable avoided emissions. For example, Applied Solutions has designed a wind turbine gearbox used in approximately 50 projects with wind turbine gearbox suppliers and original equipment manufacturers (OEMs). This solution is estimated to contribute the majority of avoided emissions for Hexagon's MI division.

Hexagon's approach to quantifying avoided emissions

At Hexagon, we recognise the pivotal role our products and solutions play in facilitating decarbonisation across industries. As a leading digital reality solution provider, we're committed to quantifying the avoided emissions associated with our offerings, empowering our customers to make informed decisions, and driving sustainable practices.

Identifying eligible customer scenarios

When selecting customer use cases, Hexagon focuses on three main criteria:



Representative
The use case should be representative in terms of region, industry, and customer type, which simplifies scaling to a product level.

Data sharing
The customer's willingness to contribute data is essential, and Hexagon has had positive experiences in this regard so far.

Clear mechanism
It's easier to quantify avoided emissions when there is a clearly understood mechanism for avoiding emissions.

To prioritise customer use cases for different products, Hexagon also considers product revenue, as avoided emissions must be reported in the context of product revenue. The approach is to choose between one and three representative use cases per product, generalise the underlying mechanisms for avoiding emissions, and then scale it up to a product level.

In some cases, avoided emissions heavily depend on the specific use case, and scaling to a product level isn't feasible. In such situations, Hexagon employs project accounting, where each project is evaluated individually.

For example, the previously mentioned wind turbine gearboxes exemplify this approach, as the gearbox design can't be scaled to other applications like vehicle gearboxes. In contrast, solutions like Emendate that help reduce gearbox weight can be scaled across different industries, as less weight translates to less material required for production, regardless of the specific application.

Implementing a robust quantification process

Hexagon follows a rigorous five-step process outlined by the World Business Council for Sustainable Development's "Guidance on Avoided Emissions."

1. **Identify the timeframe, which can be either forward-looking or year-on-year**
   Forward-looking quantification considers avoided emissions for the complete lifetime of the solution. In contrast, year-on-year quantification focuses on avoided emissions for the reporting year only. The choice usually depends on the business model — for solutions with recurring revenues, a year-on-year approach is preferred. In contrast, a forward-looking approach is used in all other cases.

2. **Define the reference scenario**
   Avoided emissions are a relative metric that quantifies the current solution scenario's benefits against the most likely alternative, known as the reference scenario. For the reference scenario, Hexagon distinguishes between four options: new demand with no previous solution, new demand with a competitor solution, replacement of an existing solution, and

improvement of an existing solution. For avoided emissions, the cases of new demand with no previous solution and improvement of an existing solution are particularly relevant.

3. **Assess lifecycle emissions for the solution and reference scenarios**
   This assessment involves considering emissions throughout the product or solution's lifecycle, from raw material extraction to end-of-life disposal.

4. **Calculate avoided emissions as the difference between the solution and reference scenarios**
   This calculation quantifies the net impact of the solution in terms of emissions avoided compared to the alternative scenario.

5. **Scale the avoided emissions to the company level, aggregate them, and report the results**
   It's crucial to separate avoided emissions from the company's carbon footprint, as avoided emissions can't be compared to or used to offset a company's emissions.

Leveraging competitive advantages

Hexagon has gained a competitive advantage by quantifying avoided emissions in supporting industrial decarbonisation. We can provide our customers with valuable insights into the impact of our solutions on their carbon footprints, allowing them to identify additional ways to decrease their emissions. Additionally, we can better understand the sustainable value propositions of our offerings, allowing us to focus investments on strengthening these value propositions and fostering growth in relevant solutions.

And by actively supporting customers in their decarbonisation journeys, Hexagon can build long-term relationships and establish itself as a trusted partner. This support enhances customer loyalty and creates opportunities for collaboration and the co-creation of innovative solutions that drive industry decarbonisation.

Looking ahead: Scaling up

Hexagon has already made significant progress in prioritising solutions within the Manufacturing Intelligence and Asset Lifecycle Intelligence divisions. We see these divisions as starting points for implementing the quantification methodology and establishing best practises that we can replicate across other divisions.

Our approach to scaling up involves identifying representative customer use cases, quantifying avoided emissions for these specific scenarios, and then generalising the underlying mechanisms to scale the results to a product level. Doing so will allow us to efficiently assess the avoided emissions potential of our entire product portfolio without analysing every use case.

The goal is to report the aggregated avoided emissions at the company level, providing a comprehensive view of our contribution to global decarbonisation. This company-wide metric will serve as a powerful tool for communicating our sustainability impact to stakeholders and guiding strategic decision-making.

At Hexagon, we recognise that solutions with a high potential for avoiding emissions aren't just environmentally beneficial — they're commercially viable in a world increasingly focused on decarbonisation. By prioritising the development and deployment of these solutions, our company aims to secure its future business success while actively contributing to the transition to a net-zero economy.

Additionally, by quantifying avoided emissions and demonstrating the sustainability value of its solutions, we can attract environmentally conscious customers and investors. As stakeholders increasingly prioritise sustainability in their decision-making, our ability to provide quantifiable evidence of our decarbonisation impact becomes a critical competitive advantage.

Sustainability

Decarbonisation of Hexagon products: Implementing Life Cycle Assessment and eco-design practices

By Eva Carranza, VP Head of Sustainability, Hexagon AB

As the impacts of climate change accelerate, sustainability has become a key focus for companies across all industries — and Hexagon is no exception. In fact, decarbonising products and implementing eco-design practises are two of our company's most critical priorities. We believe that by leveraging Life Cycle Assessment (LCA) methodologies already at the early development phases of our projects, we'll be better able to quantify the environmental impacts of our products and use those insights to drive sustainability improvements.

In this article, we'll discuss the role that LCA plays in Hexagon's sustainability efforts. We'll also highlight the four phases of LCA, explore its impact, learn more about how Hexagon translates LCA insights into design, and discover Hexagon's vision for an LCA-empowered future.

Why LCA is critical for Hexagon's sustainability progress

Hexagon, a frontrunner in digital reality solutions, understands that sustainability is essential not only for our continued success but also for tackling the critical environmental issues threatening our planet. To effectively manage and improve our sustainability performance, we need a robust, science-based tool that can provide comprehensive and reliable insights into the environmental impacts of our products. And that's where LCA comes in.

LCA allows us to efficiently and effectively improve the environmental performance of our products in several key areas:

- New product development: LCA clearly explains how different materials, processes, and geometries affect a product's overall environmental performance, allowing us to make informed decisions during the design phase
- Regulatory compliance: The growing strictness of environmental regulations requires companies to disclose their products' environmental impact. LCA equips Hexagon to meet these requirements
- Supply chain management: LCA empowers our supply chain managers to consider sustainability criteria when selecting suppliers and logistics partners
- Marketing and sales: By considering an LCA approach when quantifying the avoided emissions that our solutions bring during their use phase, we can showcase our competitive edge in sustainability performance to customers
- Strategic sustainability management: LCA insights support management in prioritising company-wide sustainability initiatives that are most cost-effective, such as in which components should be given higher priority.

By leveraging LCA throughout the product lifecycle (from material sourcing to disposal), we can gain a comprehensive understanding of our environmental impact. This holistic view enables us to pinpoint areas for improvement and make data-driven decisions that demonstrably advance our sustainability goals.

The four phases of LCA

To conduct a comprehensive, scientifically rigorous LCA, we follow the standardised methodology outlined in the ISO 14040 and 14044 standards. This systematic approach consists of four key phases that guide the assessment process from start to finish:

- Goal and scope: First, we specify the LCA study's boundaries and objectives. We define the product or process to be assessed, state the purpose of the study, identify the intended audience, and select the metrics for quantifying the environmental impacts. During this phase, we also make key decisions regarding the system boundaries, functional units, data requirements, assumptions, and study limitations.
- Inventory analysis: Next, we compile a detailed inventory of all materials and energy consumed, as well as waste, emissions, and byproducts generated at each stage of the product's lifecycle, from raw material extraction through manufacturing, distribution, use, and end-of-life. In phase two, we also collect and quantify the

resource inputs and environmental outputs, creating a comprehensive dataset that forms the impact assessment's foundation.

- Impact assessment: In phase three, we classify the inventory analysis inputs and outputs into specific environmental impact categories — like climate change, water scarcity, or cumulative energy demand. Then, we apply standard impact assessment methods to convert the inventory data into comparable units within each impact category. Essentially, we translate the inventory data into meaningful environmental metrics that allow us to quantify and interpret the potential environmental impacts.

- Interpretation: Finally, we analyse the impact assessment results, determining the most significant environmental hotspots across the product lifecycle. During phase four, we also assess the results' completeness, sensitivity, and consistency while acknowledging the study's inherent limitations and assumptions. Once our analysis is complete, we interpret the findings in the context of our original goals and scope, drawing meaningful conclusions. Lastly, we translate LCA insights into actionable recommendations for improving environmental performance.

This structured four-phase approach delivers consistent, transparent, and reliable LCAs, empowering informed decision-making and driving environmental performance improvement.

Focusing on key impact areas

While LCA provides a comprehensive framework for assessing a wide range of environmental impacts, at Hexagon, we focus on three key impact categories that align with our sustainability priorities and the most pressing global environmental challenges: climate change, water use, and cumulative energy demand.

1. Climate change, measured in kilogrammes of CO2 equivalents, is currently the most widely discussed impact category. Regulators are pushing organisations to disclose their CO2 equivalent climate impacts, with some jurisdictions implementing mandatory reporting requirements. Given this regulatory pressure and the urgency of the climate crisis, we prioritise the climate change impact category.

2. Water use, measured in cubic metres of water scarcity, tracks the water consumption throughout the lifecycle of our products. This impact category provides insights into how our products and processes affect water availability.

3. Cumulative energy demand quantifies the total energy, in joules or megajoules, required to produce a product. This impact category lets us assess our products' energy intensity and identify opportunities for efficiency improvements.

Translating LCA insights into eco-design decisions

One key way we use LCA at Hexagon is to help inform our component selection in product design. For example, when our engineers can use virgin raw materials or recycled alternatives that provide the same functionality, LCA allows us to quantify the environmental benefits of each choice.

LCA allows us to move beyond hunches or best guesses by tangibly quantifying our environmental savings with actual numbers. This data lets our engineers and managers make informed choices — like when it's worth compromising on cost to be more environmentally beneficial — based on the LCA results.

In essence, LCA empowers Hexagon to consider different alternatives. Challenges often arise when a product's sustainability conflicts with other criteria like cost or quality.

However, LCA allows us to quantify these trade-offs—for instance, showing us that reusing major components at the end of their lifetime use may raise costs slightly but deliver a significant reduction in environmental impact.

Future vision: Scaling LCA across the value chain

We're still early in our LCA journey at Hexagon, but we have a clear vision for the future.

In the short term, our focus is on driving internal adoption. Our first milestone is to reach a point where the LCA process is well established, and employees widely recognise it as the go-to solution for understanding if our actions are beneficial or detrimental in terms of environmental impact.

In the long term, we plan to extend LCA insights across our entire value chain, including suppliers, with our ultimate goal being to cover the entire product lifecycle. We're starting with what we know and making assumptions about the unknowns but gradually working to replace assumptions with actual supplier data.

We envision a future where our suppliers and us can one day provide environmental impact data the same way cost information is provided today. Eventually, anyone should be able to request the environmental 'price' of a component, just like we ask for the price in dollars.

A powerful tool

As we continue to scale LCA across our value chain and embed it into our decision-making processes, we believe it will become an increasingly powerful tool for driving sustainability improvements and reducing our environmental footprint. By engaging with our suppliers and working toward a future where environmental impact data is as readily available as cost information, we can create a more transparent and accountable supply chain.

Ultimately, Hexagon's goal is to establish LCA as an integral part of our business strategy, empowering us to make informed choices that benefit both our company and the planet. While we recognise that this journey will take time and effort, we are committed to leading the way — and setting an example for others in our industry to follow.

Sustainability

Hexagon's commitment to sustainability: A journey towards carbon neutrality and self-sufficiency

By Will Durfee, SVP Global Operations,
Hexagon's Manufacturing Intelligence division

Building upon our commitment to sustainability, we at Hexagon have been significantly upgrading our facilities worldwide to conserve resources, reduce waste and leverage renewable energy. These efforts span several locations, including Hongdao in China, Huntsville in the United States and Wetzlar in Germany, as part of a broader pledge to enable sustainable operations across all our locations.

In this article, we'll explore decarbonisation and the concept of avoided emissions. Then, we'll discuss why quantification is so important and the way that Hexagon approaches it. Finally, we'll look ahead to what the future holds for Hexagon.

Wetzlar, Germany: Flagship factory in sustainability efforts

Hexagon's Wetzlar factory in Germany is at the forefront of the company's commitment to sustainability and embodies their ambitions towards innovation, sustainability, and corporate responsibility. With approximately 465 employees, the factory has set the ambitious goal of achieving carbon neutrality and self-sufficiency.

The construction of a solar park, equipped with photovoltaic panels boasting a capacity of 1.5 MWp and battery storage capabilities of 800kWh, is a pivotal achievement. Such efforts have enabled Wetzlar to operate independent of external energy sources for a significant portion of the year, resulting in a 60-70% annual carbon reduction. The facility also introduced initiatives to enhance energy efficiency, such as electric vehicle charging stations catering to the emerging demand for electric mobility, and transitioned to a 100% renewable energy contract in 2020 for both gas and electricity consumption.

Hexagon's Wetzlar factory underscores the company's commitment to a sustainable future, with plans to further its efforts by completing the installation of its photovoltaic cells, battery storage, and heat pump systems. The company is also exploring cutting-edge solutions like Bosch hydrogen fuel cell technology.

Hongdao, China: A blueprint for future facilities

In Hongdao, China, Hexagon has both expanded and improved one of its larger sites, aiming to develop a blueprint for future sustainable production sites. This facility, boasting more than 200 R&D engineers and a manufacturing area that spans 35,000m2, has been certified as carbon neutral since 2020. The site stands out for its usage of local panels for renewable energy needs, which accounts for 80% of its total energy requirement.

Their dedication to conserving water is evident in their initiative to recover and reuse rainwater. This not only supplies for their needs but also fosters the biodiversity in its green areas. Waste management here is a success too, with zero waste being diverted to landfill. Furthermore, the facility has recycled more than 65% of the total waste generated in production as of 2023.

Huntsville, United States: Green initiatives to reduce carbon footprint

Meanwhile, in Huntsville, US, Hexagon has committed to several green initiatives aimed at reducing its carbon footprint. During 2023, the company purchased Renewable Energy Credits (RECs) covering 100% of the facility's electricity consumption. An exciting shift has also been the transition of their car fleet to hybrid and electric vehicles. They have eliminated chemical treatments from their turf maintenance, reinforcing their commitment to environmental safety. Looking forward, the Huntsville location is planning to complete its first solar project by 2024 and is also investigating the feasibility of a larger solar project for the next three to five years.

Facilities for a more sustainable future

Hexagon's dedication to sustainability is illustrated by the comprehensive measures they have implemented at their facilities across the world. With tangible actions such as increasing renewable energy consumption, reducing waste, capturing rainwater for reuse, and exploring possibilities in energy storage and generation, Hexagon is not only demonstrating its corporate responsibility, but also leading the way in how businesses address their impact on the environment.

Sustainability

R-evolution: Fostering technological innovations to fast-track green-tech ventures

By Erik Josefsson, CEO, R-evolution

As the CEO of R-evolution, a business division of Hexagon, I am delighted to shed light on our work, designed to further sustainable change. At the heart of our mission is the importance of turning profit-driven investments into green-tech opportunities. Utilising Hexagon's technologies, we focus on transforming businesses in a way that gives back to the environment and supports societal betterment. Undeniably, our initiatives in renewable energy, blue carbon ocean projects, desalination and biodiversity conservation have left a significantly positive business impact, mostly evident in the crucial sustainability contributions we made in 2023.

Solar-powered solutions for a thirsty world

One exciting venture has been our strategic partnership with Desolenator, a Dutch start-up leading the development of solar thermal desalination processes. By harnessing solar energy, clean, desalinated water becomes a reality, erasing the digital shadow of environmental harm. Desolenator's patented solution sets itself apart by eliminating damaging chemicals, membranes, and energy intermittency, typically prominent in reverse osmosis methodologies.

At R-evolution, we're accelerating the optimisation of Desolenator's process by digitally mirroring the desalination process for superior monitoring and asset performance management. This is achieved via Hexagon's state-of-the-art Smart Digital Reality solutions. Our partnership's end goal is clear: ensure affordable, sustainable and reachable fresh water for all by 2040. We're striving to create a future where clean water scarcity is no longer an issue.

A tech-driven approach to biodiversity conservation

In pursuing biodiversity conservation, R-evolution launched Green Cubes where the inaugural partner is La Gamba Tropenstation part of the University of Vienna's Department for Botanic and Biodiversity studies. From its inception in La Gamba, Costa Rica, this forest initiative strives to expedite biodiversity conservation of rainforests globally.

Green Cubes takes a ground-breaking approach, merging technology and science to keep rainforest conservation more valuable than its alternatives. Employing the Green Cubes Methodology, we utilise earth observation, airborne LiDAR, soil DNA analysis, camera traps, and passive acoustic sensors to monitor rainforest development in an urgent bid to preserve the biodiversity of our planet. Green Cubes offers an excellent opportunity for businesses to contribute to biodiversity conservation and meet their ESG engagement goals.

Lighting the path to renewable energy

Our collaboration with Google Cloud to digitalise renewable production allows us to use R-evolution's 16.44 MWpl solar park in Spain as a stage to display our joint offering combining Hexagon sensors and software with Google technology. Google Cloud Data Lake boosts speed of innovation, and when combined with our data analytics expertise, we aim to make solar power more profitable whilst actively fighting CO2 emissions.

This partnership is but a stepping-stone in our broader efforts to disrupt energy production with the power of data, making it more efficient, accessible, and sustainable. It represents the leaps we aim to continue making to accelerate the transition towards renewable energy and a greener, cleaner world.

R-evolution remains relentlessly committed to fuelling sustainable change, one innovative partnership at a time. Through this continuous development and dynamic collaborations, the potential of the renewable blueprint for solar energy production and beyond is boundless.

OneMI

Science meets surf: The sustainable future of surfboard manufacturing

By Benoit Coudray, Global Business Enablement Director, Hexagon's Manufacturing Intelligence division

In 2019, two surfer friends and engineers, Sylvain and Léo, decided to combine their athletic experience with their engineering expertise to revolutionise surfboard manufacturing. The two founded WYVE with a simple premise: revolutionising surfboards by taking a scientific approach.

By investing their savings in research and development, they were able to design and build their first prototype: a hexagonally-shaped surfboard optimised for flexibility. Committed to environmentally friendly standards, they used 3D printing technology for their project. This technology offered them greater freedom in selecting bio-sourced materials.

Equipped with their first three prototypes, Sylvain and Léo headed to California, the epicentre of surfing culture and innovation. There, they met renowned shapers, acclaimed surfers and industry experts who shared their vision and offered expert advice to help them fine-tune their approach.

> **Thanks to its digital twins, WYVE can recreate exactly the same surfboard when it breaks during a competition, for example. This core technology is unique in the world and at the moment they are the only ones who can offer it. That's why the company is receiving funding from European institutions."**
>
> – Benjamin Ostré, Academic teacher/researcher at SEATECH engineering school

In France, WYVE realised they couldn't offer competitive prices for their boards. Solving this involved bringing the entire innovation and manufacturing process in-house. That's how their idea for the 'micro-factory' was born: a delicate balance between cutting-edge technology and expert artisan skills.

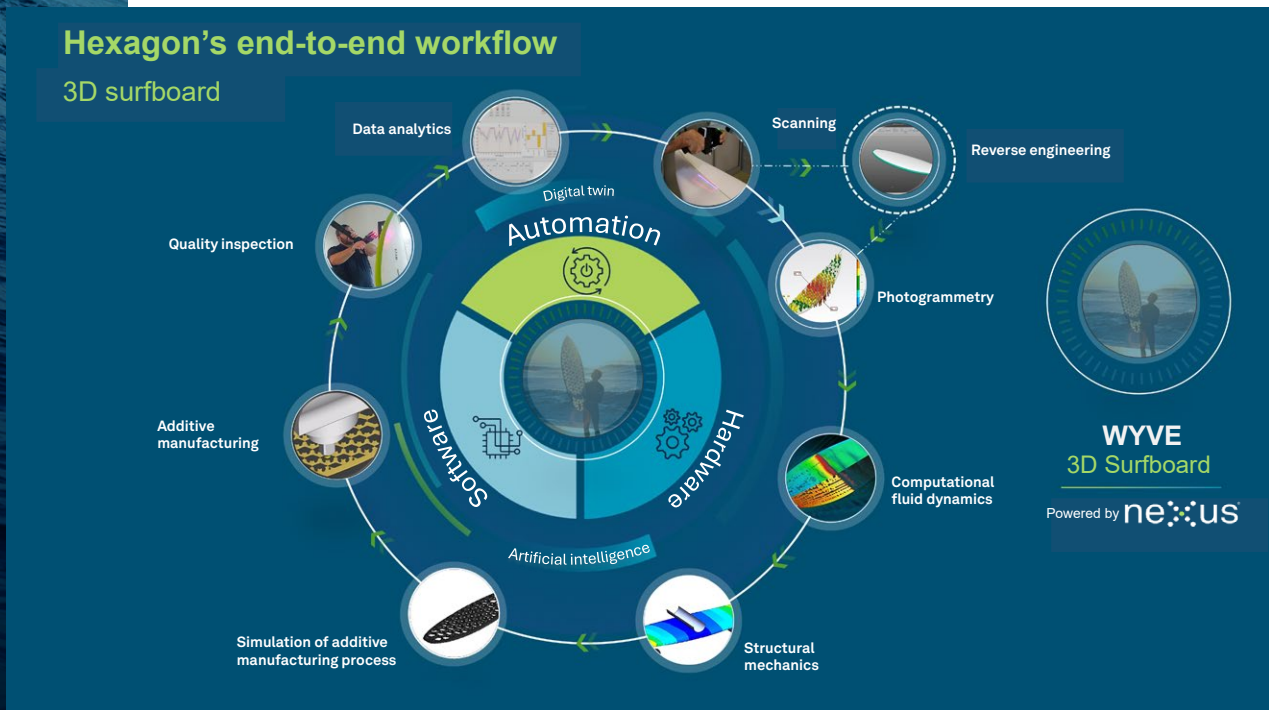
They set up shop in Anglet, in the heart of the Basque Country, and invested their funds in their first 3D printer. Their ultimate goal was to produce hundreds of customised sustainable boards.

Pushing the boundaries of peak performance

Today, WYVE's passion for innovation and commitment to excellence stands out within the surfing community. The organisation pushes the boundaries of performance in the field of surfboard design, relying on cutting-edge, environmentally friendly technologies.

Creating a better surfboard through a scientific approach involved making many prototypes and obtaining extensive customer feedback.

To do this, WYVE hired several material and numerical calculation experts and called upon SEATECH, an engineering school based in Toulon, France, to help optimise the manufacturing process.



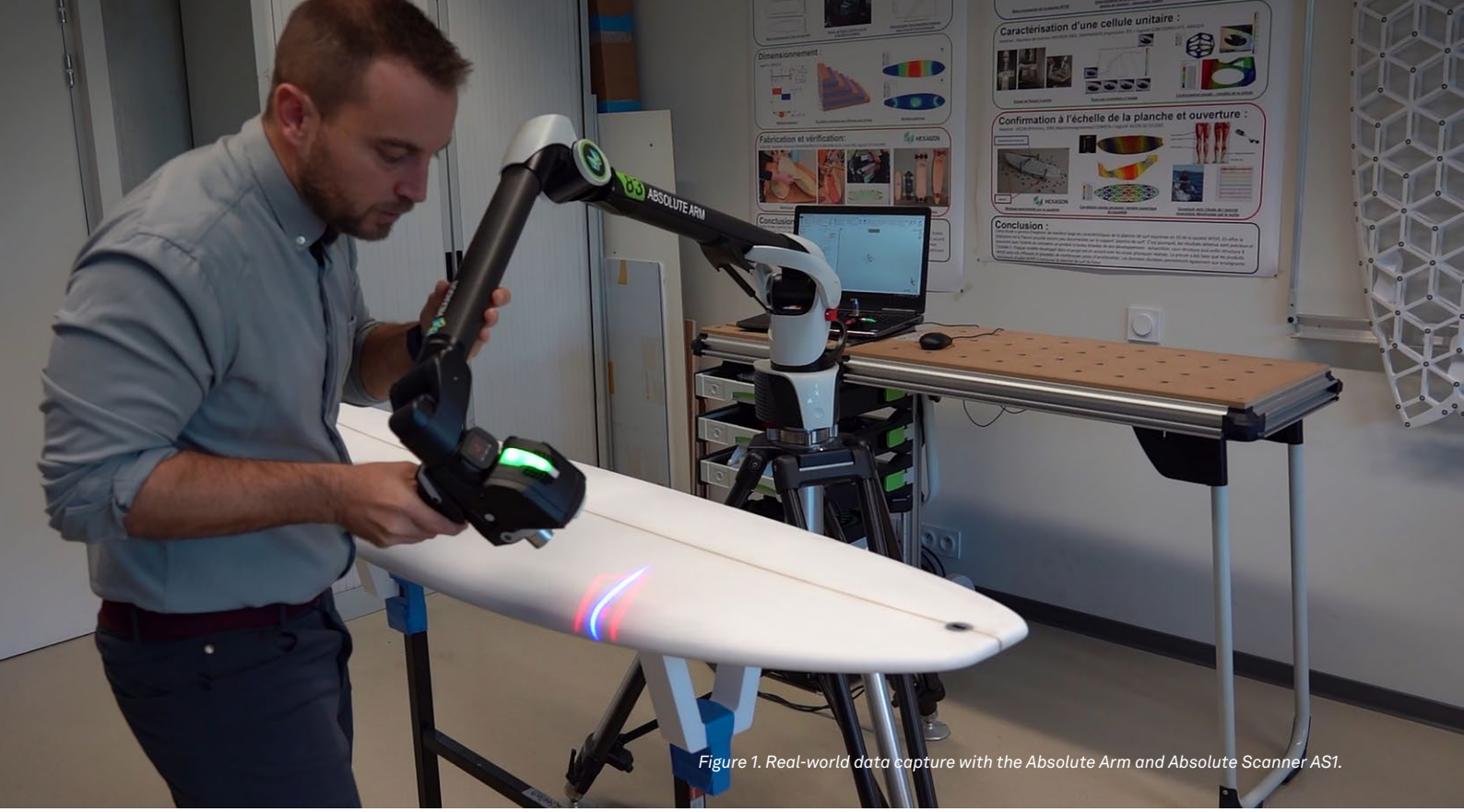


Figure 1. Real-world data capture with the Absolute Arm and Absolute Scanner AS1.

Hexagon and WYVE: Working together for sustainability

To create a sustainable surfboard production process that would work for WYVE, SEATECH leveraged Hexagon's expertise.

The team defined an end-to-end workflow that used Hexagon's software and hardware solutions at every stage. That included everything from capturing real-world data to design and validation, ensuring manufacturability and optimisation, production and, finally, quality inspection and reporting.

What follows is the complete workflow SEATECH and Hexagon engineers defined for creating WYVE's cutting-edge surfboard design, including a breakdown of how the company used Hexagon's technology at each stage.

Stage 1: Real-world data capture

The process begins with transforming real-time data about the initial surfboard design into digital data. The surfboard has tight tolerance requirements, and therefore requires extensive scanning to obtain a good profile for reverse engineering. Given the extensive number of design changes, frequent reprogramming is required.

To obtain the precise data required to meet strict tolerance requirements and perform quality analyses, WYVE uses Hexagon's Absolute Arm. This all-in-one, user-friendly portable measuring arm enables fast and accurate 3D measurement that can be carried out in the design offices or on a production floor. It can be used for a wide range of tasks in challenging environments, from high-accuracy probing to high-speed 3D scanning. The Absolute Arm is fitted with an Absolute Scanner AS1 that can capture fine details that require high accuracy.

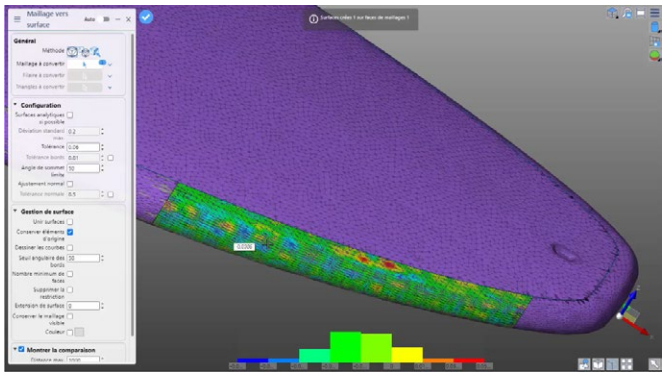


Figure 2. Reverse engineering data analysis in DESIGNER.

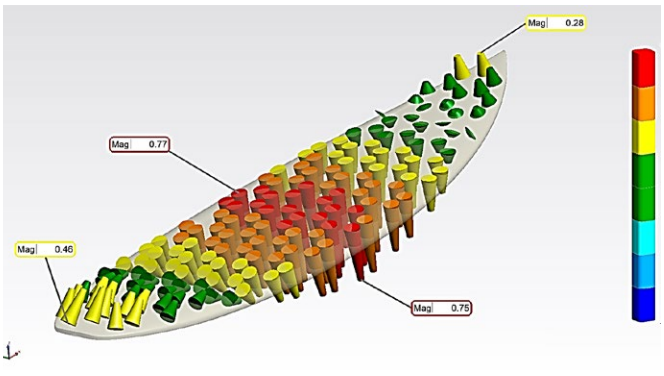


Figure 3. Deformation simulation using shop-floor photogrammetry.

Stage 2: Design and validation

To ensure the design of each part of the new surfboard is as close as possible to the original scanned part, WYVE will need to get a real part into the CAD system.

This can be done by using Hexagon's portable measuring arm together with its DESIGNER software's REcrreate module, a dedicated reverse engineering solution that provides a powerful and vital set of capabilities designed to streamline the reverse engineering process. The program's features allow the integration of real parts into the CAD system while also maintaining the precise design parameters of the real-world surfboard model.

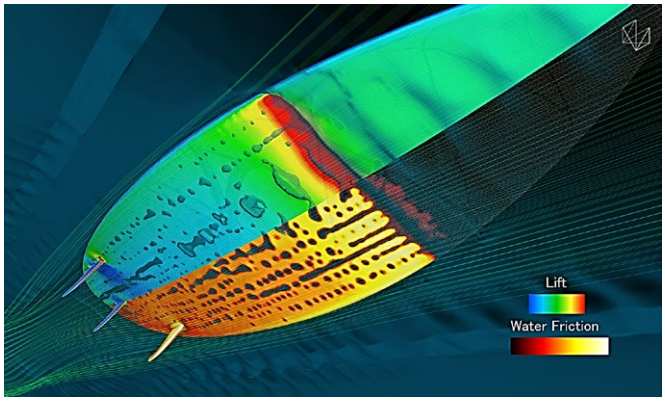


Figure 4. Computational fluid dynamics analysis in Cradle.

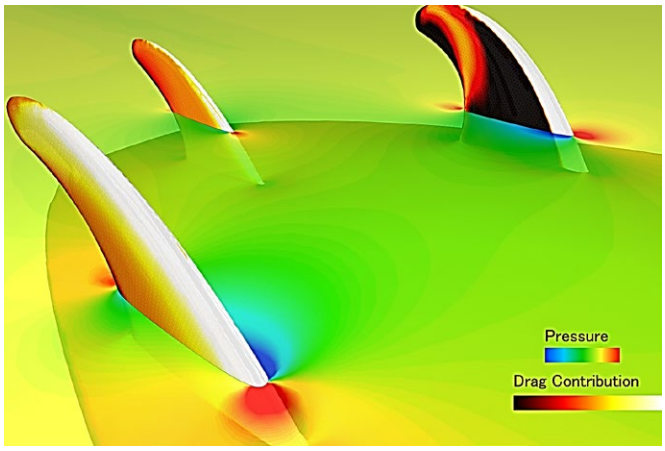


Figure 5. Analysis of individual section contributions to drag and lift forces.

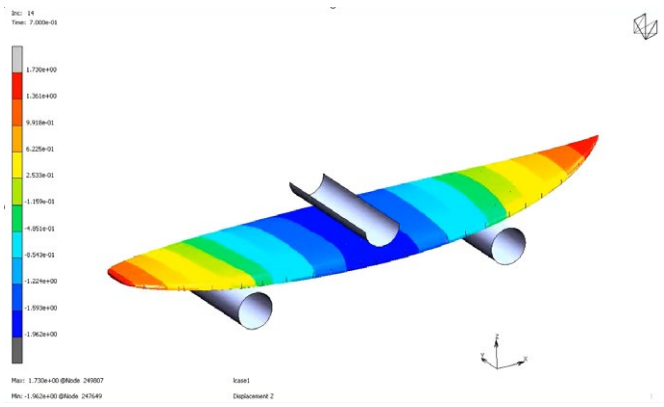


Figure 6. Structural analysis using virtual testing in MSC Marc.

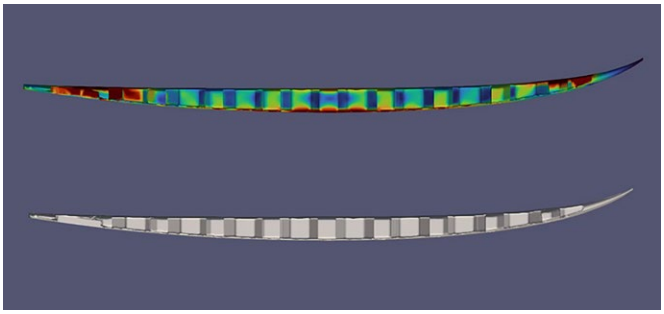


Figure 7. Optimising structures in advance of production with Apex GD.

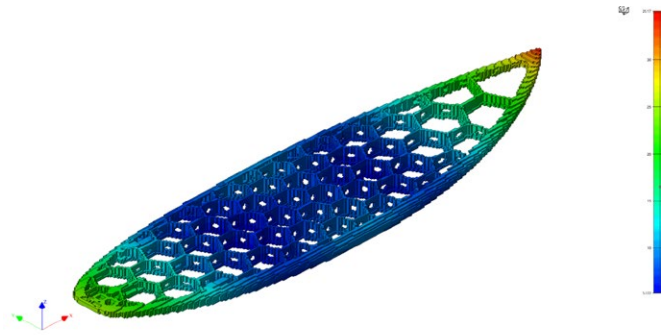


Figure 8. Digimat software simulates the additive manufacturing process.

Stage 3: Ensuring manufacturability and optimisation

To assess the behaviour of the board under strain, the next step in the process goes back to the real-world model and calls on the use of Hexagon's DPA Series photogrammetry solutions to measure deformations and track strategic points.

The speed and flexibility of this measurement technology allow for efficient deformation analyses on components that make it possible to solve measurement tasks with high precision and speed while ensuring that the test object remains unchanged through a non-contact measurement process.

Given that the ideal characteristics of surfboards vary depending on the ride scenario, the WYVE team need a solution capable of finding a balance between these characteristics on each different section of the surfboard. While tricky to figure out, Hexagon's Cradle CFD software offers the perfect solution for analysing each section of the board individually to optimise its hydrodynamic characteristics. The data from Cradle provides a thorough overview of all possible configurations and allows each section of the board to be optimised separately. This kind of analysis is vital for accelerating the learning process and capturing significant efficiency gains.

To validate the flexibility of the boards, the next step in the process calls for Hexagon's Marc software, which delivers virtual static and dynamic structural analysis testing capabilities. This would give the team fast answers to specific "what if" analyses and allow them to extend the tests to other types of loads.

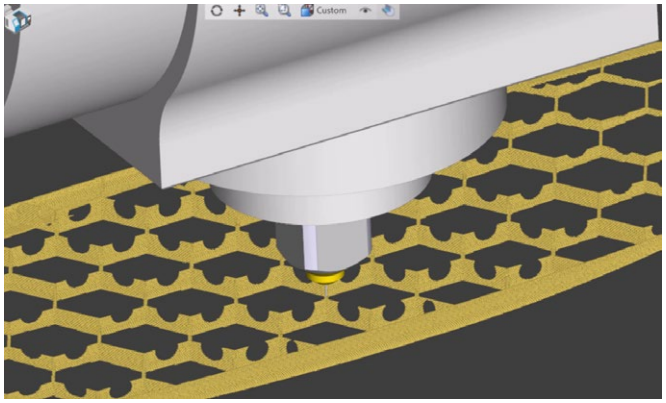


Figure 9. Espirit EDGE software manages additive manufacturing preparation.

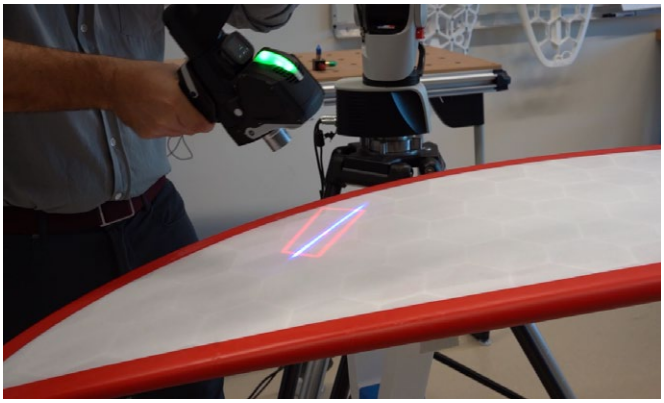


Figure 10. Quality inspection with the Absolute Arm and Absolute Scanner AS1.

For the final part of this stage of the process, the team would need to reduce the mass of the surfboard and build a customised surface.

Using Hexagon's Apex Generative Design software allows a design team to determine load paths while still considering manufacturing constraints. This is the key to optimising the mass and stiffness of the surfboards while also offering the innovative board shapes that have helped cement WYVE's reputation as a producer with a unique aesthetic.

Stage 4: Production

Printing the surfboard using the fused filament fabrication (FFF) process is a true multi-scale challenge. Process parameters such as temperature, material and tool-path properties can influence the quality of printed parts, so it is important that everything is calibrated correctly.

Hexagon's Digimat software, an additive manufacturing and simulation solution, has the facility to leverage material usage to its full potential, including improving sustainability measures by making sure the design is printed right first time. It also helps estimate printing costs and optimise process parameters to enable lightweight product design and reduce waste.

Finding the right part orientation, developing the right supporting structure and maximising printing throughout production, all while also maintaining quality, are key challenges. Hexagon's ESPRIT EDGE software optimises orientation based on printing time, material usage and the risk of distortion. That results in a wide choice of supporting structure types and options that can meet even the most advanced requirements.

Stage 5: Quality inspection and reporting

For quality control, the process once again comes back to the Absolute Arm and Absolute Scanner AS1, combined with Inspire software — a comprehensive portable metrology solution designed to simplify the process of taking measurements to save time and improve productivity.

This solution allows the team to import and use all native CAD formats with minimal training required – they are now able to compare each printed part to the original design to ensure it meets requirements.

Reporting these results is the final step. While many reporting tools available on the market are slow and convoluted and offer limited access to data, Hexagon's Metrology Reporting software offers a modern user experience. Providing easy and secure access to centrally stored data, it enables faster and more confident decision-making and allows secure access to data at any time, from anywhere, to increase efficiency and reduce errors.

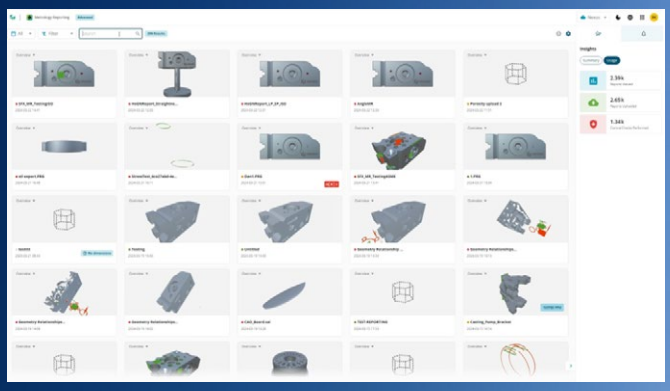


Figure 11. Metrology Reporting provides a wide range of useful measurement report options.

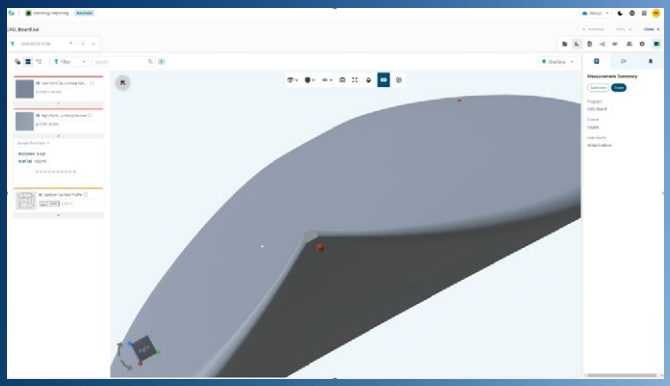


Figure 12. Comprehensive reports support faster and more confident decision making.

Offering superior quality products through collaboration

Collaborating with Hexagon and SEATECH has helped WYVE make a significant start on their journey to optimising the additive manufacturing process that will enable them to create a unique and sustainable surfboard from a 3D model using 3D printers. This puts them in the perfect position to offer superior quality products designed to meet the specific needs of the most demanding surfers.

With the integration of advanced scanning, reverse engineering, simulation, production and inspection solutions from Hexagon, WYVE are ready to push the boundaries of innovation by creating an ultra-performing and durable surfboard ideal for expert surfers across the world.

Digital Materials

Hexagon helps RadiciGroup deliver high-performance parts

By Claudio Ghilardi, CAE Analyst, Marketing and Technical Service
RadiciGroup High Performance Polymers,
and Hédi Skhiri, Technical Specialist Lead, and Marco Veltri,
Business Enablement Manager, Hexagon's Manufacturing Intelligence division

Hexagon and RadiciGroup collaborated to develop a lightweight and durable rear swing arm for eBikes, using innovative design, sustainable materials and advanced technology tools to deliver a transition from metal to plastic construction.

With approximately 3,000 employees, a turnover of 1,542 million euros in 2022 and a network of production units and commercial offices located across Europe, North and South America and Asia, RadiciGroup is today a world leader in the production of a vast range of chemical intermediates, polyamide polymers, high-performance technopolymers and advanced textile solutions, including nylon yarns, polyester yarns, yarns from recovery and bio sources, nonwovens and protective devices in the healthcare sector.

The company develops products for multiple industrial sectors, including automotive, electrical and electronic, consumer goods, clothing, furniture, construction, household appliances, and sports.

RadiciGroup High Performance Polymers is one of the most highly regarded multinational manufacturers and suppliers of technopolymer compounds and can rely on a global team including applications development, technical service and R&D, capable of providing their customers with the highest professional support throughout all project phases, from conceptual design to engineering and production.

Challenge: Replace a metal eBike part with a light, strong plastic

Acerbis, a leader in aftermarket motocross plastics, bike protection, and accessories, approached engineering polymers manufacturer RadiciGroup with a specific request: they wanted to replace a particular bike part — a rear swing arm then crafted from an aluminium 6061 alloy — with a piece that was lighter weight and made with strong plastic. The new swing arm design for electric, two-wheeler bicycle must deliver equivalent performance while simultaneously blending with the captivating bike's aesthetics, with an attractive surface appearance and colour options able to resist fading under prolonged UV rays exposure.

"We needed a solution combining stiffness and mechanical strength resistance to static loads, as well as fatigue resistance," explained Claudio Ghilardi, CAE analyst, marketing and technical service of RadiciGroup High Performance Polymers. "And due to the outdoor nature of the sport, we also needed a product that is less moisture sensitive."

Solution: A cost-effective and lightweight eco-design

Across industries, manufacturers are increasingly seeking to replace metal parts with engineering plastic counterparts that offer equivalent functionality. While this transition to engineering polymers has been ongoing for decades, new opportunities continue to arise across all industrial sectors, extending even to parts previously not considered a target for metal replacement. Beyond the reduced production costs, environmental impact is now a key driver, from full material recycling to the lowered emissions through lightweighting.

There are numerous advantages in replacing metal parts with engineering polymers:

- Reduced production costs
- Decreased product weight
- Increased freedom in form and design
- Improved environmental sustainability
- Reduced assembly and post-processing machining time
- Enhanced aesthetics and colourability
- Diminished total cost of the part

When it comes to metal replacement, the aim is not simply the substitution of a metal part with a plastic part with the same functionality; instead, the approach is to consider how

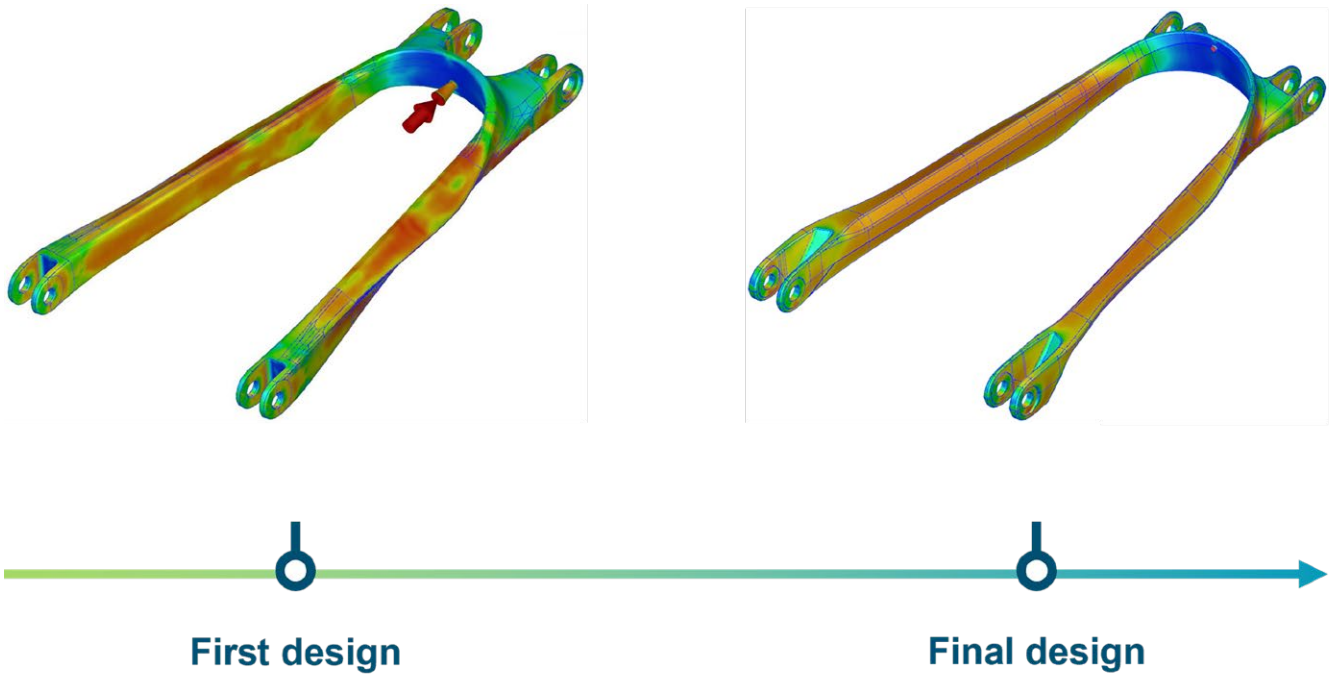


Figure 1. Design optimisation of the rear swing arm.

to take advantage of plastics' unique features. To achieve this, the manufacturer must consider the part's functional requirements, including implicit ones, and how the part interacts with other parts in a larger operating environment.

They must also consider plastic's intrinsic properties, which are radically different from metal, meaning that manufacturers must effectively design the part so it may be used properly. To ensure the components work with the product as a whole, the manufacturer must have an overall view of the larger project, allowing them to preselect the material and then redesign the part, as illustrated in Figure 1.

Digimat & CAEfatigue help RadiciGroup deliver an innovative solution

RadiciGroup delivered a rear swing arm made from a special blend based on polyamide 66 reinforced with glass fibre instead of aluminium for the first time in the market. Fantic, an Italian company specialising in the production of electric motorcycles and bicycles, was the first adopting this innovative product, including it in some of the company's trail and enduro bike models, first previewed at the Milan Motorcycle Show (EICMA) and now already in production and available for purchase.

RadiciGroup used Hexagon's material modelling platform Digimat to bridge the gap between the manufacturing process and structural part performance. "With Digimat, RadiciGroup can provide their clients with advanced multiscale material cards that are perfect digital twins of the materials they characterise in the lab so that clients don't have to do their own time-consuming and expensive testing," said Hedi Skhiri, technical specialist lead at Hexagon.

Skhiri added, "To replace the aluminium part with reinforced plastic, RadiciGroup first created the finite element model using MSC Apex and Marc, including the appropriate boundary conditions defining the applied forces based on their design requirements. Then Digimat was used to transfer the manufacturing data such as the fibre orientation and weld lines from the injection moulding mesh to the structural mesh. Finally, a coupled analysis using Marc simulation with Digimat as material solver was conducted to predict the performance of the part, taking into account the effect of the local fibre orientations and weld lines on the stiffness properties of the material."

"Having completed the static simulation, the stress results can be used to compute the lifetime of the part using CAEfatigue coupled with Digimat. The fatigue material description is first calibrated in Digimat through limited experimental stress-life data. It can then consider the effect of the fibre density and orientation as well as the applied mean stress, which vary both with the part location and load case. CAEfatigue allows replicating both the in-service and bench-test conditions, defining the fatigue events through sequence of loadings and repetitions and computing the expected lifetime of the parts " said Dr. Marco Veltri, business enablement manager at Hexagon.

Veltri added, "RadiciGroup realised a true multiphysics process; using the combined depth of Marc, Digimat and CAEfatigue to virtually exercise the part over different force levels and repetitions, they can make sure their designs are extremely unlikely to fail."

The Radistrong difference

RadiciGroup created the part from its Radistrong product due to its high mechanical resistance and low moisture sensitivity versus a standard PA66. "The component was part of the bike frame — a structural component — so we proposed a special blend based on polyamide 66 reinforced with glass fibre to ensure the design could withstand the continuous and strong stresses it's subjected to.

Additionally, our solution's mechanical properties — like stiffness and resistance — are less influenced by humidity absorption. We also paid great attention to the aesthetic result: the material surface looks attractive, stable against UV rays, and is designed to resist exposure to atmospheric events over time," said Claudio Ghilardi, CAE analyst, marketing and technical service of RadiciGroup High Performance Polymers.

RadiciGroup tasked its engineering services team with the full project. The early deployment of Digimat and the use of computer assisted engineering simulation (CAE), allows the company to predict the behaviour of the material during the moulding phase, along with the mechanical response of the products already in the very early stages of their development. The ensuing deliverable engineering services include:

- Project feasibility assessment
- Validating material selection and part design and redesign
- Troubleshooting both in prototyping and regular production
- Coordination between R&D, external suppliers and software providers, ensuring new and reliable material cards for RadiciGroup products are made available for use in simulation communities
- Communicating with customers' designers, engineers, and CAE experts in order to facilitate a positive exchange of material selection and modelling information
- Optimisation of clients designs' geometry and technical performances
- Providing higher accuracy and reliability in predicting stiffness and failure
- Gathering a more in-depth understanding of the material behaviour
- Lead to a reduced tendency to overengineer and use high safety factors
- Reduce the need for prototype testing

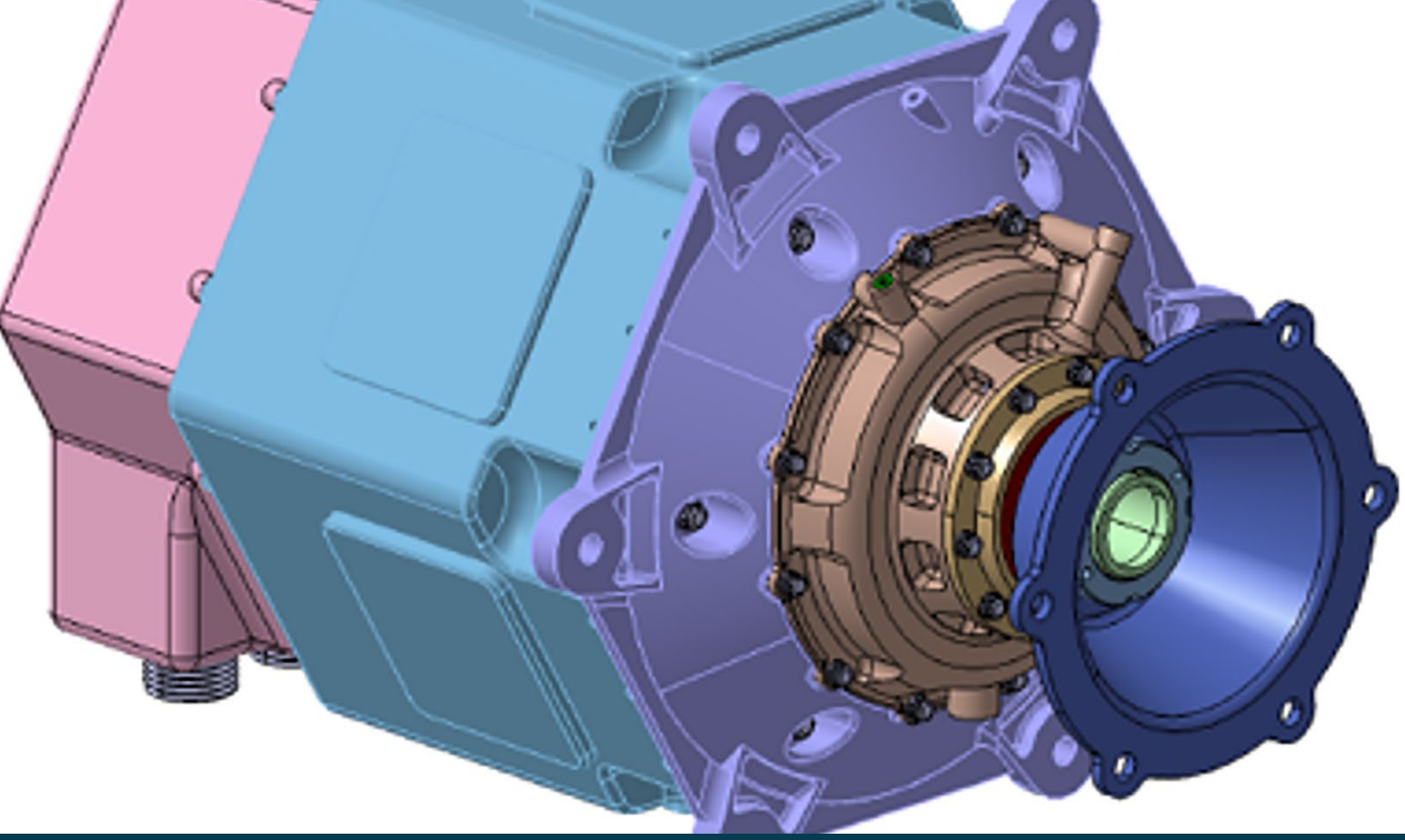
Results: Simplified, shortened production times and sustainable design

Using RadiciGroup's compound — empowered by Hexagon's digital materials and multiphysics solutions suite — the eBike rear swing arm is now 10% lighter than the previous design. Additionally, because RadiciGroup's technopolymers are coloured during the material extrusion phase, the component is ready for use at the end of the injection moulding phase, with no painting necessary.

RadiciGroup, Acerbis, and Fantic closely collaborated in all project phases — from product design and material formulation to mould creation and the mould injection process, up through the mounting on the eBike. Many severity tests were carried out at the customer's laboratories, showing that the new part helped exceed the initial requirements by 2x. And to top it all, the new innovative rear swing arm contributes to lowering the environmental impact of an eBike and can be recovered and mechanically recycled at the end of its useful life. In fact, this bike part was the result of applying eco-design principles to fuel a virtuous system of nylon recycling towards the realisation of a circular economy.

"The project allowed us implementing a metal part replacement by re-engineering it and improving its function; by simplifying and shortening production times, we have increased the quantity of products placed on the market in a short time," concluded Guido Acerbis, CEO of Acerbis.

Figure 2. Multiphysics process combining Marc, Digimat and CAEfatigue.



Applied Solutions

Revolutionising **urban mobility**

By Connor Lynch, Technical Business Development Manager, Applied Solutions, and Giorgio Valente, Senior e-Machine and Drive Engineer, Applied Solutions, Hexagon's Manufacturing Intelligence division

Exploring eVTOL's high power density e-propulsion units: a deep dive into the innovative technologies underpinning the future of sustainable aviation systems.

The advent of Electric Vertical Takeoff and Landing (eVTOL) aircraft represents a groundbreaking leap in the field of aviation. These innovative vehicles promise to revolutionise urban mobility, offering an efficient and sustainable solution for short-distance travel within cities and metropolitan areas. At the heart of eVTOL's success lies the electric propulsion system (e-Propulsion unit), enabling the electric vertical flight with minimal emissions, reduced noise, and a significantly lower carbon footprint compared to traditional aviation technologies, as well as alleviating the mass of the energy storage systems which are typically battery based.

The development of these advanced propulsion units is the result of a confluence of cutting-edge technologies including high-performance electric motors, lightweight materials, advanced battery technologies, and sophisticated power electronics. When considering the numerous technical challenges associated with eVTOL, the need for high power density e-Propulsion units becomes increasingly evident. These challenges encompass power management, thermal management, system integration, and more, making this system a focal point for engineering innovation.

Hexagon's Applied Solutions Group (ASG) have developed a 3-in-1 e-Propulsion unit concept utilising Hexagon and 3rd party software's to ensure a high level of confidence in the design. The unit comprises a planetary gearbox stage mechanically coupled to a high-speed dual-redundant Permanent Magnet Synchronous Machine (PMSM) which is fed by a dual three-phase inverter. The electrical system (power electronics and e-Machine) is single-point-of-failure tolerant and is designed to provide full power in the event of loss of one of its three-phase sub-system. Thermal management of the system and lubrication of the gearbox are achieved by a single cooling circuit where oil is used to cool first the power electronics, then the e-Machine, and finally to provide adequate lubrication to the gearbox.

Design approach for high reliability and functional safety

Propulsion systems are usually required to meet Design Assurance Level A (DAL-A) safety risk reduction in terms of process rigour, high reliability targets with the ability to be tolerant to a single point of failure while maintaining the overall functionality and performance required at the aircraft level, i.e. 'Control Thrust'. Although safety is paramount, this can complicate power density endeavours.

A number of external assumptions were derived at the aircraft level for which a credible e-Propulsion unit concept could be developed. At the airframe level it was decided that there would be two independent high voltage power supply systems and two independent cooling systems. Having targeted candidate fixed-wing eCTOL and eVTOL aircraft, some additional assumptions were declared around the flight/mission profile, payload, and how many full e-Propulsion unit failures could be tolerated in order to maintain safe flight. In addition, it was considered that the e-Propulsion architecture would be 'cross connected' with the power and cooling systems, meaning safe flight could continue in the event of a failure in either one of these systems all be it with degraded safety margins. It was surmised that a minimum of 8 e-Propulsion units would be housed on the airframe, and that up to two independent permanent unit failures could occur without affecting safe continued flight.). In the event of loss of 2 units, the remaining units will need to operate in overload condition. The e-Propulsion unit has been designed to withstand an overload for a maximum of 3 minutes, which is considered a sufficient time to allow the aircraft to safely land.

Using exemplar mission profiles and airframe modelling using the 1D Modelica based Elements tool, the nominal and abnormal operating propulsion performance requirements were derived. Even with aircraft-level redundancy, the preliminary safety and reliability analysis concluded that the e-Propulsion unit's internal electrical architecture would

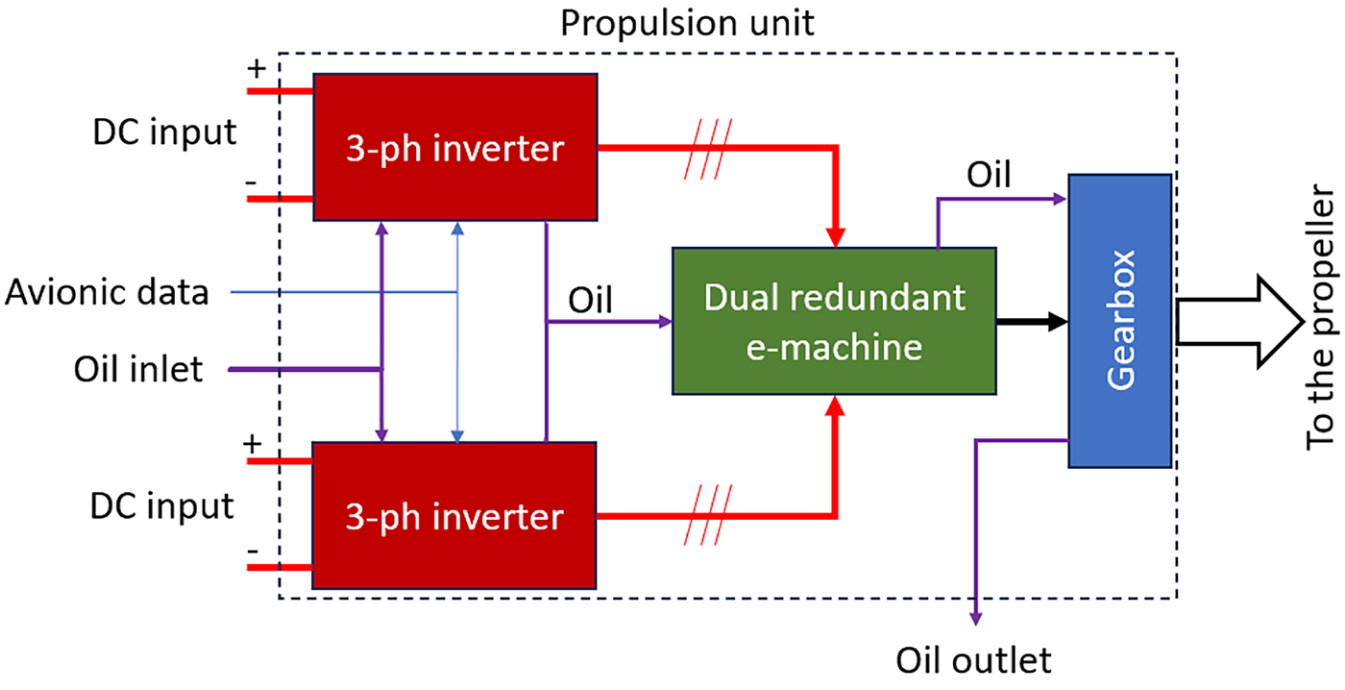


Figure 1. High-level e-Propulsion unit architecture

Parameter	Value
Rated output power	100 kW
Overload output power	133 kW
Propeller speed	2500 rpm
Input HVDC voltage	800 Vdc
Maximum combined efficiency	> 91%
Maximum altitude	35000 ft
Operating temperature	-45 to 70°C
Target system dry mass	< 24kg
Maximum length	400 mm
Maximum OD	300 mm

Table 1. e-Propulsion Unit specifications.

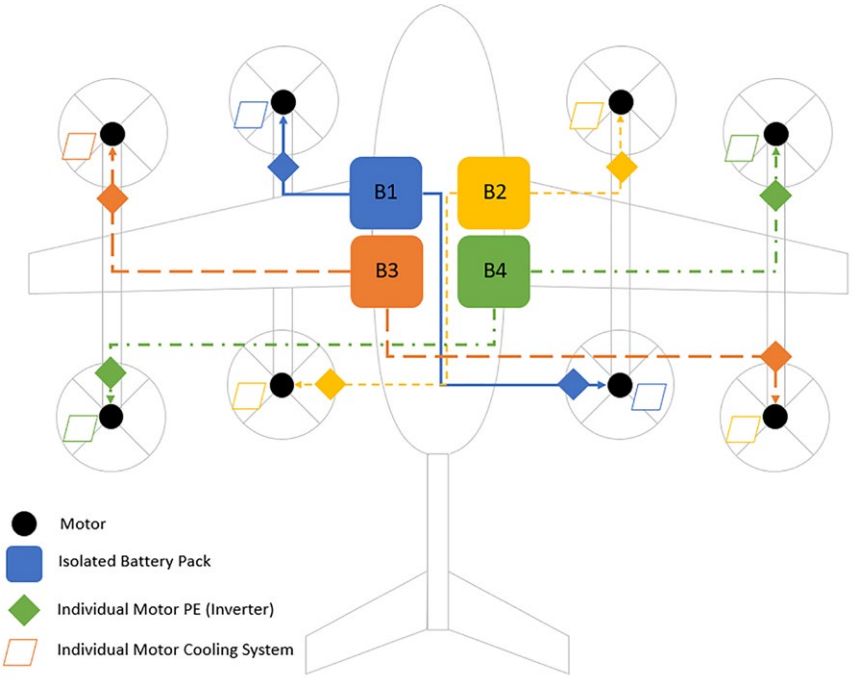


Figure 2. Example eVTOL ePropulsion architecture.

also be required to be single-failure tolerant and provide the abnormal operating power demand for a limited time in order to enable a safe landing in the event of a hazardous failure.

The ePropulsion unit's electronic architecture required a level of redundancy to achieve the overall DAL-A reliability target of ≤10-9/hr, unless the item was severely life limited which is clearly undesirable. It was concluded that a dual-redundant electrical architecture would be sufficient and compliant to the derived system-level safety, reliability, and availability requirements, and so a dual redundant 3-phase electrical machine concept was formed supported by two independent inverters. Supported by additional analysis in Romax, this confirmed the acceptability, in reliability terms, of a single gearbox and a single cooling system per propulsion unit

Gearbox design

The housing assembly is a multifunctional component in that it supports the torque transfer from the e-machine through to the propeller, packages the power electronics, e-machine, gearbox, and drive shaft into a single unit, provides the boundary for the common electrical and mechanical cooling system and provides a simple interface with the aircraft via a flange with six mounting positions. A cross section of the complete system is shown

The employed transmission consists of a planetary gearbox which reduces the size of the e-machine required. The gearbox has been sized to provide efficient operation and reducing the motor speed to the required speed at the propeller. The selected single planetary design was evaluated relative to a direct drive design; and a two-stage planetary design, with the single planetary design coming out most favourably on high power density.

For compactness, the sun gear has been integrated with the motor rotor shaft, and the planetary carrier upwind end supports the main bearing. This integration avoids the alignment issues of noise and wear often seen when a spline connection is used between e-machine to gearbox.

With the additional demands, the planet carrier becomes a structural member of the system, both transferring the torque from the motor to the propeller and reacting the radial and axial loads exerted on the transmission from the propeller. The planetary carrier thus becomes a complex part to design to ensure that it is suitably stiff but not over engineered and too heavy. Here, a combination of FE tools are employed to ensure that an optimum design is achieved.

Additional to the static strength requirements, the design has to consider the durability of the components for the required life of transmission. The fatigue life of the gears, bearings, and shafts are evaluated within the RomaxDT system study whilst the planetary carrier, housing and other structural parts using CAEFatigue.

e-machine design

The e-machine design consists of a dual-redundant system which is achieved by two physically separate three-phase windings. The machine topology considered for this concept design is a 12-slots/10-poles Surface-Mounted PMSM, with a Halbach magnet array which helps to further increase the magnetic loading and consequently the power density,

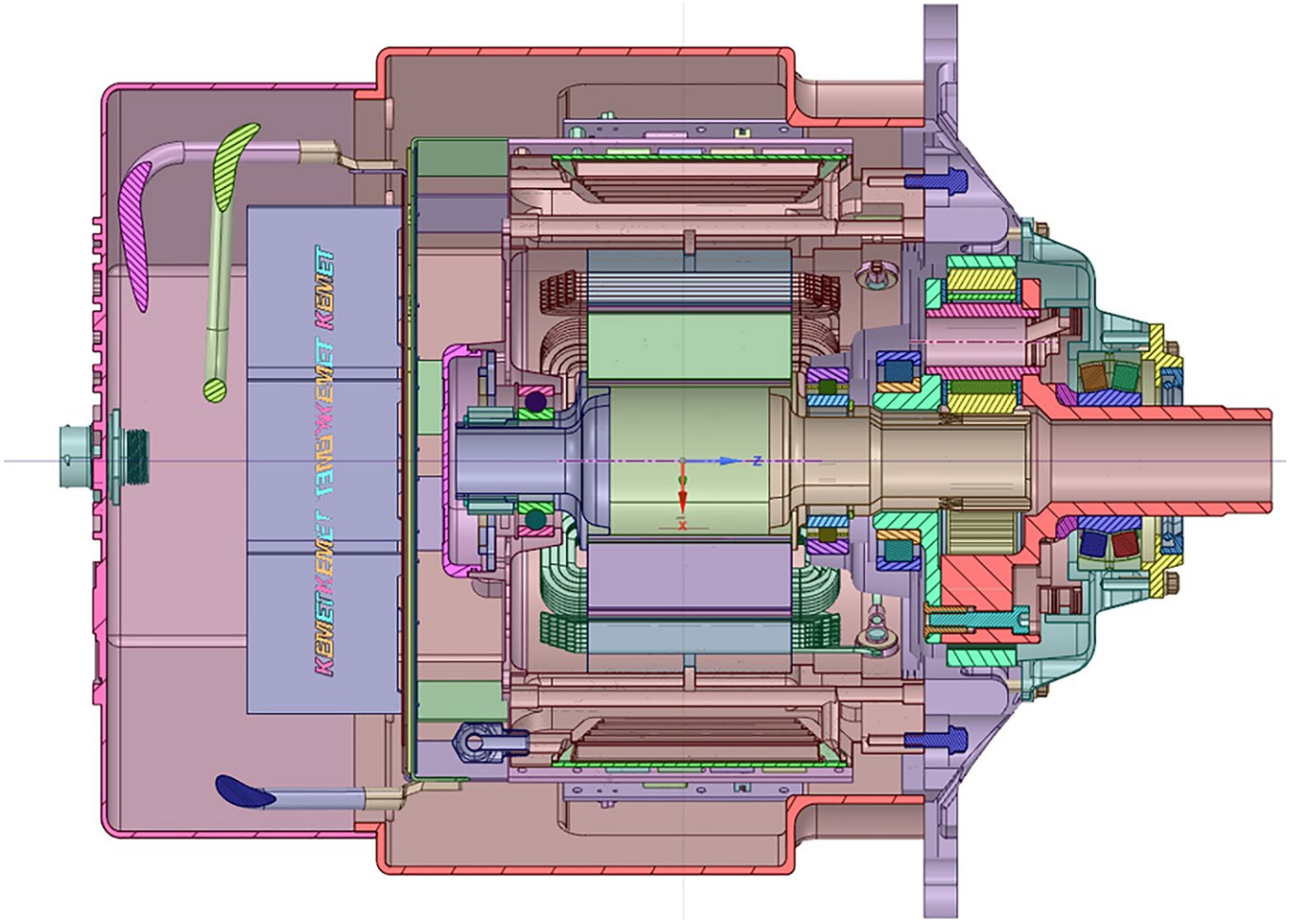


Figure 3. Cross-section view of ePropulsion Unit

compared to the conventional north-south arrangement. The machine cross section with the no-load flux density map is presented in Figure 4 (top), while the dual three-phase winding schematic is shown in Figure 4 (bottom).

A concentrated winding topology has been chosen for this design because of the superior fault tolerant features when compared to the distributed winding counterpart. Indeed, each machine phase consists of an independent coil which is wound around a stator tooth so that there is no overlap or contact between different phases, neither inside the slots nor on the end windings, negating the possibility of a phase-to-phase failure.

To increase reliability and reduce the risk of magnet demagnetisation at high temperatures, samarium-cobalt magnets are selected. The maximum rotor speed is 15,000 rpm, therefore high-strength carbon fibre is used to retain the magnets at high rotational speed. The need for rotor laminations is eliminated thanks to the Halbach magnet array, while on the stator side a cobalt iron alloy has been chosen as material for the laminations with the aim of maximising the electromagnetic performance and reducing the iron losses. Thanks to the aforementioned design choices, a 97% peak efficiency is reached (see Figure 4), while the power density, calculated including both active and structural components, is 17 kW/kg.

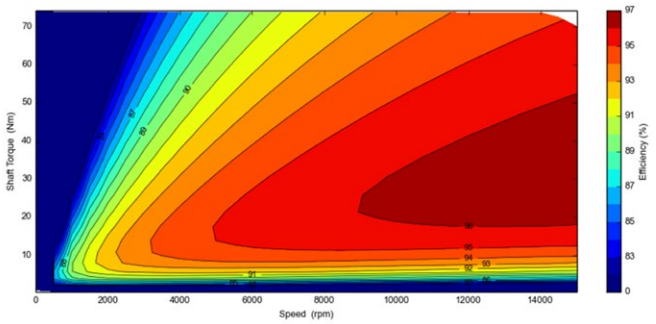


Figure 4. e-Machine efficiency map

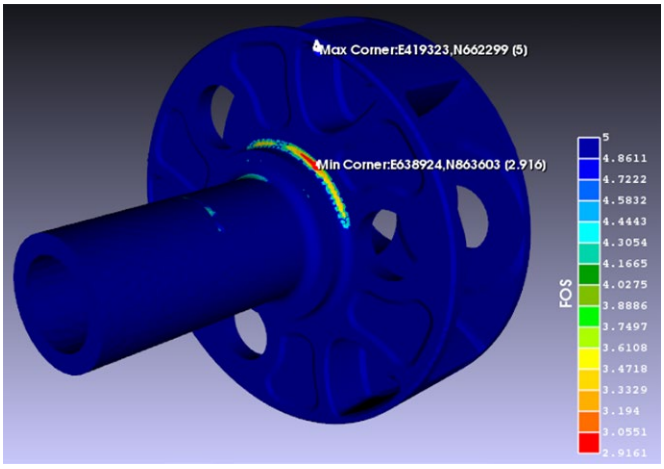


Figure 5. Fatigue analysis of planet carrier

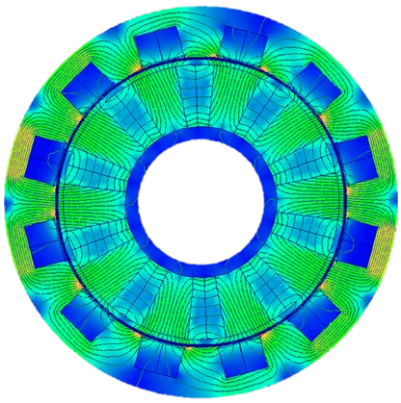


Figure 6. No-load flux density map.

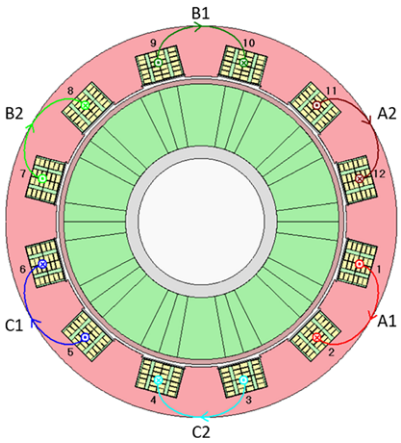


Figure 7. Radial winding pattern.

Figure 8. Mounting arrangement of half-bridges.

Power electronics design

The design of the power electronic stage of the e-Propulsion unit poses several challenges: it must meet the strict safety requirements, while keeping a low size and weight, and it has to withstand mechanical vibration coming from the motor, gearbox and propeller. Moreover, it has to reliably operate in a hostile environment, where the impact of low air pressure imposes demanding constraints for creepage and clearance, and the effect of cosmic rays on semiconductor devices has to be considered.

The fault tolerant inverter design is achieved thanks to the selected dual redundant architecture. Separate DC link inputs and independent controllers are used for the two inverter channels. Each channel is composed of a two-level three-phase inverter where each switch is made of four SiC MOSFET devices connected in parallel. A total of six half-bridges are required for the two inverters which are physically distributed around the e-machine hexagonal housing and attached to a cold plate. An 800 Volts DC input voltage has been selected to be compatible with most of the recent battery charging infrastructures. SiC based MOSFET were chosen, as this technology drastically reduces the switching losses compared to the IGBT counterpart, and therefore allows to push the switching frequency boundaries, high switching frequency allows for control of high-speed motors (or motors with a high fundamental frequency) more effectively but leads to increased switching losses and therefore reduced inverter efficiency. A tradeoff study was then carried out to determine the optimum switching frequency showing that 20 kHz was a good compromise. The power stage has been sized to be able to deliver the full rated power in case of loss of one inverter channel (full three-phase system).

Preliminary thermal analysis has been carried out, showing a maximum operating junction temperature of 92 °C and 131 °C for healthy operation (six-phase) and faulty operations (three-phase) at the rated power, respectively. A maximum of 99.1 % efficiency can be achieved thanks to the employed state-of-the-art switches.

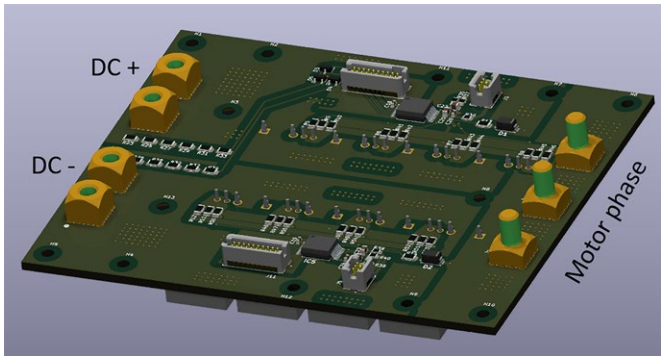


Figure 9. Half-bridge power board.

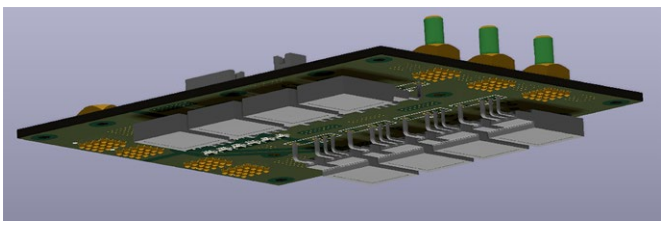


Figure 10. Half-bridge power board (bottom).

Thermal management and lubrication

The integrated thermal management and lubrication system includes: a single inlets; six parallel-flow channels (one for each bank of eight MOSFETs) direct-cooled motor windings; and a jet lubricated gearbox. The cooling medium is oil, chosen for both its high specific heat capacity and effectiveness as a lubricant, as well as high operating temperature range, suitable for eVTOL applications.

The switches on each power module are connected to the stator housing with a thermal interface material (TIM). The housing has a number of cooling channels which the oil passes through directly from the heat exchanger. Being first in the cooling path means that the cooling capacity of the oil is maximised. Figure 9 provides an illustration of how the power boards are distributed around the hexagonal machine housing.

To maximise thermal performance, the motor uses direct oil cooling, where the oil (after cooling the power electronics) is distributed in a circumferential channel around the centre of the motor at the outer diameter, fed radially into the slots, then passes axially though channels in the windings and out each end. There is additional flow from nozzles for the end windings and rotor, additions evidenced by the system-level 1D thermal analysis carried out on the propulsion unit. The direct cooling drastically increases the heat transfer to the oil allowing for a smaller machine whilst maintaining thermal performance.

Finally, the gearbox is lubricated and cooled by supplying oil allowing for a smaller machine whilst maintaining thermal performance.

Finally, the gearbox is lubricated and cooled by supplying oil through nozzles onto the bearings and gear flanks. Oil will be scavenged from the sump housed beneath the gearbox and filtered before passing it through a separate air-cooled heat exchanger unit and looping back to the inlet. The gearbox is last in the cooling path as it can tolerate a higher inlet temperature than the power electronics and motor.

A number of changes were implemented for the cooling system based on the results of the intial 1D thermal analysis: increasing the capacity of the heat exchanger to cope with the total heat input in the faulty overload condition; improving the switch cooling by introducing micro-fins into the cooling path to increase the heat transfer to the coolant; improve the rotor cooling by adding nozzles directed onto the end plates; and improve the winding cooling by removing the additional stator flow-path and diverting the flow through the slot cooling channels, as well as adding nozzles for the end windings. Following these changes and by increasing the flow rate effectively reduced the temperatures of the windings, MOSFETs, and magnets to within their operating limits, even after three minutes in the faulty overload condition.

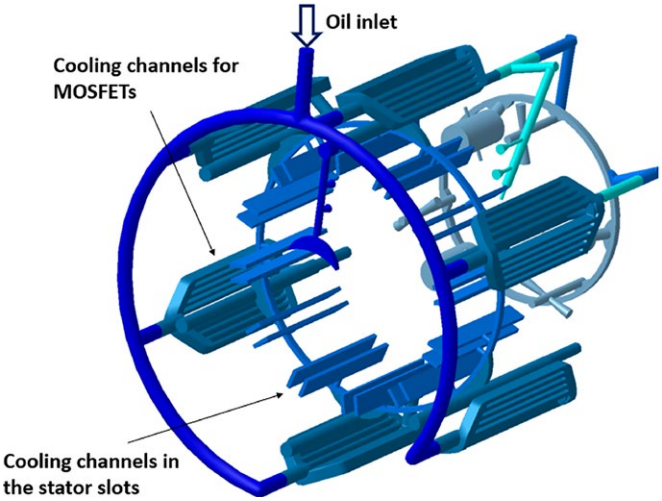


Figure 11. Cooling and lubrication circuit

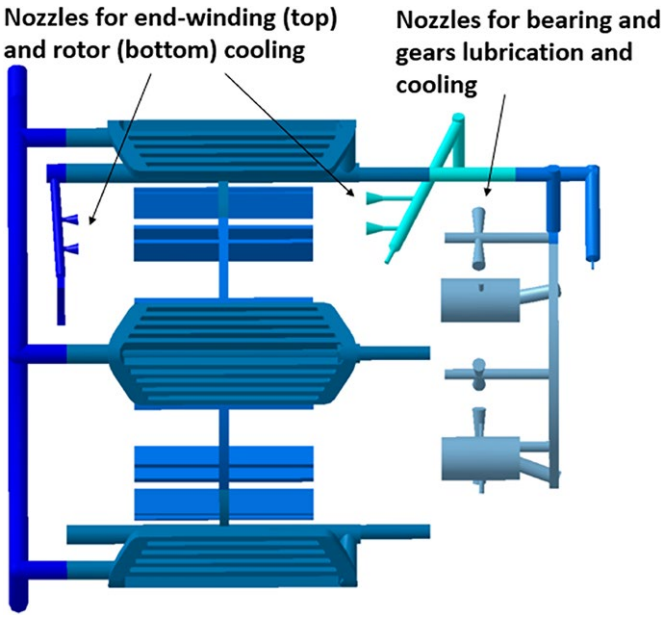


Figure 12. Cooling and lubrication circuit

System level performance

The 3-D model of the e-Propulsion unit is shown in Figure 18. As can be seen, the outer dimensions are 393 mm and 260 mm for the length and diameter, respectively. These are within the maximum allowable dimensions specified in Table 1. The total dry mass of the system at the current state of development is 25.8 kg, which results in a power density of 5.2 kW/kg. The mass is currently exceeding the target of 24 kg, and a design iteration with structural optimisations will be carried out to achieve the system target. It has to be noted that the power density figure is calculated for a peak power of 133 kW, whilst the system is actually sized for twice as that for redundancy.

Finally, a combined peak efficiency of about 92% could be achieved with the e-Propulsion unit, which exceeds the target set in Table 1. The efficiencies of the power electronics, e-machine and gearbox has been considered for this calculation.

Figure 13. Exploded view of ePropulsions system

Conclusions

Hexagon's Applied Solutions Group set out to create a compact and efficient 3-in-1 propulsor that could play an effective part in the electric flight revolution. The electric machine developed has a specific power density exceeding the current state of the art at a high efficiency level. It has been designed to withstand both an open circuit and a short circuit fault in one of the winding systems and still deliver the overload power – meeting the requirements for DAL-A. All of this was achieved with technology which is in production today. A liquid cooling and lubrication solution is sized to enable a safe landing in the event of a fault during a mission. The mechanical system has been sized to allow the electrical system to interface with typical propellers in a lightweight and compact manner. It is directly cooled and lubricated to give the best possible durability. Overall, an efficient and safe system has been concepted that can complete the typical eVTOL and eCTOL mission profiles.

Hexagon's Applied Solutions group are a dedicated multi-disciplinary engineering services group with other 30 years of experience delivering innovative, robust and functional designs to market across multiple industries. Utilising a CAE-led Model Based Systems Engineering approach and the entire Hexagon Portfolio.

If the specific topic of ePropulsion unit design and development is of interest, an extended version of the article has been produced and will be presented at conferences in the coming months. Hexagon's Applied Solution Group would welcome discussion on the topic, speak to your local Hexagon sales representative to get in touch.

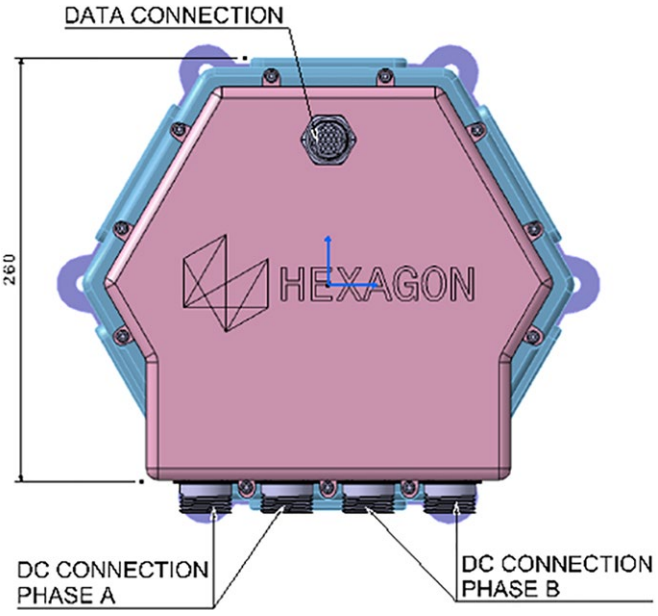


Figure 14. Front view of ePropulsion system.

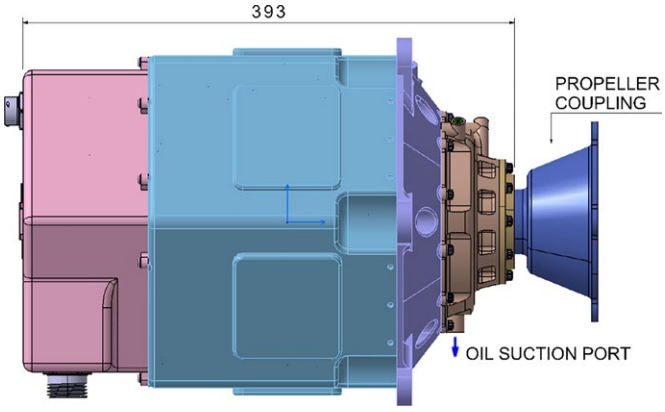
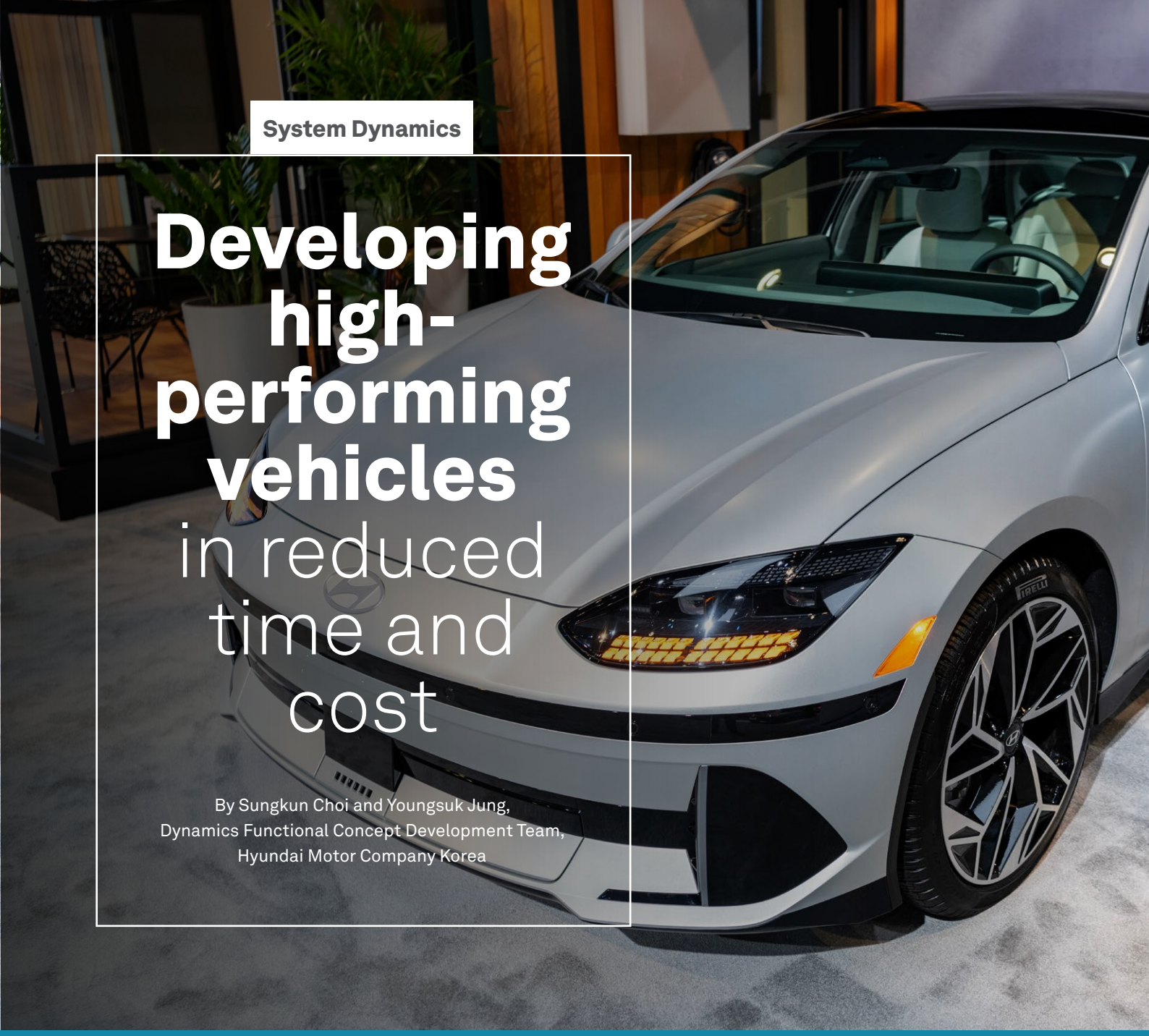


Figure 15. Side view of ePropulsion system

System Dynamics

Developing high-performing vehicles in reduced time and cost

By Sungkun Choi and Youngsuk Jung,
Dynamics Functional Concept Development Team,
Hyundai Motor Company Korea



Hyundai Motor Company leverages Adams Real Time for subjective evaluation of vehicle models on dynamic simulator, developing high-performing vehicles in reduced time and cost

The Hyundai Motor Company (HMC) is an original equipment manufacturer (OEM) that works alongside the Namyang Research and Development Centre (NRDC) to develop and manufacture vehicles. For nearly 40 years, HMC has partnered with Hexagon by utilising our design and engineering simulation software to iterate and develop their vehicles rapidly. Adams, a key component of Hyundai's system dynamics toolkit for more than 25 years, has played a crucial role in providing HMC with the simulation capabilities necessary to remain competitive in the challenging automotive market.

Our partnership with Hexagon has truly transformed our approach to projects. Adams' strategic insights and innovative technologies have yielded tangible and measurable results, including exceptional ROI, a significant boost in iteration capability, and accelerated project completion. The streamlined processes and collaborative tools introduced by Hexagon enabled us to adapt swiftly to evolving project requirements, fostering a culture of agility and innovation within our organisation. The acceleration in project completion timelines has been nothing short of remarkable."

– Kyungjin Hong, Part Leader, Driving Comfort Virtual Development team, Hyundai Motor Company Korea

Figure1. Ansible Motion Dynamic Simulator Delta S3 with Adams Real Time and cosin FTire at NRDC.

The Dynamics Functional Concept Development Team (DFCD) within NRDC is responsible for establishing initial vehicle concepts and providing direction for achieving the desired ride and handling performance by HMC vehicles. Recently, DFCD faced the need to cut both time and cost during the development phase of car and suspension designs.

Driving toward seamless integration and rapid iteration goals

DFCD conducts research at NRDC using a Dynamic Driving Simulator for vehicle handling performance improvement and development. Previously utilised tools and platforms suffered from a cumbersome integration process: the team had to obtain results from Adams Car or actual Suspension Parameter Measurement Devices (SPMD) and then model the vehicle again with each iteration.

Accommodating even a minor update in the simulation model could take up to three days. Multiple design iterations are required to reach optimal ride and handling performance and this tedious process resulted in delayed development. At times, resetting the entire configuration for each iteration added weeks to the product development cycle.

Ultimately, the team's goal of improving the development process was to accurately simulate the optimised suspension configuration in the testing process without sacrificing time.

Creating more accurate simulations in less time for a comfortable ride

In Hyundai's search for solutions, Adams Real Time proved capable of integrating with the Dynamic Simulator and supporting parametric modeling, avoided the need to create a new model for every iteration. Integrating Adams Car, Adams Real Time, cosin FTire, Ansible Motion Dynamic Simulator Delta S3, Concurrent RealTime, RedHawk Linux and SimWorkbench provided a comprehensive solution offering a seamless process to rapidly make changes to the vehicle model and feel the impact on riding behaviour in the simulator.

This technological integration provides a more realistic representation of the vehicle dynamics by incorporating higher fidelity representations of the subsystems. One example is the use of flexible bodies for a precise representation of suspension components. Adams Real Time offers an accurate representation of ride comfort in the Dynamic Simulator with the added flexibility of on-the- fly design modifications. With Adams Real Time, Hyundai has reduced the simulation lead time by 95%. Now, model modifications and iterations can be made in as few as five minutes, rather than delaying prototypes by days or even weeks, effectively eliminating the constraints and delays associated with the previous process' real-time operation.

"We've discovered that with this technology, it's possible to evaluate ride comfort performance in the Dynamic Simulator subjectively," explains Youngsuk Jung, team leader of the Dynamics Functional Concept Development Team.

Jung adds, "This opens up opportunities to further extend the utility of the Dynamic Simulator, shorten the automobile development process, and, in turn, reduce development costs and time. We have high expectations for the positive impact this will bring, in addition to our ROI with a faster iteration process."

Transformative benefits

Hyundai says that Adams Real Time has been transformative for design and testing procedures.

- Modification and iteration agility
- Increased efficiency across the automobile development process
- Improved roll-motion simulation in vehicle handling performance
- Fewer physical prototypes resulting in reduced manufacturing costs
- Reduced project timelines and production costs
- Optimised suspension configuration, maintaining a standard of comfort
- Innovation exploration across business units
- Business expansion into adjacent sectors

HMC is pleased with the 'amazing' success of the Adams Real Time implementation. The newfound agility to make modifications quickly and easily has significantly streamlined the automobile development process and ultimately reduced associated costs.

Immediate improvements were seen in the simulation of roll motion in vehicle handling performance. The addition of cosin F-Tire/HIL enabled more realistic assessments of ride comfort, providing a more holistic understanding of vehicle performance without the need for physical prototypes. These integrated solutions offer new possibilities in the Dynamic Simulator by way of extending the applications and innovation derived from the Dynamics Simulator platform.

"Our partnership with Hexagon has been a game-changer for our organisation," explains Wookyoung Kim, Senior Research Engineer, MLV Chassis and Body CAE team. "The impressive return on investment, improved iteration capability and accelerated project completion have positioned us for sustained success in an ever-evolving business landscape. Thanks to the seamless integration of Adams' technology solutions, we experienced a significant reduction in project delivery time. This not only allowed us to meet tight deadlines but also provided us with a competitive edge in the market. The enhanced speed of project completion has

Figure 2. A simulator screen view for the simulator control team

Figure 3. FTire simulation with Adams Real Time

positively impacted our market positioning and customer satisfaction, further reinforcing the value of our collaboration with Hexagon."

HMC plans to capitalise on their improved development process by expanding the Hexagon platform solutions to leverage Adams Real Time into the growing eMobility sector. The team aims to look beyond precision analysis to increase real-time simulation capabilities and improve integration with hardware. The company aspires to make significant contributions in the fields of Hardware-in- the-Loop (HIL) and Driver-in-the-Loop (DIL) testing, aligning with the evolving landscape of automotive technology.

The expanded use of Adams Real Time for wider applications within the Dynamics Simulator and electronic control HIL testing showcases Hyundai's forward-thinking approach. By exploring Adams Real Time to its fullest potential, the company will continue to innovate and improve efficiency across all facets of the development process.

Industries

Automotive industry leadership

A conversation with Ignazio Dentini, Industry VP for Automotive, Hexagon's Manufacturing Intelligence division

Hexagon's industry content specialist Ashley Bray recently sat down with Ignazio Dentici, Vice President for Automotive for Hexagon's Manufacturing Intelligence division. The pair dived into Dentici's role at Hexagon, offering insights into how the company is adapting and leading the way in an automotive industry that is undergoing significant transformation.

From enabling automation in manufacturing to non-destructive testing capabilities for automotive batteries, Dentici sheds light on how Hexagon seizes opportunities amidst industry challenges. He also explores the relationship between Hexagon and its customers, the company's strategic focus and its ambition to delve further into areas like electrification and battery development. As the automotive industry races alongside technology, Hexagon is capturing that pace and looking forward to an innovative future.

Ashley Bray: Ignazio, what does it mean to be VP for Automotive at Hexagon?

Ignazio Dentici: In essence, being VP for Hexagon involves witnessing the transformation of the company to connect more closely with our customers. In the automotive sector, this is significant as the industry is undergoing arguably the biggest transformation in its history. This is a fantastic time to be VP for Automotive; we have an incredible opportunity to support customers during this transformation.

AB: Where do you get these insights from? How do you gauge what is needed?

ID: I've been passionate about automotive since my youth. This led me to study engineering associated with the automotive sector. I then spent over 15 years in the industry working for original equipment manufacturers (OEMs). I joined Hexagon two years ago, and my goal now is to bring my expertise and insights from my extensive sector experience into the company. The automotive industry races alongside technology, so there is always a need for innovation to stay competitive. Our customers need sustainability—both environmental and financial—combined with new technologies, which answer the demands for innovation and sustainability.

AB: Can we have some examples of new advancements in the industry that Hexagon has had a hand in?

ID: One key area is automation in manufacturing, where new technologies are allowing flexible offline and online inspection. This assists our customers in adapting to market uncertainties and manufacturing needs. Furthermore, our software's capabilities for CT inspection, coupled with volume graphics, is a major breakthrough. It enables non-destructive testing of parts such as automotive batteries, a technology totally unknown in the automotive industry 5-10 years ago.

AB: Could you speak about Hexagon's industry footprint and the direction we're headed?

ID: Today, Hexagon Automotive has impact over 95% of the automotive industry. Our substantial footprint gives us insight into the industry's main issues and allows us to act as a partner when they face challenges. Now, our task is to develop and provide the new generation of technologies to support customer growth and to offer solutions to entire process issues.

AB: How does Hexagon's role differ from consultants or integrators?

ID: We supply the tools and solve the actual issues. We do offer consultancy in certain areas and we can lead consultancy partnerships. Regarding system integration, our customers are looking for a partner that takes on the responsibility of system integration—a role we're prepared for.

AB: Finally, can you share the main short-term priorities you're focusing on?

ID: My main priority is to leverage Hexagon capabilities as well as our partnerships to support customers and offer them comprehensive solutions to drive transformation in the key Automotive industry areas.

AB: We do harbour big ambitions, don't we?

ID: Indeed we do, and we must.

AB: Thank you for your time, Ignazio. It's always illuminating to gain insights about our present position, future direction and the ways to get there.

Metrology Devices

High-performance resources to meet aeronautics standards and regulations

By Rodrigo Alfaia, Laser Tracker Product Director,
Hexagon's Manufacturing Intelligence division

POTEZ AÉRONAUTIQUE's quality control system, which includes a Leica Absolute Tracker AT960, accompanied by an Absolute Scanner AS1 and a Leica T-Probe, meets the highest standards of its prestigious customers

A leading partner to major aircraft manufacturers, the family-owned POTEZ AÉRONAUTIQUE group designs and manufactures complex aerostructures and cabin fittings. With more than 900 employees, the company brings together all the necessary skills: design, industrialisation, manufacture of metal or composite parts, supply chain management, assembly, wiring and support. It also offers high added-value industrial services.

POTEZ AÉRONAUTIQUE's innovation drive is based on two key objectives: to constantly improve the performance of its resources and products, while adopting an increasingly environmentally-friendly approach. They are investing in Industry 4.0 by introducing innovations in industrial processes, such as automation, cobotics and digital control systems. The company is also focusing on product innovation through a number of research and technology projects in composite materials and door systems.

A family heritage of innovation

Today, innovation plays a key role in the company's development strategy. As a Tier 1 and Tier 2 supplier, POTEZ AÉRONAUTIQUE enjoys the trust of long-standing partners and many major players who will shape the future of aviation.

Following the acquisition at the end of 2019 of POTEZ COMPOSITES, a Lot-based company specialising in the manufacture of elementary composite parts, the group has extended its range of skills to include aircraft interior fittings. Here too, the group offers design and manufacturing services. By adapting to the specific needs and requirements of its customers, both in terms of quality and deadlines, the company is able to intervene in both series production and prototyping activities.

Whether it's for business class seat shells, coverings or interior fittings, POTEZ AÉRONAUTIQUE works on technical components with standard or premium finishes for major customers. For example, the company contributes to the production of premium, made-to-measure seats for airlines, with composite moving parts mounted on mechanical systems, as well as armrests (for comfort or ease of access for the disabled), partitions and retractable doors. They are then fitted, painted or decorated, and delivered to the manufacturer for final assembly. POTEZ AÉRONAUTIQUE is involved from the industrialisation phase through to the delivery of finished products, including co-design services.

Quality, safety, and the environment

"We attach the utmost importance to the quality of our products, because they play an essential role on board aircraft, contributing to their safety in flight and on the ground. This is why we are committed to offering our customers the highest level of quality," says Benjamin Andrianome, Process Engineer at POTEZ AÉRONAUTIQUE.

Figure 1. The Absolute Scanner AS1 quickly measures large and small parts.

Figure 2. External scan of a door using the Absolute Scanner AS1.

POTEZ AÉRONAUTIQUE's management system complies with aerospace and defence standards and regulations. Its quality control is backed up by high-performance equipment, including Hexagon as a supplier since 2012.

ISO standards and new contracts for leading-edge slats

Standards are crucial in the aerospace industry, and the major principals require their suppliers to comply carefully with them. As a result, suppliers have to equip themselves with the methods and resources they need to meet these requirements as effectively as possible.

POTEZ AÉRONAUTIQUE's measuring arm and former laser tracker were reaching the limits of their usefulness for checking large parts and finished sub-assemblies.

In particular, a major contract for the production of leading-edge slats (located on the forward section of an aircraft's wing and designed to prevent air stream separation) convinced the company that it was time to renew its quality measurement resources, particularly in terms of scanner technologies for profile measurements.

"Our decision to invest in new technologies was motivated both by our customers' requirements in terms of strict standards and new contracts, and also by our teams' need to save time and improve quality, achieve better results and open up new opportunities," recalls Andrianome.

An easy technological choice

The team began by obtaining information from its customers, as well as from other suppliers and subcontractors, before carrying out a benchmark. In the end, POTEZ AÉRONAUTIQUE chose Hexagon once again.

"We stuck with technologies we were already familiar with, namely laser trackers. Mainly because of the ease of implementation, but also because of the speed," adds Andrianome.Hervé Capdevielle, 3D Controller and main user of the laser tracker at POTEZ AÉRONAUTIQUE, also remembers the process: "Yes, the choice was quite easy, particularly from a technical point of view. The Absolute Tracker with the Absolute Scanner AS1 and the Leica T-Probe offer a cutting-edge technological combination that provides unique flexibility in the means of measurement".

Below are the criteria and key points that the Hexagon tracker and its accessories have successfully met:

- ISO-standard tool
- Precision of the measuring equipment
- Multi-disciplinary measuring equipment
- Suitability for measuring large parts
- Implementation in production
- Possibility of reverse engineering
- Measurement of hidden points

Figure 3: Manufacture of aircraft doors.

- Mobility of the metrology tool
- And above all, it saves time, with the aim of halving quality control time

Design, manufacture, set up

The Leica Absolute Tracker AT960 is used at POTEZ AÉRONAUTIQUE for quality control at assembly level, in the inspection of series parts, for tooling requirements and in particular for all assembly frames, on which annual checks are carried out, as well as for large parts, up to 6 metres long.

POTEZ AÉRONAUTIQUE produces as many mechanical parts as sheet metal parts, which do not require the same levels of precision. Mechanical parts are 'run through' on a CMM, while sheet metal parts are measured with the Absolute Arm.

"Our Absolute Arm is also used for various checks, such as when small parts are received from subcontractors, on composite parts, 3D printing and sheet metal parts," says Andrianome.

A home-made culture

"Our corporate culture means that we try to keep as much of our know-how in-house as possible. Whether it's tooling or, more recently thanks to our new resources, measuring. The team tries to be as autonomous as possible. For example, we have developed all the specific measurements for leading-edge slats, and there are other projects for the future", concludes Benjamin Andrianome.

Metrology software increases production and keeps workflows running smoothly

Quality professionals used to worry about CMM uptime and making production decisions on unreliable data. Modern manufacturers know these are concerns of the past.

Hexagon's Metrology Asset Manager and **Metrology Reporting** apps provide real-time information on CMM performance, as well as information and insights enabling increased productivity based on data-driven decision making.

Metrology Asset Manager

Metrology Asset Manager tracks CMM use, identifies bottlenecks and spare capacity and monitors machine health and performance. Get real-time visibility and health status of your CMMs.

Metrology Reporting

Metrology Reporting centralises the reporting function and provides real-time information and insights enabling increased productivity based on data-driven decision making. Track the real-time status of measured parts, get failure details, and view metrology reports on any device at any time.

To be competitive in fast-paced manufacturing, businesses need real-time performance data and the ability to make production decisions fast using real-time metrology data.

These apps are easy to learn and use with little to no training required.

Learn more

nexus.hexagon.com/home/product/metrology-reporting
nexus.hexagon.com/home/product/metrology-asset-manager

Metrology Software

From chaos to clarity: How Danfoss automated data collection and improved quality with Q-DAS

By Adam Břicháček, Application Engineer,
Hexagon's Manufacturing Intelligence division

Founded in 1933 by Mads Clausen in Nordborg, Denmark, Danfoss has become a global leader in innovative, energy-efficient solutions. Their focus areas include refrigeration, air conditioning, heating, and more, all of which target increased machine productivity, reduced emissions, and lower energy consumption.

Danfoss engineers don't just develop these solutions; they apply them across a wide range of industries. This includes industrial machinery, automotive, marine, and off- and on-highway equipment, as well as advancements in renewable energy like solar and wind power. They're also involved in district-energy infrastructure for cities.

With a rich history of innovation dating back to its founding, Danfoss remains a family- and foundation-owned company. Today, it employs over 42,000 people and serves customers in over 100 countries through a global network of 95 factories.

The challenge: Siloed data hinders quality control

In many manufacturing organisations, engineering, production, and quality assurance departments work together with the common goal of making high-quality products. But how do these departments effectively close the data quality loop when data is locked into a specific machine or device, making the process of capturing, sharing, and acting on that data difficult, if not impossible?

Some manufacturers try to sidestep the issue by manually tracking measurement data on Excel spreadsheets and via other paper-based methods. However, this approach is time-consuming, difficult to share and collaborate on, and introduces concerns about data accuracy. Moreover, other application-based solutions have their own limitations.

Additionally, previous manual methods don't provide a secure, statistically reliable way to work with the data, increasing the opportunity for data loss or employees inadvertently recording inaccurate data results. Ultimately, employees must spend hours each day collecting and processing data and then making adjustments based on their analysis.

Engineering solutions provider Danfoss faced similar challenges. The company had numerous systems providing data but needed a way for process and quality engineers (and management) to collect and evaluate that data.

"Many of our systems weren't integrated, making it difficult and time-consuming for us to evaluate effectively," explained Robert Knoll, Design & Deliver Group, Delivering Manager (IT) at Danfoss. "We lacked statistical process control (SPC) tools. We wanted to automate this data collection and enable more robust reporting solutions so we could improve internal and external quality."

The Q-DAS solution: Streamlining data collection and analysis

Knoll and his team explored potential solutions, ultimately deciding to adopt Q-DAS. "We were able to more or less perform a self-installation and setup when we originally deployed Q-DAS back in 2005 — it was a really easy installation," said Knoll. Based on the lessons learned so far, the team feels competitive regarding improvement activities and proposals as part of the process approach.

With Q-DAS, Danfoss has been able to standardise its configuration and catalogues across the company and plants, building a process encompassing everything from the measurement request to data evaluation. The company used many of Q-DAS's standard settings and customised several K-fields used by dynamic data filters for reporting.

"Using Q-DAS has improved our statistical process control and measurement system analysis, helping audits go much more

Figure 1. Danfoss' operations feature seven distinct but interrelated quality loops, each with a different purpose and goal.

smoothly," said Knoll. "One of the most common advantages is replacing the reactive managerial module with a predictive one in terms of data visualisation and following investigation of the trend facts."

Danfoss has appreciated Hexagon's support. "Sometimes, we need something unique for a specific client — like a customised catalogue and special settings. In this situation, we connect with Hexagon's support team and get their assistance in creating the necessary catalogues. And because Hexagon offers local support in our area, they can react quickly — and with no language barrier. Hexagon's support has been excellent — if we have a critical question or issue, they often get us the solution the next work day. It also saves me time and allows me to handle other critical IT tasks." Knoll explained.

The team has been able to expand the utility of the Q-DAS solution by adding custom utilities. "I can write utilities or programmes we can use with devices that don't directly support Q-DAS. Because Q-DAS is supplier agnostic, it can support other suppliers' equipment — not just Hexagon's. We export data from those systems to Q-DAS and can monitor all of the systems on our shop floor — not just the machining area, but also in the assembly line and testing," Knoll said.

Beyond automation: Building quality loops

Q-DAS has helped Danfoss create an integrated system of quality loops. These different quality loops allow Danfoss to leverage its data differently for other processes throughout the organisation.

Quality loop 1: Metrology lab

The first loop is in the metrology laboratory. CMM operators measure the pieces coming from the production according to priority and reason for measurement. After measuring each piece, they can see its result and historical data in the Q-DAS module's O-QIS MCA/CMM reporting. The operator can decide to accept or reject the measurement, typically only rejecting when they find a problem during measurement. After they accept the measurement, the data may move in several different directions. For example, in the case of "standard" or "setup" measurement, the data proceeds to quality loop 2. In the case of a special measurement reason — like measurement system analysis (MSA) or production part approval process (PPAP) — the data goes straight to centralised upload processing in preparation for loop number 4.

Quality loop 2: Production

In production, personnel have a computer—enabled with an O-QIS MCA/CMM reporting module—next to the CNC machines. The CMM reporting module waits for the measured data from the metrology lab, and once it arrives, the machine operator can see the results and some historical data. If something is "wrong" in the process, the screen displays alarms, alerting the operator to decide if and what intervention is necessary. This feature allows operators to react immediately to potential process problems without unnecessary delays. Then, data continues to the central database to be saved.

Quality loop 3: Production+Metrology

The third quality loop also takes place in production, but no one is waiting for the metrology lab's results. Pieces are measured on local measurement stations with hand gauges, and each station has a computer with a Q-DAS module and an O-QIS procella. In the procella, operators can load the test plan and perform measurements according to the instructions and pictures.

Similar to MCA/CMM reporting, operators can see historical data and receive alarms in the case of process problems like stability or control limit violations. This context allows operators to react quickly to process changes and problems. Similar to the previous loops, measurement data is directly saved in the central database.

Quality loop 4: Engineer measurement request

The fourth loop begins with an engineer making a measurement request—typically for an MSA or PPAP. Once the measurement is done, it goes to the central database for analysis. The engineer can open the measurements based on filters and analyse anything they need.

Quality loop 5: Assembly + special test strands

The fifth loop occurs in the assembly area equipped with special test stands, with testing occurring on parts of the finished product. In quality loop 5, pressure, temperature, and other special characteristics are measured, and results are automatically converted to Q-DAS format and sent to the central database for later evaluation.

Quality loop 6: Organisation

Though not currently in place, the sixth loop will eventually encompass the organisation. Nowadays, vision, asap reality, hopefully. M-QIS reporting will be installed on the server module, and thanks to this, it will be able to create and distribute reports automatically based on the data saved in the central database. These reports will be issued periodically, and each will have different recipients. For example, process engineers will receive e-mails every Monday morning with reports from the processes for which they are responsible.

The report will only visualise the previous week, evaluating it from a process capability point of view, with the "worst" results shown at the top of the report. Similarly, the production manager will receive a report every Friday afternoon. This report will display overall results across the production process, highlighting the ratio between in-tolerance and out-of-tolerance measurements for each machine.

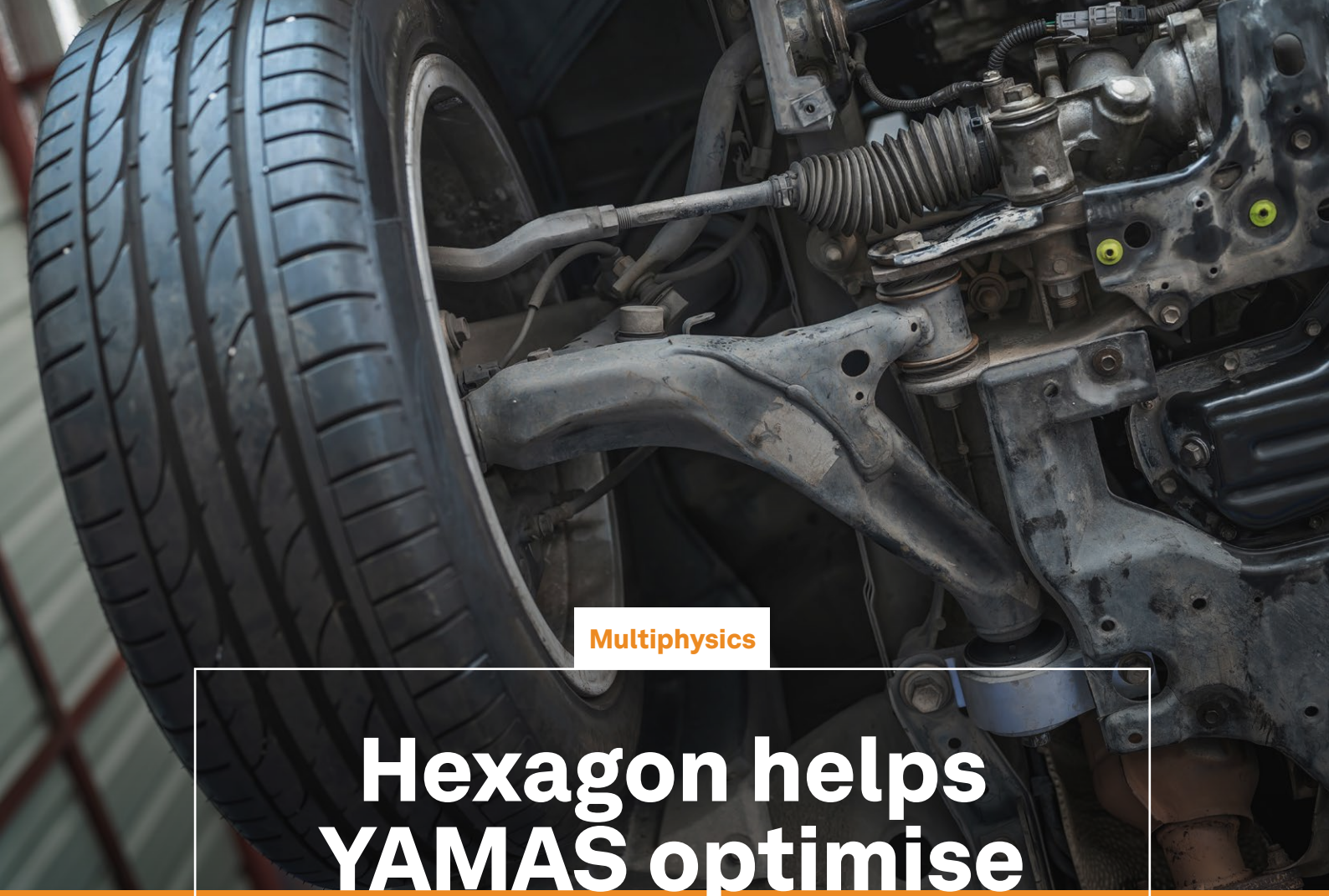
Quality loop 7: Organisation + PC qs-STAT modules

The last loop encompasses the entire organisation and includes qs-STAT modules installed on numerous PCs. Quality and process engineers can load data onto these PCs from the central database and then make any desired evaluations and special reports that M-QIS doesn't handle.

Results: Fully automated data collection and evaluation

Working with Q-DAS, Danfoss has fully automated its data collection and evaluation — meaning everyone can work with the results, but no one has to work to get the results. Its quality loops enhance the company's data security, providing near real-time results across the process and allowing its engineers and operators to make fast, informed decisions on addressing process problems. That leads to significant time savings, optimises processes over time, and leads to less scrap.

With Q-DAS and quality loops in place, Danfoss can leverage its data as much as possible, with minimal effort required from staff. "We collect thousands of data per day—and it would be impossible for us to capture, record, analyse, and evaluate it manually. With Q-DAS running everything automatically, we can perform measurements, analysis, and process adjustments in moments. Q-DAS has allowed us to reduce the number of conflicts in the system," Knoll concluded.



Multiphysics

Hexagon helps YAMAS optimise anti-vibration rubber-metal suspension bushing design

By Jean-Daniel Lecuyer, Structures Product Management, Hexagon's Manufacturing Intelligence division

YAMAS, a global leader in the production of rubber-based noise and vibration-damping elements for the automotive industry, has been serving customers with its strong R&D infrastructure and co-design competence since 2002.

YAMAS's customers include automotive OEMs such as Volkswagen and Porsche. The company operates from two locations in Karacabey, Bursa, Turkey, with a total area of over 31,000 m² dedicated to production, testing, research & development, and warehousing. YAMAS's product range covers various anti-vibration components for passenger, commercial, off-highway, rail, and industrial applications.

Challenge: Designing to withstand radial and cardanic movements

Control arm bushings, which connect the control arms to the frame or body of a vehicle, play a critical role in allowing suspension components to move easily when a vehicle encounters rough or uneven surfaces. Rubber — an inherently flexible material — minimises the transmission of noise and vibrations to the vehicle's chassis.

However, YAMAS found its anti-vibration bushings faced challenges when operating under radial and cardanic movements. "Strain values are very high on the region where the bushing is subjected to tensile and shear forces during the simultaneous cardanic and radial movements. For this reason, cracking occurred in the specified region in the continuous dynamic movement of the bushing under vehicle service conditions," explained Semih Koçak, R&D Engineer at YAMAS.

He continued, "Our main challenge was to design the weak area on the rubber during radial and cardanic movement while still meeting the static requirements of the bushing in all directions. The design constraints included the length of the inner tube, the outer tube diameter, and the inner tube diameter of the bushing. Independent of the vehicle assembly area, the design variables included the inner tube centre form diameter and inner tube centre form."

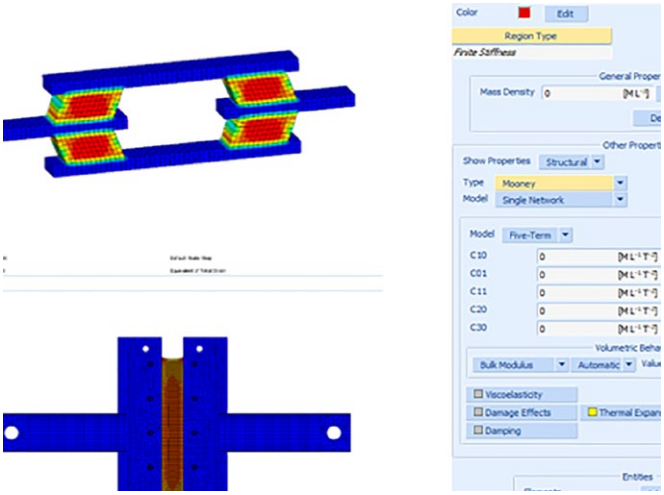


Figure 1. Virtual testing of rubber materials.

Solution: Increasing bushing performance with simulation

To overcome this challenge, YAMAS employed advanced simulation tools and accurate material models. Koçak and his team knew that numerous key factors would contribute to the company's ability to have good simulation results and develop an efficient engineering workflow, including:

- A robust simulation tool
- A well-proven Finite Element (FEA) solver
- Accurate rubber material models capable of simulating very large elastic deformation
- Accurate metal material models capturing elastoplastic behaviour
- A proper mathematical, numerical algorithm, such as Herrmann Reduced Integration for the elements modelling the rubber part

Three simulation steps

With these factors in mind, YAMAS used Marc, Hexagon's advanced nonlinear simulation solution, to develop an engineering workflow that involved three simulation steps:

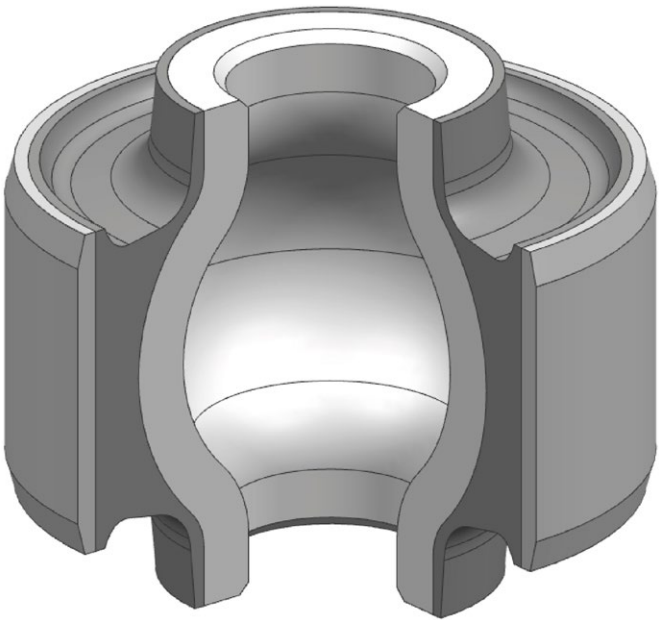


Figure 2. Control arm bushing geometry.

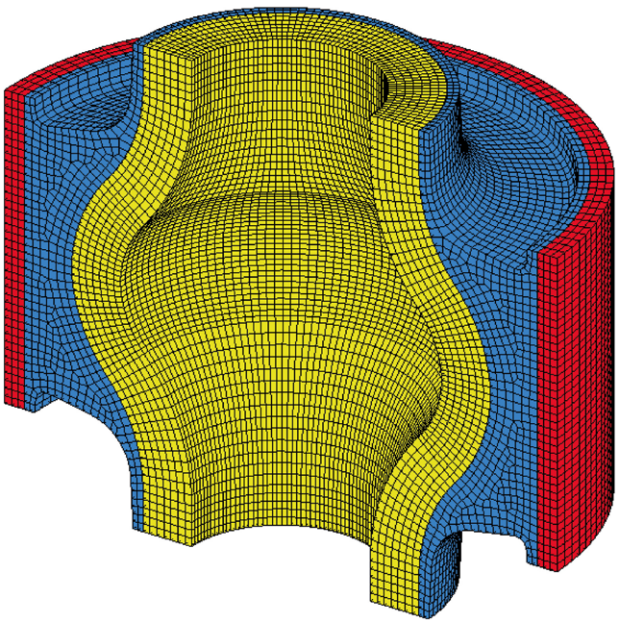


Figure 3. Finite element model of the bushing

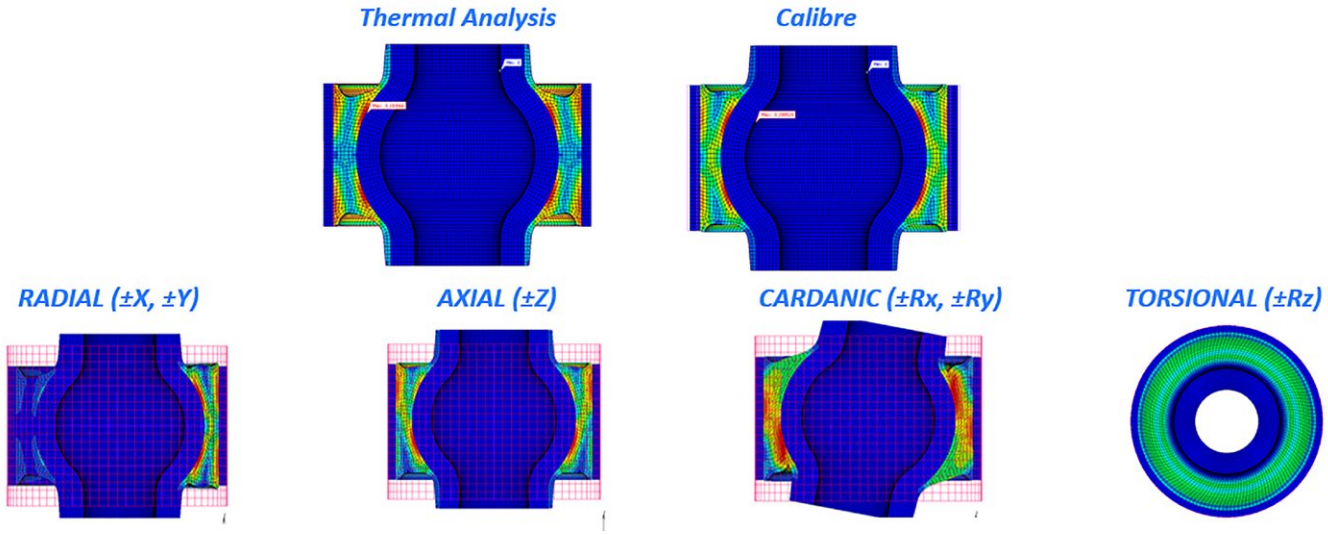


Figure 4. Typical loading conditions for the simulations.

Step 1: Thermal analysis to simulate the cooling of the part after vulcanisation

Step 2: Swaging to simulate the swaging process applied to the part

Step 3: Related direction movement to simulate the static tests applied to the part, including radial, axial, cardanic, and torsional loading

YAMAS also prepared the mesh structure for the simulations using Apex, Hexagon's CAE-specific direct modelling and meshing solution. This enabled efficient pre-processing and high-quality mesh generation. The company then leveraged symmetrical modelling capabilities to reduce the model size and simulation running time for loading conditions in the radial and axial directions.

Validating simulation results

One of the project's most important parts was YAMAS's ability to validate simulation results. To accomplish this, the company compared simulation outputs with data from physical tests to ensure the virtual models were accurate and reliable. "The validation process gave us confidence in the simulation methodology and the design decisions based on the results," Koçak said.

An improved bushing configuration

The design optimisation process focused on two critical parameters identified as having the most significant impact on reducing strain values: the inner tube's outer shape and the rubber thickness. Koçak explained, "By evaluating these two variables together, we were able to reduce strain values and increase the bushing's operating performance under dynamic conditions. This targeted optimisation approach allowed us to efficiently explore the design space and arrive at an improved bushing configuration."

Results: Accelerated development and improved product performance

By deploying advanced simulation tools and accurate material models, YAMAS significantly improved its engineering workflow and product performance. "The analyses that Hexagon solutions provided allowed us to validate components, reducing our development processes from a month down to a week one week," Koçak said.

The optimised bushing design resulting from the simulation-driven approach exhibited reduced strain values and increased operating performance under dynamic conditions. Impressively, the simulation accuracy rate reached 93.5%, enabling YAMAS to minimise the time and resources spent on physical prototyping and manual design iterations.

Looking ahead with Hexagon

Looking ahead, YAMAS plans to build on this project's success by further improving its bushings' dynamic performance accuracy. "We're going to pair the current study with dynamic finite element solutions to gain a deeper understanding of the relationship between strain rates and cracking on rubber," he said.

But the company isn't stopping there. Recognising the potential of emerging technologies to streamline its design processes even further, YAMAS plans to deploy Hexagon's ODYSSEE platform. By leveraging ODYSSEE, YAMAS aims to integrate artificial intelligence and machine learning techniques into its workflow. "Ultimately, our goal is to get to optimal designs faster and accelerate our time-to-market for new products," Koçak concluded.

Transforming the global plastics industry with Nexus Connected Worker

By Dr Asif Rana, President Nexus Connected Worker,
Hexagon's Manufacturing Intelligence division

In the bustling industry of global plastics and packaging, where operational efficiency dictates success, one company's journey with Hexagon's innovative solutions marks a significant pivot towards the future of manufacturing. A global plastics and packaging leader, serving industries from food and beverage to pharmaceuticals, faced escalating challenges that threatened its competitive edge in the fast-evolving Industry 4.0 landscape.

Historically, the company grappled with inefficient, paper-based systems that bogged down its operations. These antiquated processes led to cumbersome work order management, frequent human errors in data entry, and a glaring lack of real-time insight into operations. With more than 70 facilities scattered across North America, the disjointed data collection and management practices hindered not only productivity but also the strategic and timely decision-making capabilities essential for growth.

Enter Nexus Connected Worker—a beacon of digital transformation tailored for high-demand manufacturing environments. The company launched an ambitious revamp of its operational model, incorporating sensor hardware and the Nexus Connected Worker platform. Crucially, the integration of these components transformed the company's stagnant, error-prone data landscape into a dynamic, insight-rich operational powerhouse.

The core of this transformation lies in strategically integrated sensor technology. These sensors, capable of real-time data integration, were deployed across production lines to monitor various metrics such as machine uptime, cycle counts, production KPIs, and overall equipment effectiveness (OEE). The real-time data gleaned from these sensors provide more than mere statistics; they offer a constant flow of actionable insights, encouraging immediate adjustments and predictive maintenance strategies that far outpace traditional reactive models.

Moreover, the Nexus Connected Worker digital workflows harness this sensor data to empower employees. Workers now have mobile access to real-time operational data, drastically reducing the time spent on administrative tasks like downtime tagging—from two hours per shift to less than ten minutes. This newfound efficiency has boosted productivity and significantly cut down the mean time to repair by empowering maintenance technicians with instant notifications and comprehensive machine health data.

The results speak for themselves. Since implementing Hexagon's solutions, the company has seen a substantial reduction in scrap rates by 25% and has improved OEE scores significantly across its production lines, not to mention the immediate and real-time availability of this OEE data. The strategic integration of sensor technology with Nexus workflows has not only streamlined operations but also fostered a culture of proactive maintenance and efficiency.

This case study exemplifies how embracing modern technology and integrating comprehensive sensor systems with intelligent workflows can transform manufacturing operations. The journey of this global plastics company with Hexagon's technology illustrates a successful marriage of innovation and practical application, setting a benchmark for others in the industry to follow.

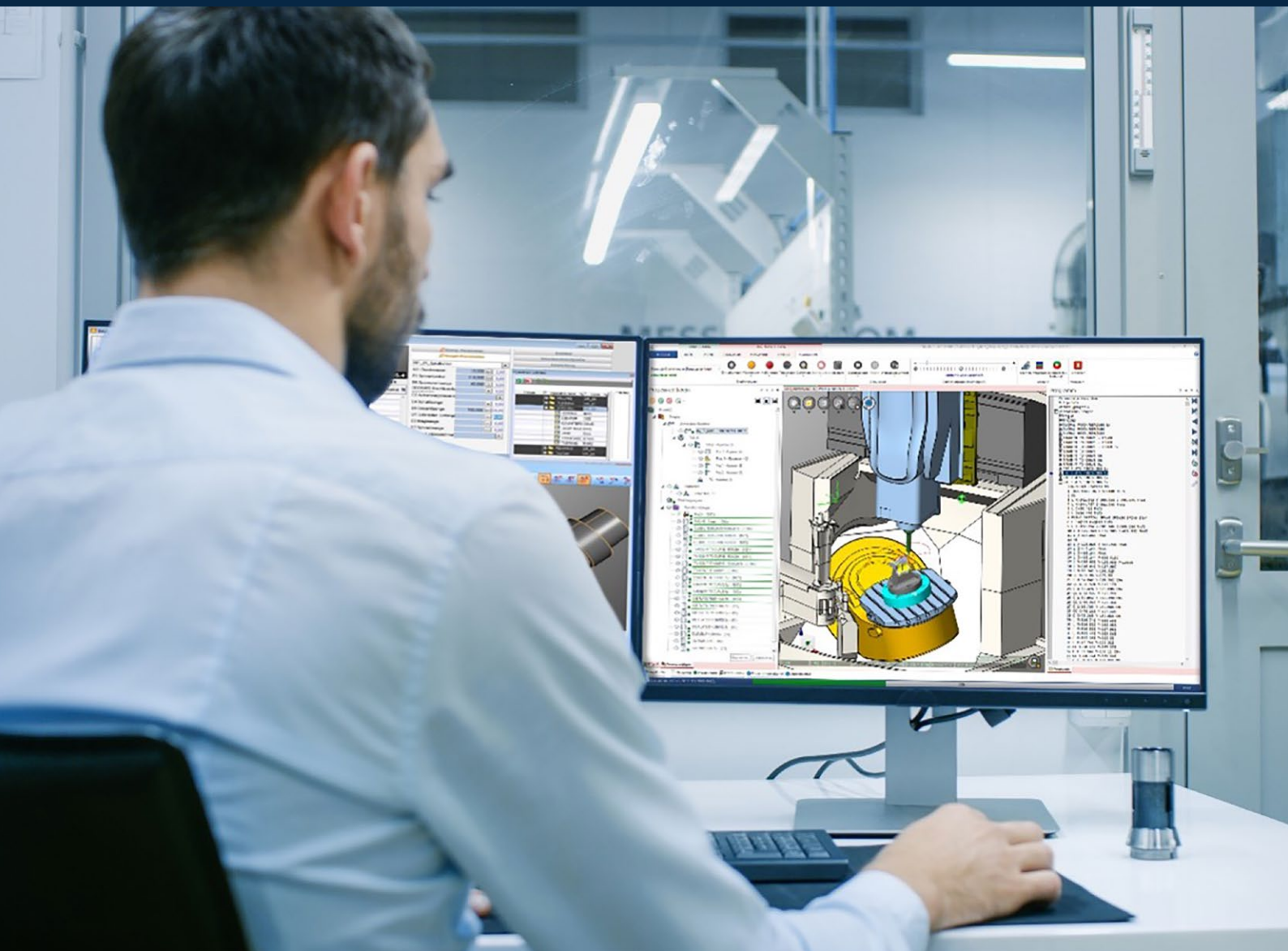
For a deep dive into the details and transformative impact of the Nexus Connected Worker system, visit nexus.hexagon.com.

Production Software

Moulding the future: Innovations and solutions in plastic injection

Efficient toolpaths and high-quality surfaces for precise moulds

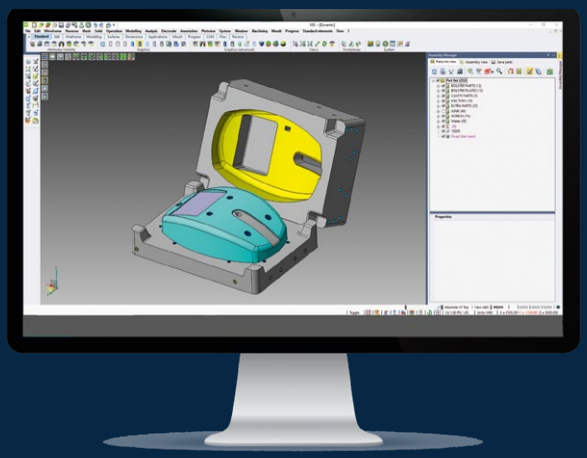
By Paul Losavio, Director Product Marketing, Production Software,
Hexagon's Manufacturing Intelligence division

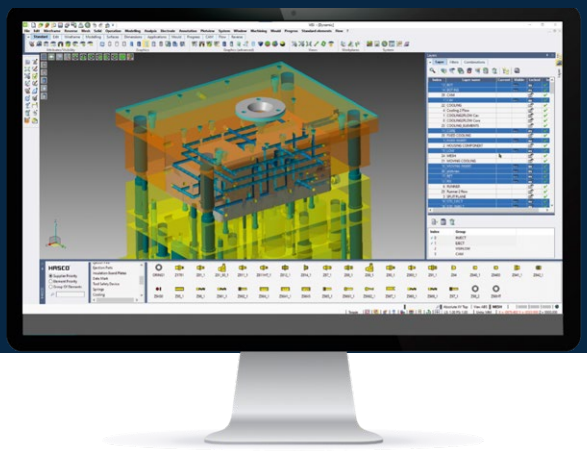


Rising global demand for moulded plastic products — coupled with advances in hybrid machines, increased usage of all-electric injection moulding machines, and a rising trend of using lightweight yet strong plastic composites — have all combined to create significant growth in the plastic injection moulding industry. As the industry evolves, manufacturers face increasing pressure to deliver high-quality products quickly and cost-effectively while also addressing concerns about sustainability and environmental impact.

To meet and overcome these challenges, many manufacturers are turning to advanced solutions like Hexagon's Mould & Die Suite, which provides a comprehensive, end-to-end approach that streamlines the design, simulation, and manufacturing processes.

Here, we discuss ways to optimise the mould design process. We'll also highlight how simulation can help imbed quality in the design process and uncover how Hexagon solutions can help manufacturers solve even the most complex moulding challenges.



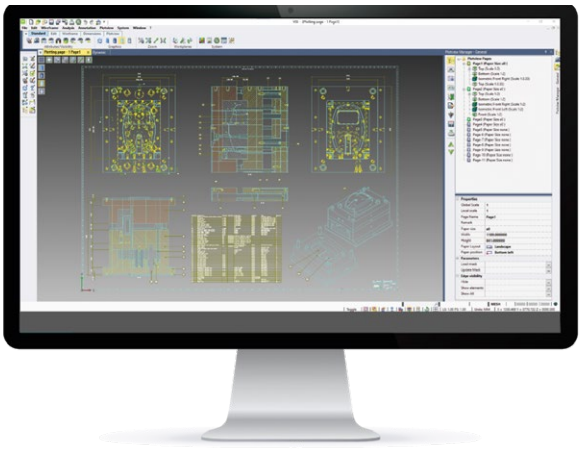


Optimising the design process

Designing moulds and mould assemblies comes with several unique challenges — including defining core and cavity geometry, designing electrodes, and managing complex assemblies. And Hexagon's Mould & Die Suite addresses these challenges. For example, the suite's reverse engineering capabilities empower designers to create accurate 3D models from physical parts quickly. Complemented by advanced morphing capabilities that let designers easily manipulate and refine 3D model geometry, Hexagon's Production Softwares allow for rapid design iterations and optimisation.

Additionally, the Mould & Die Suite's automated core and cavity extraction features use intelligent algorithms to identify and extract the corresponding geometry from the part model, saving designers significant time and effort. The suite's full assembly management capabilities offer a comprehensive solution for designing and validating the entire mould assembly, including the mould base, ejection system, cooling channels, and other components. The Suite's CAD and CAE capabilities allow designers to check for interferences, analyse the assembly's kinematics, and ensure proper function before manufacturing.

Other ways that Hexagon's Mould & Die Suite benefit designers include:



- Part design optimisation: The suite's topology investigation tools help optimise part design for manufacturability by identifying areas where material can be removed without compromising strength or performance.
- Informed decisions early: The Mould & Die Suite's comprehensive supplier component library and material characteristics database mean that designers can make informed decisions early in the design process, reducing design time and ensuring component compatibility.

- Clear downstream communication: Hexagon's automatic drafting and dimensioning features ensure that necessary information is communicated to downstream processes, generating detailed 2D drawings and 3D annotations directly from the CAD model.

How simulation helps imbed quality in the design process

Plastic injection moulding designers face numerous challenges, including:

- Predicting material flow
- Analysing warpage
- Optimising cooling channel design
- All of them helping in preventing defects

Hexagon's advanced simulation capabilities allow designers to address and overcome these challenges. Using the Mould & Die Suite's powerful flow analysis tools, designers can simulate the injection moulding process, predict how molten plastic will fill the mould cavity, and identify potential issues that may negatively impact part quality.

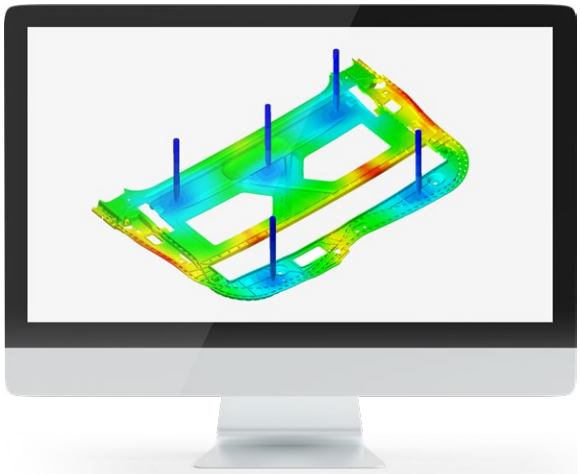
The suite's thermal analysis module simulates heat transfer within the mould, allowing designers to optimise cooling channel placement and prevent issues like hot spots or uneven cooling. Hexagon's warpage estimation and compensation tools help designers predict and mitigate material shrinkage and deformation effects, ensuring the final part is dimensionally accurate.

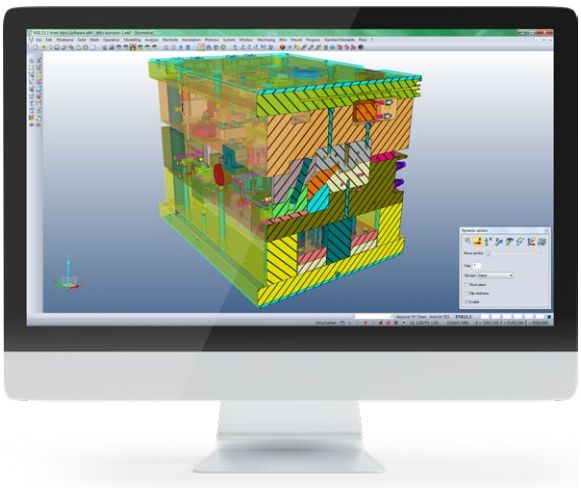
Additionally, the suite's kinematics and simulation capabilities allow designers to validate the entire mould assembly's performance, including the operation of sliding cores, lifters, and ejector systems.

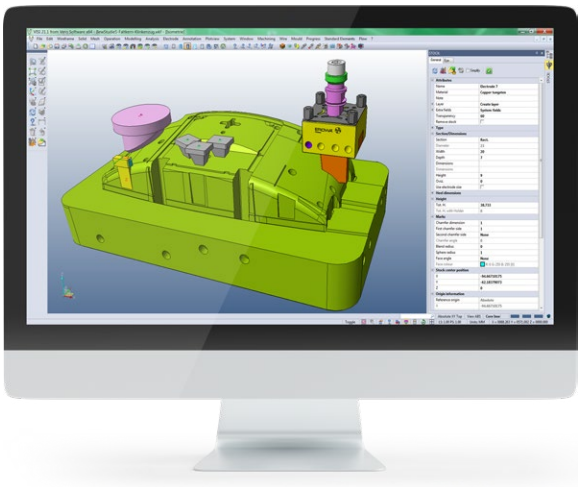
Manufacturing the mould

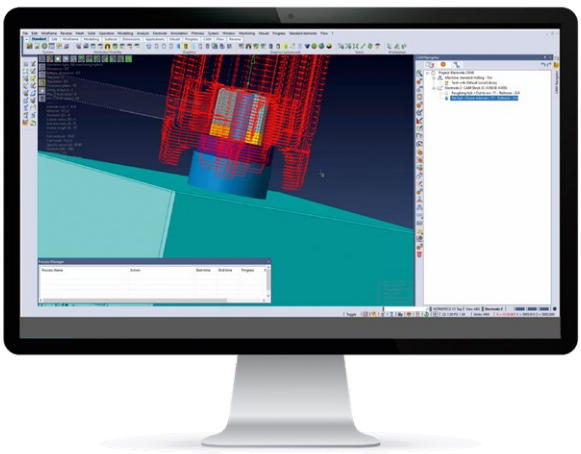
Programming the machining processes for manufacturing moulds can be complex and time-consuming, with challenges like:

- Optimising toolpaths: Generating efficient toolpaths that minimise machining time, reduce tool wear, and ensure consistent material removal can be challenging, especially for complex mould geometries.
- Achieving high surface quality: Moulds require very smooth, high-quality surfaces to produce accurate, aesthetically pleasing parts. Achieving the required surface finish can be difficult, particularly in hard-to-reach areas or when machining tough materials.
- Machining difficult materials: Moulds are often made from hard, wear-resistant materials such as tool steels or high-performance alloys, which can be challenging to machine efficiently and accurately.
- Ensuring compatibility with a wide range of machine tools and controllers: Mould manufacturers regularly use a variety of CNC machines and controllers, each with specific requirements and limitations. Generating NC code that is compatible with multiple machines and









ensuring smooth post-processing can be time-consuming and error-prone.

Hexagon's Mould & Die Suite provides powerful CAM programming capabilities that solve these challenges. The suite includes tools for 3- to 5-axis milling, enabling the efficient machining of complex mould geometries.

High-speed machining strategies optimise cutting parameters to reduce cycle times while maintaining tool life and surface quality. And the suite has integrated ultra-quality surface finishing techniques — like 3D morphing and circle segment finishing — to ensure that mould surfaces meet injection moulding's tight surface finish requirements.

The Mould & Die Suite's safe toolpath generation features and dedicated post-processing capabilities prevent collisions while ensuring compatibility with a wide range of machine tools and controllers. Its programming automation capabilities streamline NC code creation, reducing programming time and ensuring consistency between parts. And digital twin simulation and cycle time optimisation tools allow designers and programmers to validate and optimise toolpaths before running them on the machine.

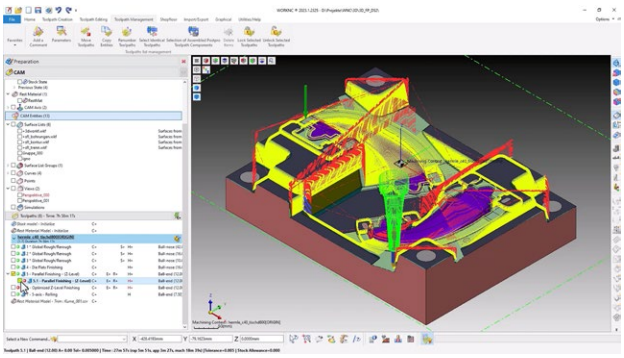
Streamlining the end-to-end workflow

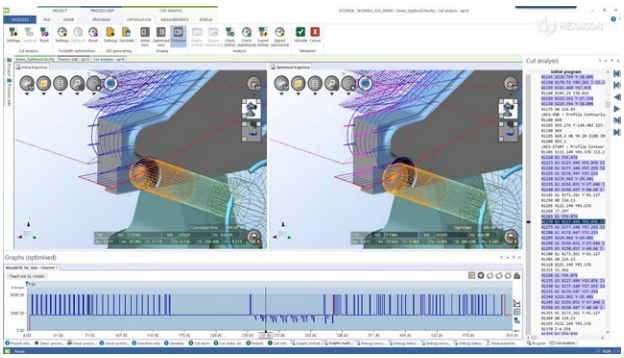
In essence, Hexagon's Mould & Die Suite streamlines the workflow from design to manufacturing, facilitating a smooth transition between each process stage. The suite's integrated approach ensures that data flows seamlessly between the various tools, eliminating the need for manual data translation or file conversion.

Thanks to simultaneous access to and modification of the same data, designers and engineers can collaborate more effectively. This access ensures everyone is working with the most up-to-date information.

The suite's automation features reduce the time and effort required for repetitive tasks. That includes its automated core and cavity extraction, as well as programming automation. These automation tools also help ensure consistency and quality across different projects and teams, as best practises and proven strategies can be captured and reused easily.

By providing better control over product quality and facilitating faster time to market, the Mould & Die Suite helps manufacturers meet the growing demand for high-quality plastic products while controlling costs. The integrated workflow facilitates faster iterations and design changes, allowing manufacturers to quickly respond to changing customer requirements or market demands.





Navigating complex mould design, simulation and manufacturing challenges

As the plastic injection moulding industry continues to evolve, manufacturers must stay at the forefront of innovation to maintain their competitive edge. And Hexagon's Mould & Die Suite can play a critical role in helping navigate this dynamic landscape, providing a comprehensive solution that addresses the challenges of designing, simulating, and manufacturing complex moulds.

The suite's advanced capabilities — from reverse engineering and topology optimisation to high-speed machining and digital twin simulation — mean manufacturers can create optimised, high-quality designs and streamline production.

By investing in Hexagon's Mould & Die Suite, manufacturers can reap the rewards of greater collaboration, automation, and data-driven decision-making — including reduced costs, improved quality, and accelerated time to market.

With its flexible, scalable platform — and Hexagon's commitment to continuous innovation — the Hexagon Mould & Die Suite is poised to help manufacturers embrace emerging technologies and succeed in an ever-changing industry.

As they face new challenges and opportunities in the years ahead, Hexagon's Mould & Die Suite will remain a trusted partner, giving manufacturers the cutting-edge tools, expertise, and support needed to stay ahead of the curve and create innovative products.

Metrology Devices

Automation and smarter EDM manufacturing enabled by shop-floor metrology solutions

By Takashi Sumikita, Head of sCMM Sales Japan, Hexagon's Manufacturing Intelligence division

To enhance automation and ensure product quality in its customers' EDM process, Sodick selected Hexagon's TIGO SF CMM and PC-DMIS metrology software for their Smart SITE solution.

To help their customers increase automation and flexibility in their EDM production process, Sodick partnered with Hexagon on metrology solutions that ensure product quality and boost measurement efficiency, laying essential foundations towards a fully realised smart factory.

Sodick is an advanced technology company based in Japan that was founded in 1976. The company specialises in producing electrical discharge machining (EDM) machines, including the development of non-consumable electrodes.

They introduced numerically controlled (NC) EDM machines to the Japanese market and also manufacture CNC machining centres, metal 3D printers, injection moulding machines, noodle-making machines, and aseptic packaged cooked rice production systems. Sodick's in-house manufacturing of linear motors and NC devices ensures high performance in their various machine tools, earning them high praise in the mould processing industry.

With approximately 600 employees and covering an area of about 50,000 m², the Kaga factory in the Hokuriku area is Sodick's largest manufacturing plant in Japan.

In 2022, Sodick took significant steps to enhance automation and flexibility in the EDM industry. To further boost the Flexible Manufacturing System (FMS) they offer their customers, they developed the 'Sodick Smart SITE' at the Kago factory – a packaged solution designed to semi- or fully automate a customer's EDM manufacturing process.

Solving skills shortages and ensuring product quality

The move towards increased EDM automation is primarily driven by the shortage of skilled employees the industry faces and aims to ensure stable product quality and enhanced process productivity.

For die-sinking EDM, custom electrodes are manufactured using CNC machining centres to match the desired workpiece shape. The Sodick Smart SITE solution currently offered is a semi-automatic system that reads preprogrammed QR codes on electrodes and workpieces. This allows the automatic execution of NC, EDM and measurement programs without human intervention.

To ensure the utmost quality of these electrodes, Sodick introduced Hexagon's TIGO SF shop-floor 3D coordinate measuring machine (CMM) and 3D metrology software PC-DMIS to obtain correction values for electrode machining adjustments and final electrode quality checks.

"In mould manufacturing, precision to one micrometre (µm) is required," says Yuki Tsuda, Manager of Sodick's Technological Development Section. Also, it's essential that customers can place their metrology equipment near production machinery while maintaining precision measurements. These are why we chose the specialised shop-floor CMM TIGO SF as an integral part of our Smart SITE solution."

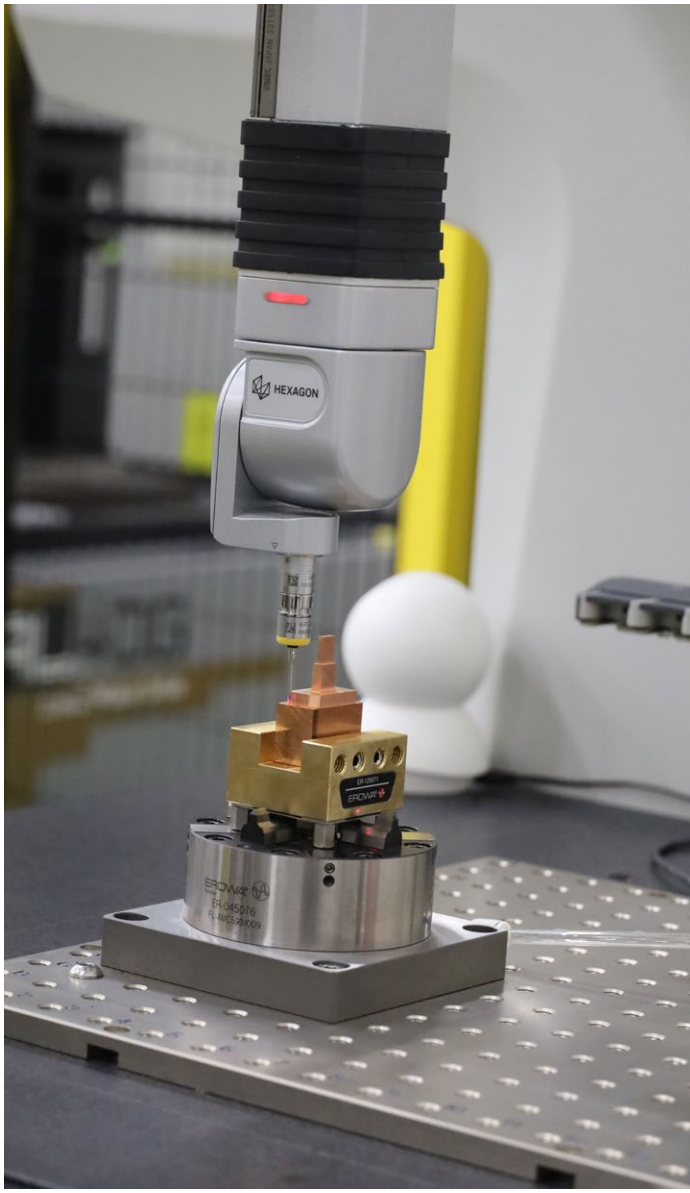
Integrating Hexagon's metrology products into Sodick Smart SITE empowers Sodick's customers to automate various tasks. This includes measuring multiple electrodes, acquiring correction/rework offsets for EDM, generating metrology reports and seamlessly saving quality data to their servers.

PC-DMIS easily integrates with Sodick's JvMAS mould automation system used in machining centres, EDM machines, and 3D measurement machines, eliminating the need for

Overall optimisation of measurements has led to a 100% improvement in our customers' Smart SITE measurement efficiency."

– Yuki Tsuda, Manager, Technological Development Section, Element Development Department, Machine Tools Division, Kaga factory, Sodick Co., Ltd

Figure 1. A close-up of the sophisticated surface of an artefact.



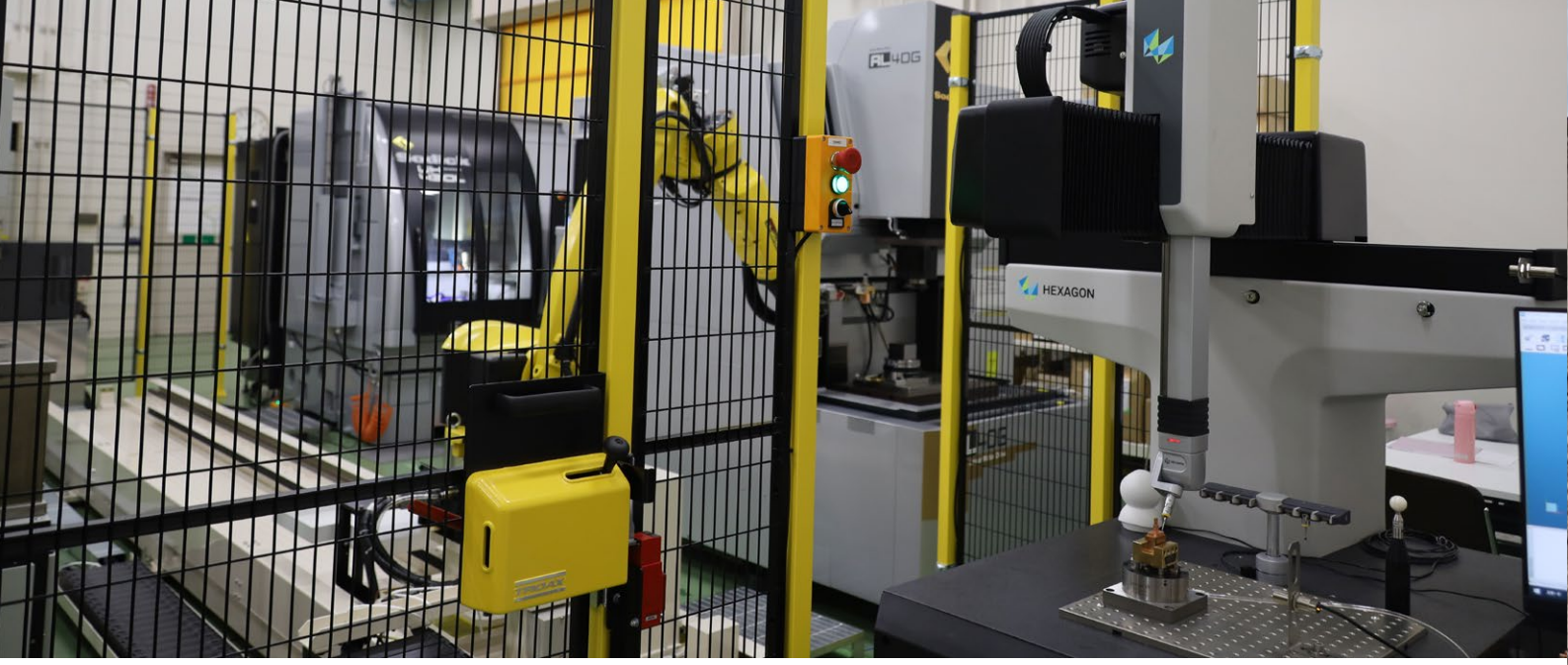


Figure 2. Hexagon's TIGO SF shop-floor CMM shown here in the Sodick Smart SITE semi-automated solution with the Sodick high-speed milling machine UH430L (rear left) and the Sodick die-sinker EDM machine AL40G (middle).

multiple specialised software. PC-DMIS imports JvMAS settings seamlessly without manual intervention, resulting in impressive productivity improvements: "Overall optimisation of measurements has led to a 100% improvement in our customers' Smart SITE measurement efficiency," Tsuda says.

Expert support points to wider collaboration

"And I've been really impressed with the support we received during the implementation process. The Hexagon team was quick to assist, with thorough guidance on PC-DMIS file specifications and giving us in-depth suggestions to enhance safety measures and address other aspects."

"The hands-on support from engineers with specialised expertise in hardware and software made a big difference and was key in getting the automated line, including the new CMM, up and running quickly," he says.

Tsuda envisions their customers using measurement data from TIGO SF for ongoing machinery and tool maintenance. In addition, he's looking to accelerate their innovation towards enabling even more sophisticated manufacturing by integrating FMS with a customer's Manufacturing Execution Systems (MES). Combining IoT with ERP systems for mould manufacturing will enable more efficient planning, paving the way for a fully realised smart factory, and boosting the competitiveness of a customer's operations.

Hexagon offers comprehensive hardware and software solutions throughout the manufacturing process. Tsuda looks forward to continued collaboration to tackle challenges such as labour shortages, traceability and reproducibility – with this collaboration extending beyond the further automation of EDM production processes to finding holistic solutions for these issues.

**"I've been really impressed with the support we received during the implementation process ...
(which was) key in getting the automated line, including the new CMM, up and running quickly."**

– Yuki Tsuda, Manager, Technological Development Section, Element Development Department, Machine Tools Division, Kaga factory, Sodick Co., Ltd

Multiphysics

Making exceptional vehicles with Hexagon: CAE solutions for multibody dynamics and nonlinear analysis

By Melinda Corley, Product Marketing Manager Multiphysics, Hexagon's Manufacturing Intelligence division

TATRA'S mission is to create vehicles that are safe, comfortable, cost-effective, and efficient to manufacture. This can be an ambitious goal, as these factors are deeply interconnected. Safety and comfort must be balanced with cost constraints, all while considering the feasibility of production. Decisions in one area can significantly impact the others, which makes the ability to understand how disparate systems within a vehicle interact critical to producing a safe, reliable, and efficient truck.

The road to reducing prototypes

Unfortunately, creating physical prototypes to test each variable in accurate operating conditions is cost and time-prohibitive. Simulating these interactions with CAE (Computer-Aided Engineering) software can offer companies like TATRA an accurate and reliable way to optimise systems and components and validate them for safety, comfort and manufacturability.

TATRA, a company with a rich heritage spanning more than 170 years, has played a pivotal role in shaping the automotive industry both in the Czech Republic and around the world. With its subsidiary, TATRA METALURGIE a.s., the company focuses on producing heavy-duty off-road vehicles and trucks for combined on/off-road transport and continually enhances its offerings to meet the ever-evolving demands of its customers. TATRA-branded trucks are renowned for their exceptional go-anywhere ability in challenging terrains and extreme weather conditions, high reliability, and outstanding utility properties, making them ideal for extreme conditions like frosty weather and scorching desert temperatures.

Creating trucks that satisfy customers and regulations

In the automotive industry, creating engineering solutions that meet regulatory requirements is critical for success. For satisfactory vehicle performance, some requirements must be met for braking, steering, acceleration, and more. To fulfil these obligations, TATRA relies on Hexagon CAE solutions to simulate vehicle behaviour and perform virtual tests that will ensure their vehicles meet industry and government regulations. For example, lifting and tie-down elements at emergency vehicle frames have specific requirements called STANAG standards in the defence sector, Homologation regulations for RUPD (rear underrun protective device) and FOPS/ROPS (Falling-Object protective / Roll-over Protective Structures) mean meeting passive safety requirements for civilian and industrial cargo transport.

These standards and regulations extend to performance at high speeds over difficult terrain or in heavy off-road conditions, driving comfort, vehicle stability on turns and on slopes, and high chassis rigidity. Ensuring regulatory compliance and meeting standards requires accurate simulation capabilities to evaluate design concepts, perform trade-off studies, and improve vehicle performance.

To optimise designs to meet these regulations and high standards, TATRA uses Adams from Hexagon to perform multibody dynamics simulations and Marc for nonlinear analysis to correlate simulation results with physical test data for extremely accurate and reliable predictions.

The simulations performed with Adams allow TATRA to validate full vehicle models against physical test data so the company can predict vehicle performance using different driving manoeuvres and set tyre parameters. Other capabilities in Adams ensure that TATRA meets regulatory requirements and industry standards for braking systems and suspension systems. Adams enables the company to predict braking distances for loaded and empty trucks and the virtual hydraulic testing rig in Adams allows TATRA to design vehicles with appropriate stiffness and damping settings for better comfort, as well as determine the fatigue life of the cabin suspension system.

Figure 1. Braking simulations are used to validate that trucks will meet requirements and homologation for empty and loaded vehicles.

Figure 2. The full-vehicle model results are correlated with physical tests.

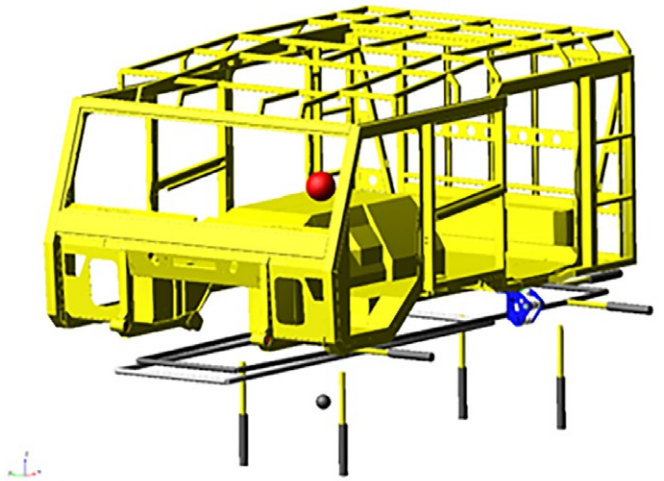


Figure 3. Simulations in Adams help TATRA choose ideal mounting conditions and balance price, comfort, and durability inputs for FEM calculation.

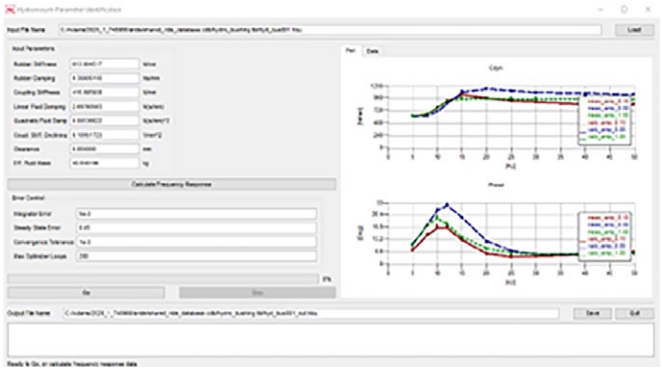


Figure 4. TATRA uses Adams to simulate vibrations for critical revolutions and torque and forces against the frame, and uses the results to inform FEM.

Powerful solutions for multibody dynamics and nonlinear analysis

Hexagon CAE solutions help TATRA meet regulations and optimise the truck designs to achieve better performance. Adams plays a crucial role in highlighting the capabilities of vehicle design and opportunities for optimisation.

TATRA uses Adams to make informed decisions on powertrain and cabin mount locations and their orientations and manage the transition of forces from the mainframe to the cabin. Adams simulations help the company determine the optimised load distribution on the axles and account for changes to the wheelbase or a shift in the centre of gravity for the components. Studying these factors results in reduced cabin vibrations, lower steering effort, better comfort, lighter components, and lower manufacturing costs. These simulations also provide critical road load data inputs for FEM (Finite Element Model) calculations, where the company uses MSC Apex as a pre-processor for shell mesh object generation.

> **“Simulations are key to evaluating design concepts, performing trade-off studies and optimising our trucks. Accessing the right solutions at the right time is crucial in this competitive environment.”**
>
> – Dušan Otisk, Structural Engineer, TATRA

The interoperability of Hexagon’s solutions is key to Tatra’s design and engineering processes. The integration of MSC Apex with Adams streamlines the process of preparing mesh and interface points for flexible bodies, such as frames and axles. This integrated solution facilitates the creation of MNF files for flexible bodies, making the design process more efficient and accurate.

Marc is used to establish connections with Simufact Forming for external loading. This enables it to analyse the impact of external loads on its products, enhancing overall product design and performance. These integrated workflows save valuable engineering time, making it easier to adapt to rapidly changing market conditions and new requirements.

Simufact Forming empowers TATRA to simulate the technological processes of truck part manufacturing, including welding and forming. These simulations allow the company to understand the impact of manufacturing on its designs, enhancing product quality and efficiency. It can also integrate these results as pre-stress data with operational load sets, providing a more comprehensive view of vehicle performance.

Optimised designs and virtual testing mean better, more cost-efficient vehicles

The Hexagon software multibody dynamics (MBD) solution, validated by experimental tests and in collaboration with technical universities, has significantly improved TATRA's design process. The company can rely on these simulations to make informed decisions and optimise their designs, ensuring vehicles that meet safety, comfort, cost, and manufacturability requirements.

TATRA is excited about the future possibilities of expanding its simulation and design capabilities by further exploring Hexagon software. It hopes to add capabilities for virtual test tracks and proving grounds, which will further enhance its ability to simulate real-world scenarios. Features like FTire will enable more accurate tyre modelling, contributing to a more realistic and comprehensive simulation. Faster meshing will streamline the design process, saving time and resources, and analysis using CAEfatigue will enhance the company's understanding of product durability.

The collaboration between TATRA and Hexagon has allowed the company to meet their complex challenges of creating safe, comfortable, cost-effective, and easy-to-manufacture vehicles. Using the power of advanced simulation and CAE tools, it has not only met industry and government regulations but has also optimised designs to excel in a competitive automotive market. With an eye on the future, TATRA is poised to continue innovating and delivering exceptional vehicles to its customers.

> **"The ability to correlate virtual tests with physical tests ensures we're making the right decisions and getting accurate results from our simulations."**
>
> – Vojtěch Adamec, Structural Engineer, TATRA

Figure 5. 4x4 fire truck chassis-cab from TATRA

Gear data exchange: Optimising design and manufacturing

By Ian Mottashed, Product Marketing Manager,
Hexagon's Manufacturing Intelligence division

Since 2003, the VDI/VDE Society for Measurement and Automation Technology has established a guideline for the data interchange standard for gears. The VDI/VDE 2610 'Exchange format for gear data – Gear Data Exchange Format (GDE Format)' facilitates the electronic transfer of all geometric parameters for cylindrical gears. It serves primarily in industries that design, manufacture, and analyse gears, such as automotive, aerospace, and machinery.

GDE aims to establish a standardised format encompassing all geometric specifications for cylindrical gears. This specification would facilitate a smooth transfer of gear data across design, manufacturing, and quality assurance departments.

GDE not only includes the nominal geometry of cylindrical gears but also contains the specifications for the metrological analysis. It encompasses the scope of quality assurance as well as the specifications of the manufacturing parameters for a variety of production steps in gear manufacturing.

It also represents a primary data set for various software

Figure 1. Cylindrical gear measurement and data exchange.

packages involved in the gear lifecycle. GDE also serves as a digital data carrier for the exchange of metrological data, such as acquired measurement data and calculated evaluations. The GDE exchange file becomes the golden master for all specifications and analysis documentation for cylindrical gears.

Benefits of GDE

Interoperability: GDE enables seamless exchange of gear-related data between different software applications used in design, manufacturing, and analysis. GDE facilitates interoperability between various software tools used in various stages of the gear manufacturing process, such as CAD (Computer-Aided Design), CAM (Computer-Aided Manufacturing), CAE (Computer-Aided Engineering), and PLM (Product Lifecycle Management) systems.

This interoperability ensures accurate and efficient data transfer by eliminating the need for manual intervention or data re-entry.

Improved Efficiency: GDE helps save time and resources by streamlining data exchange processes. Engineers and designers can focus more on design iterations, optimisation, and analysis rather than dealing with data conversion or compatibility issues between software tools.

Reduced Errors: Manual data entry and conversion processes are prone to errors. GDE minimises the risk of errors associated with transferring data between different systems, leading to higher accuracy in gear design and manufacturing.

Enhanced Collaboration: GDE facilitates collaboration among different teams and departments involved in the gear manufacturing process. Engineers, designers, manufacturers, and analysts can easily share and access gear-related data, fostering better communication and teamwork.

Cost Savings: GDE can help reduce software procurement and maintenance costs by eliminating the need for redundant software licences or custom data conversion tools. Additionally, reducing errors and rework can lead to cost savings associated with scrapped parts or delayed projects.

Faster Time-to-Market: GDE improves efficiency and reduces errors, expediting the gear design and manufacturing process, resulting in shorter development cycles and faster time to market for new products.

Standardisation: GDE promotes the use of standardised data formats for gear design and manufacturing, ensuring consistency and compatibility across different software platforms and systems.

Structure of a GDE file

Leveraging XML's flexible structure, gear data can be seamlessly exchanged between design, manufacturing, and quality control software, streamlining the entire gear production process.

A GDE file primarily consists of three sections: "Identification," "Geometry," and "Inspection." These divisions are subdivided as required to detail all relevant gear specifications thoroughly. Additional details can also be included in a "User" section if needed.

The main sections are again divided into logical sections to capture and organise Gear data, Process data, and Tool data. Geometry includes basic geometry, modifications, tolerances, inspection, measurement conditions, and measurement results. Additional Identification metadata, including customer ID, order number, and drawing number, can also be added to help with categorisation and discoverability.

To ensure that every software system can reliably import and process consistently structured GDE files, the VDI offers validation files for the respective GDE version, with which a quality check can be carried out.

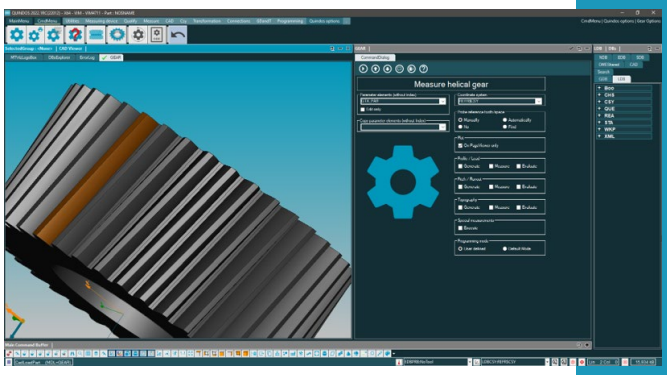


Figure 2. Gear measurement and analysis.

How Hexagon products use Gear Data Exchange

QUINDOS metrology software

QUINDOS is the leading modular metrology software for gearing inspection and analysis. Part of Hexagon's ecosystem of industry-leading software applications and metrology devices, It connects with a wide range of CMMs and sensors to deliver effective gear measurement solutions.

The power of QUINDOS comes from the additional Special Geometry modules, which can be added to the core QUINDOS application. They offer an unrivalled portfolio of modules for powertrains with challenging measurement and evaluation strategies.

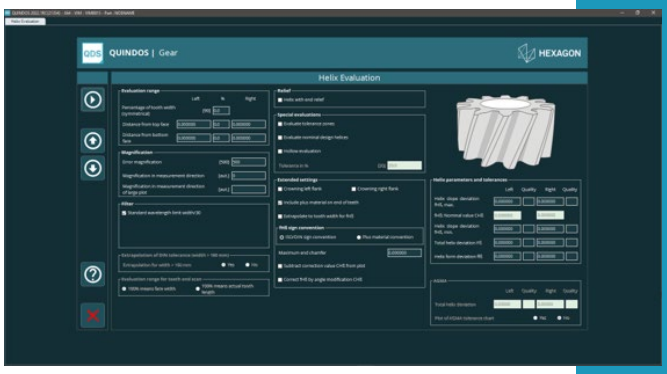


Figure 3. Gear evaluation and reporting.

Figure 4. Analysis of mesh and point cloud.

The industry-tested modules comply with international standards and guidelines and have been integrated with QUINDOS to deliver automated measurement and evaluation and enable guided routines for operators.

By using a standardised data format like GDE, QUINDOS is able to share data with other software tools or systems to seamlessly exchange gear data without the need for manual transfer or re-entry of information. This helps improve interoperability and efficiency in the design and manufacturing process of gears.

Romax Enduro

Romax Enduro is part of the Romax Software Suite, an integrated set of applications for the design and simulation of ePowertrains and other geared rotating systems.

It provides rapid and intuitive modelling, detailed structural simulation, and component rating for powertrain durability design, analysis, and optimisation. Enduro helps powertrain engineers and gear designers from small and large OEMs, as well as suppliers and service providers, design durable and robust geared electro-mechanical systems.

Its rapid modelling and analysis make it suitable for designing space exploration and asking what-if questions to improve the performance and robustness of any rotating machine, from initial concept design through to design for manufacturing and virtual testing.

Gears are a hallmark feature of Romax software. Romax Enduro offers a wide range of features related to gear modelling and design, rating, analysis, optimisation, and manufacturing simulation.

Gear design software allows for three levels of gear representation: loading gears for quick iteration of ratios and layouts, concept gears to choose module and tooth count combinations, and detailed gears with complete macro and micro-geometry.

The micro-geometry can be defined from typical design inputs such as crowning, slope, tip relief, etc., specified as an arbitrary grid or imported from measurements using Gear Data Exchange (GDE) format from metrology systems such as QUINDOS.

Working together with GDE

Within a closed-loop production cycle that includes QUINDOS and Hexagon's Romax simulation software, gear manufacturers can continually improve their design, streamline processes, and adapt faster with data-driven insights.

Conclusion: Optimising the Gear Lifecycle with GDE

Overall, Gear Data Exchange plays a crucial role in optimising workflows, enhancing collaboration, and driving innovation in industries reliant on gear design and manufacturing. Moreover, the VDI committee consistently endeavours to systematically expand this format, particularly concerning gear-cutting tools and other related processes.


Romax
Analyse manufactured part
Proof of design concept
Romax
CAE-lead design
Manufacturing simulation
Ensure manufacturability
of design
Manufacture part
Design macro geometry as
nominal input for QUINDOS –
Import via GDE file
Metrology System
Capturing data with the QUINDOS
Gear Measurement module
QUINDOS
GDE file
with real
gear data
Check real part
against design
GDE
GDE

Metrology Devices

Adopting next-gen metrology in the machine shop: A comprehensive look at Hexagon's machine tool measurement solutions

By Micha Neininger, Director Machine Tool Measurement, Hexagon's Manufacturing Intelligence division

In any machine shop, three critical aspects indicate the mark of success – the quality of the manufactured part, the reliability of the process, and speed, in terms of short process and lead times. Improving these facets has long been the focus of numerous innovations and research, leading to something extraordinary - the world of machine tool measurement. A seminal player in this arena, Hexagon, brings forth solutions that help in various ways.

Assuring quality

Quality in any machine shop is a function of how accurately a part has been processed. Factors defining this include dimensions, surfaces and features, temperature, wall thicknesses of the part just like the condition of used tools. To achieve consistency in quality, real-time checking during production is unavoidable. Hexagon's machine tool measurement solutions offer on-machine measurements, leading to unparalleled quality assurance.

Ensuring reliability

Reliability in a machine shop depends on machine calibration and accuracy. Constantly verifying and calibrating the machine ensures the integrity of components produced. Devices must work optimally, and ensuring this demands in-depth testing of the linear and rotary axes. Recognising this, Hexagon offers suitable solutions that effectively enhance process reliability.

Minimising time

Time is of the essence in any industry, and in a machine shop, it is predominantly concerned with the speed of the processes and the lead times. Hexagon's machine tool measurement solutions optimise these timelines through automatic part alignment, real-time measurement and easy documentation. These are facilitated by efficient measurement programs, systematic alignment strategies with Best Fit, comprehensive documentation of measurement results, and easy export to

statistical evaluation software, like Hexagon's own Q-DAS solutions.

The legacy of Hexagon in machine tool measurement

Hexagon's journey in machine tool measurement solutions has always been pathbreaking. Hexagon were the first to introduce a working, small radio-wave probe to the market. The momentum didn't stop as Hexagon rolled out the first-ever measurement software for machine tools - 3D Form Inspect, a measurement software that enjoys undisputed leadership even today. Recently, Hexagon went on to pioneer sensor technologies to set industry standards covering workpiece temperature and wall thickness capture.

Moving towards a future where production processes will be heavily automated, Hexagon prepares its customers for the upcoming revolution. This is evident in solutions like Best-Fit alignments or HxGN NC Server, which are setting the new standard – automated probing on machine tools.

Hexagon's shift of metrology towards the machine shop

Reimagining the classical form of metrology to an even more efficient system has always been a goal of Hexagon. While manufacturing keeps relying on certified measurements on measuring machines as per the ISO 10360 standard, Hexagon also transposes metrology right into the heart of machine tools. Various sensor technologies capture and measure all kinds of specifications and pieces.

Figure 1. Laser scanners for machine tools can quickly capture the complete surface data for a part while it is still clamped, bringing new levels of speed, precision and flexibility to machine tool inspection.

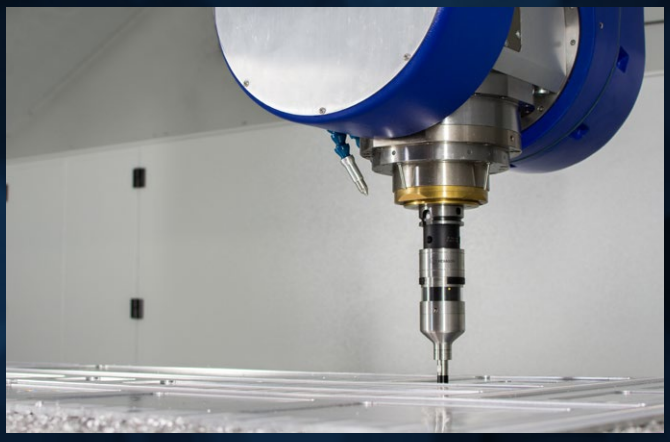


Figure 2. Automated wall thickness measurements on the machine tool with ultrasonic probes replace time-consuming manual measurements with external devices, without the need to move heavy and large parts to dedicated measurement spaces, ultimately resulting in significantly faster inspections and enhanced data capture.

Figure 3. Solutions like the ETALON X-AX LASERBAR for the geometric analysis, monitoring and accuracy improvement of machine tools help to improve the overall quality of produced parts.

Figure 4. Touch probes are standard on almost every CNC production machine, and Hexagon's portfolio of probes with radio or infrared transmission benefit from many unique capabilities, such as the combination with other technologies, exchangeable measuring units and more.

Figure 5. In-process measurement of the component is performed directly in the clamping to avoid measurement deviations due to spring back or warping.

While Hexagon ensures measurements are captured with accuracy and reliability, it is how they utilise the data that's rather ingenious. The results are statistically evaluated to discover the unexplored potentials in the production process while simultaneously resolving bottlenecks like process time on CMMs, part transports and personnel shortages.

Mainstream role of machine tool probes in the past were limited to simple probing tasks, such as defining the raw part's position before machining. For more precise measurements, the utility of other devices, such as coordinate measuring machines, became inevitable. To make the best use of all devices and at the same time remove bottlenecks, Hexagon's goal is to perform detailed measurements also directly on the machine tool with advanced measurement technologies like ultrasonic measurements, laser scanning and highly accurate probes. In essence, these technologies facilitate on-machine inspection processes, which streamlines quality control procedures significantly.

Hexagon accompanies these technologies with dedicated calibration and verification devices that monitor the geometric condition of the machine tool to derive correction values. This ensures the measurement process capability and reduces dependency on external measurement devices. The combined use of advanced technology and calibration methods not only maximises the potential of CMMs but also reduces the process times, while considerably minimising the demand of highly skilled operators.

Hexagon's machine tool measurement products

Hexagon has established itself in machine tool measurement solutions, boasting a wide range of innovative tools that enhance production efficiency and accuracy in the industry.

Machine calibration and optimisation
Hexagon provides system solutions for the accurate and comprehensive geometric analysis, monitoring and accuracy improvement of machine tools, measuring machines, robots and structures with the ETALON machine calibration and optimisation range.

Tactile workpiece measurement systems
Accurately measuring workpieces is pivotal in any machining operation. Hexagon's tactile workpiece measurement systems utilise radio or infrared transmission to record individual points on the workpiece. This data helps in determining the part's position in the clamping and inspecting its dimensions and quality.

Tactile and optical tool measurement
Constant production quality can be ensured through accurate tool data. Tactile and laser tool setters monitor tool wear or breakage. Hexagon's tool measurement solution automatically feeds this precise data into the control's tool table, enabling a highly reliable and accurate machining process.

Innovative, application-based sensor solutions
Keeping customer needs at the forefront, Hexagon develops innovative sensor solutions:

Ultrasonic probe for wall thickness measurement
The RWP20.50-G-UTP ultrasonic touch probe simplifies the process of measuring the wall thickness of larger parts. Unlike manually measuring wall thickness, which generates machine downtime and a lot of manual effort, the RWP20.50-G-UTP ultrasonic touch probe automates the process using ultrasound technology on the machine tool.

Temperature probe
Monitoring part temperature during the machining process has profound benefits. Hexagon's temperature probe, which measures the temperature automatically, allows for adjustments to the machining parameters during production based on the temperature readings, thus avoiding potential quality issues due to thermal changes.

Machine tool laser scanner
Hexagon's m&h LS-R-4.8 is a wireless laser scanner that transmits data via radio to the machine control and measuring software. By capturing and analysing a complete, data-rich image of a part while still clamped, it enhances precision and accelerates machine tool inspection, while minimising the need for external measurement devices.

State-of-the-art machine tool measurement software
Hexagon's suite of software products caters to diverse measurement needs. From performing quick setups and verifying critical dimensions in process to conducting complex quality analyses, it all becomes a streamlined affair.

HxGN NC Measure: Simplifying the inspection of a wide range of parts directly on the machine tool.

3D Form Inspect: Enables logging ruled geometries and forms on all sides and axes on the machine tool.

HxGN NC Gage: PTB-certified algorithms grant high precision to machines and performance.

HxGN NC Server: Connecting machine tools with the power of PC-DMIS measurement software, it enables the execution of CMM-like operations directly on the machine tool and facilitates active monitoring of measurements across multiple machine tools.

In essence, Hexagon's innovations transform machine shops into highly efficient production units. With thoughtful, productive leaps in every stage of machining processes, right from measurement to quality control, Hexagon stands at the forefront of leading a new age in the realm of machine tool measurement.

With advanced products and solutions that transcend the limits of current processes to offer in-depth real-time measurement, calibration and verification, Hexagon isn't merely offering tools for quality and efficiency. They are reimagining processes, redesigning methods and recreating systems to form a future where machine tool measurement is integral to the machine shop, making the pursuit of precision less a process and more a standard.

Figure 6. Hexagon's versatile measurement probes and sensors turn every CNC machine to a multisensor device, adding advanced capabilities and applications to the shop floor and removing QA bottlenecks.

Metrology Devices

Significant time savings thanks to a high-end testing system

By Andreas Rietdorf, Product Manager Photogrammetry,
Hexagon's Manufacturing Intelligence division

The Volkswagen plant in Zwickau has a history of more than one hundred years in car manufacturing. Founded in 1904 and 1909 respectively as the Horch and Audi plants, Volkswagen settled at this location in 1990. Initially, Volkswagen produced internal combustion vehicles in Zwickau, but in 2018 began converting to the production of electric cars, which began at the end of 2019 with the production of the VW ID.3.

The Zwickau vehicle plant is still home to the traditional production areas of body construction, paint shop and final vehicle assembly, but since 2020 only electric cars have been manufactured there. The approximately 10 700 employees at this Volkswagen site now produce fully electric vehicles such as the VW ID.3, ID.4 and ID.5, the Audi Q4 e-tron and the Seat Cupra Born.

The conversion of the plant to eMobility production has also changed the work processes in the department of measurement technician Marc Guendel.

"Contrary to popular opinion, it has become rather more involved," Guendel explains. "The support effort for the supplied assemblies is massive. With individual parts we have very little effort in terms of measurement, but with welding groups we have more work. As a result of the changeover, we now have to pay attention to many more large and important components. To cope with the extra work, we need the right measurement systems."

In 2022, VW Zwickau acquired the DPA Industrial photogrammetry system from Hexagon. These measurement systems are equipped with only a single portable camera unit, making them the most portable metrology systems in the world. The DPA Industrial with its 50.6-megapixel industrial sensor is one of the high-end models from the DPA Series range of products. The C1 Camera unit is integrated into a robust housing with IP51-rated protection and is therefore particularly suitable for use directly in the production environment or in outdoor areas. Together with the DPA Pilot software platform, the system guarantees a complete high-productivity workflow, from signalling and recording to calculation and reporting, and with minimal training.

Fast and smooth inspection

"We use DPA Industrial as an inspection system for our fixtures," explains Guendel. Even if the fixtures are delivered already measured by the supplier, Guendel and his team have made it a habit to check the fixtures again and, if necessary, to readjust them themselves. Afterwards, a data recording is made with the DPA Industrial. For this, special adaptors are inserted into the reference bores and targets applied to the fixture. All relevant fixing points are signalled with uncoded marks.

A template is created with the data generated during the measurement with the DPA system. If a problem is detected with a specific fixture, a comparison with this template can

quickly determine whether the relevant fixing points have changed and how big any change is.

"We simply take a few pictures with the DPA Industrial and can make a quick statement as to whether the fixture is ok or not," says Guendel. A quick check is important because many of the 300 to 400 geometric fixtures are integrated in protective circuits that must be interrupted for the check, which in turn means downtime in production. "That means the times we can use to check the fixtures are relatively limited. During normal working hours, these are the breaks. With the DPA Industrial, we only need 15 minutes for the inspection – a lunch break is enough to get a clear statement about a fixture. That prevents weekend work for us."

It is not always easy to use measuring systems in the narrow environment of the manufacturing shop floor. Space is often confined and it can be difficult to find a suitable stand due to cable aisles or the vibrations of the production equipment. In this regard, the complete freedom of movement offered here by the handheld DPA Industrial is a huge benefit.

For uniterupted production

We also use the DPA Industrial to check our skids," adds Guendel. Skids are part carriers that are used to bring the individual components to the processing station. To do this, the components are placed on the skids by robots, which then move them to the production line. At the VW plant in Zwickau, there are six identical skids for each assembly; in total, that makes 180 part carriers for all the vehicle models produced there. "We have to check the skids in exactly the same position as they remain in the production line. For this we have a special measuring table on which we can quickly perform checks."

As with the fixtures, the skids are photogrammetrically recorded for this purpose before the first use. The resulting point cloud is used to create a template that is later used for quick checking.

To keep the automated production lines running, the part carriers must be available at all times. "If a problem is reported to us with one of the skids, we need to be able to react immediately," explains Guendel. "If, for example, a crash happens in the plant, the whole system comes to a stop, which means we have production downtime. That's why time is a critical factor: with the DPA Industrial, we can carry out a quick check and determine in no time what damage has been done to the skid. With other measuring systems, this inspection takes three to four times longer."

Referencing for scanning

The most important application for the DPA Industrial at VW Zwickau is currently its use as an add-on for a handheld scanner. "This is really phenomenal," explains Guendel. "We signal distinctive alignment points and holes on the car body with targets, record them photogrammetrically with the DPA Industrial and export the captured points from DPA Pilot. We then import these points into the scanner software. Now we can easily scan in alignment with the car body using the handheld scanner. And that's despite the fact that we can't fix the body and it's only on a loose trolley."

Figure 1. Before inspecting, the skid is signalised with scale bars, reference crosses and targets.

Figure 2. After signalising, the skid is simply photographed from different directions with the hand-held C1 Camera.

Figure 3. When measuring the fixtures, the spatial conditions are often cramped. As a handheld camera, the DPA Industrial offers 100% freedom of movement.

Figure 4. The point cloud created with the DPA Industrial is used to reference the handheld scanner.

Figure 5. The C1 Camera is integrated into a robust industrial-grade casing that makes it ideal for use on the shop floor, in the workshop or outdoors.

The fact that they have managed to get these two independent systems – the DPA Industrial and the handheld scanner – to 'talk' to each other saves Guendel's team the time-consuming task of sticking targets on the car body – "and the subsequent removal of the measuring marks," Guendel adds.

The DPA Industrial has a decisive advantage when compared to the photogrammetry system offered with the scanner: "The DPA Industrial can also measure coded measuring marks and adaptors. This means that the DPA offers us many more possibilities for later applications."

Guendel and his team are still in the early stages of using the DPA Industrial at VW Zwickau: "We are still in the discovery phase as far as possible applications are concerned. We have built ourselves up over the last 20 years so that we can measure everything. Now we want to make sure that we become faster."

To do this, he and his team have been studying the topic intensively and trying to think ahead. "We now know how it works and are looking for areas of application ourselves. In concrete terms, this also means that we are trying to make our work easier when measuring by making our own connection igloos or angle adaptors."

In addition to the photogrammetry system, the measurement technicians at VW Zwickau also rely on laser trackers and portable measuring arms from Hexagon, among other measurement technology. "We have known some of Hexagon's employees for 20 years," says Guendel, who is very satisfied with his team's long-standing cooperation with Hexagon. "It's also beneficial for us to have such a cooperation. And I deliberately want to speak of cooperation here, because we have also further developed certain products together."

With such a well-established and successful partnership, even more fruitful cooperation lies ahead for Hexagon and Volkswagen.

This is how digital photogrammetric analysis works

In the first step, the component is signalised with targets. Appropriate measuring adaptors are used to measure hidden points or elements, such as drill holes or edges.

Then the component is photographed from different directions with a handheld camera. It is important that the targets are in the measuring field and that there are overlaps between individual photos.

With the help of special photogrammetry software, the resulting images are processed either simultaneously with the data acquisition (online) or afterwards (offline) by a special photogrammetry software tool such as DPA Pilot. The software automatically calculates the 3D coordinates of all target points. The calculation is based on the principle of spatial triangulation of images and is fully automatic.

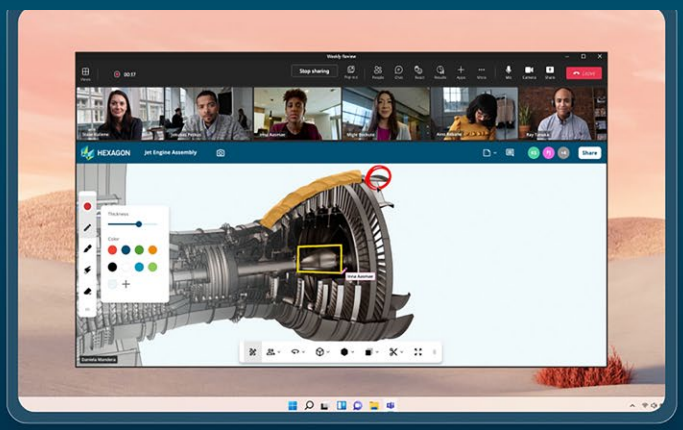
“I’ll put it quite simply: we take a few pictures and can then tell whether the fixture is OK or not OK.”

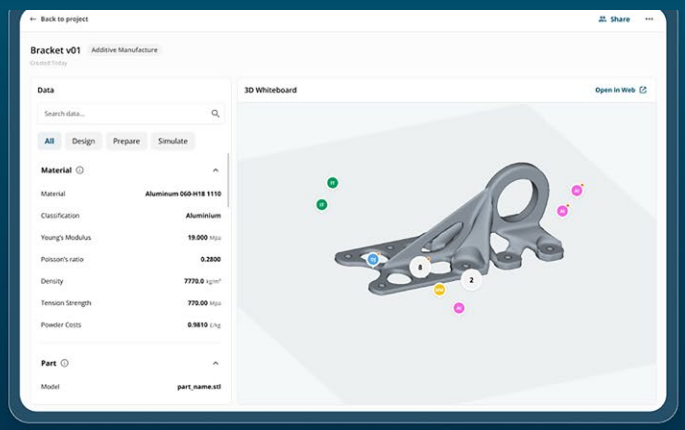
– Marc Gündel, Assembly master, analyses and metrology, Volkswagen Sachsen GmbH, Zwickau, Germany

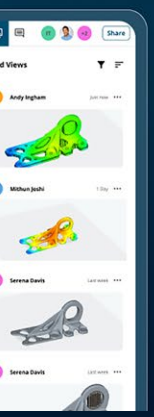
Figure 6. Thanks to the built-in high-speed WiFi connectivity, images processing within the DPA Pilot software platform starts immediately.

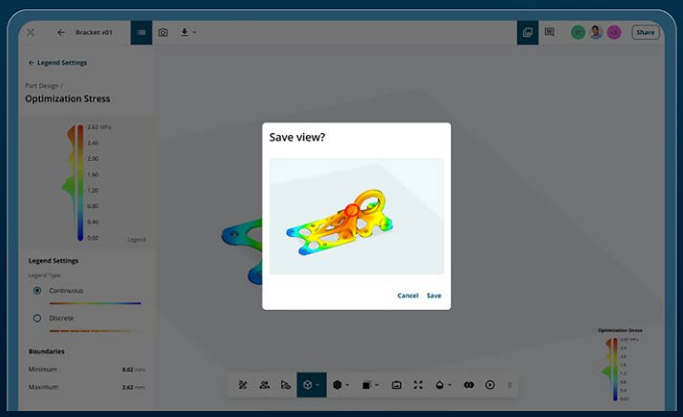
Talent wins games, **but teamwork and intelligence win championships**

By Sashank Ganti, Senior Product Manager, Visualisation,
Hexagon's Manufacturing Intelligence division









Collaboration across departments in manufacturing companies can be challenging. Departments often operate in silos, lack alignment and coordination, and face inadequate infrastructure that hinders collaboration. Without the right tools, sharing information, collaborating on projects, and tracking progress can be difficult.

The million dollar question

How can designers, simulation analysts, and manufacturing engineers solve complex problems in real time and in a 3D environment? The short answer: big problems, like data flow between departments, require advanced solutions.

Introducing Nexus 3D Whiteboard

Nexus 3D Whiteboard brings the ease of day-to-day document collaboration, like Office 365, to the world of complex 3D data. This tool allows experts from multiple disciplines to connect their sophisticated tools and collaborate seamlessly in real time.

Key features

Real-time insights: a simulation analyst can quickly share insights from a complex simulation with a designer by overlaying results directly on the CAD model.

Collaborative canvas: the 3D Whiteboard provides a canvas for designers and analysts to mark up areas of interest on the shared model and discuss potential design changes immediately.

Enhanced accuracy: a metrologist can superimpose scanned point cloud data on the CAD model to articulate problems to designers and other analysts, eliminating delays and rework.

Real-time collaboration

Nexus optimises data flows to occur in real time, allowing users to focus on solving problems rather than dealing with complex tools and data exchange processes. The analyst, designer, and quality specialist can work simultaneously using their applications, while Nexus keeps the collaboration data up-to-date.

Zero install and secure

The 3D Whiteboard is a zero-install, browser-based 3D viewer that can natively load various CAD, CAE, and Point Cloud data files. It includes built-in data security and identity management from the Nexus cloud platform. Using open data formats (gltf, glb, obj, STEP), it is extensible to many workflows across the value chain. The 3D Whiteboard is also available as an app on Microsoft Teams, boosting productivity with familiar tools.

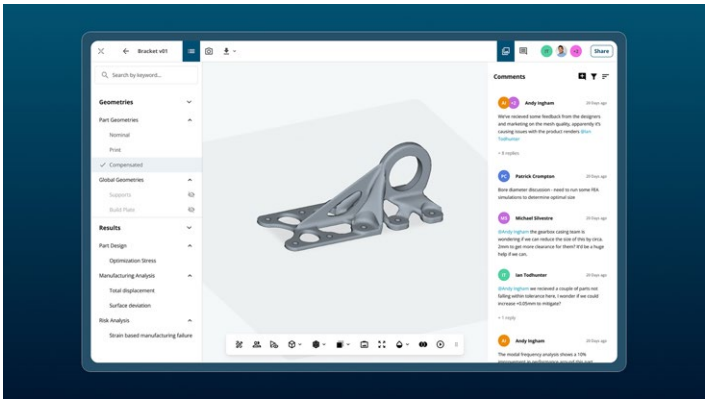
3D Whiteboard for design reviews

The first go-to-market offering of the 3D Whiteboard is the Design Review module in Hexagon's popular CAD for CAM product, the DESIGNER. This offering allows users of DESIGNER to seamlessly invite stakeholders to review and approve changes to the design for machining.

Suppliers and machine shop owners receive CAD models from their customers for manufacturing. Oftentimes, the CAD has to be modified to machine the part using the available equipment. This requires collaboration between the suppliers and their customers. Traditionally, this collaboration occurs through screenshots contained in emails that are exchanged back and forth until contracts are finalised. This process is prone to errors due to a lack of proper communication and suffers from a high risk of contract violations due to a lack of proper change tracking.

The Design Review module in DESIGNER provides a seamless solution to this problem. With a few clicks, DESIGNER users can share an annotated 3D model with their customers, articulating proposed changes in full 3D detail. The customer can then use the 3D Whiteboard to understand the proposal and its implications and respond back. The easy-to-use commenting interface with Snapshots, 3D Pins, and inking keeps all of the communication in one place in the shared document for all parties to review at any time. Actions and decisions can be tracked together with the full context of the change for anyone to understand.

Furthermore, the system automatically generates emails and notifications to alert involved parties to changes. Users of Microsoft Teams can also pull up the 3D Whiteboard in any Teams call and immediately dive into an immersed 3D view where each user can manipulate and annotate the model individually.



Learn more: nexus.hexagon.com/home/product/3d-whiteboard

Sixth Sense

One plus one equals three: Reflections on Sixth Sense's third cohort

Interview with Milan Kocic, Sr. Director, Hexagon Accelerator, Hexagon's Manufacturing Intelligence division

Sixth Sense is all about looking to the horizon and around corners, exploring the challenges and opportunities of tomorrow. But that's not to say we don't also recognise the need to look back from time to time to reflect on what we've achieved so far.

No different from the learning journey of our Sixth Sense startups, each cohort teaches us something new, serving as a vital jumping-off point to iterate, optimise, and evolve — taking the programme to the next level.

So as our third challenge focused on sustainability and digital reality in manufacturing draws to a close, let's take a moment to reflect on our third cohort – Zaptic, Flexxbotics, Acerta, Launchpad, RVmagnetics, TOffeeX, Dessia, and Rafinex – as well as the dynamic Sixth Sense Summit in London this year.

We sat down with Milan Kocic, the head of Sixth Sense, to get his take on the key learnings, reflections, and insights from our third pioneering programme and what's in store for the next chapter.

What are your main reflections from the third cohort?

Milan: At Sixth Sense, we use this "one plus one equals three" expression to underline how we help Hexagon and startups join forces to create more value for both companies and for customers.

Our third cohort exemplified this approach more than ever, with many of the startups embracing the programme's core purpose: connecting the dots between Hexagon and their transformative solutions—building a joint idea.

Sandy Reid, Zaptic's CEO and co-founder, underscored this at the Sixth Sense Summit, highlighting how Sixth Sense opened doors to explore synergies between Zaptic's technology and Hexagon's manufacturing solutions.

We're now looking for ways to lay the foundations for these strong connections from day one; hosting a pre-cohort pitch day to get to know cohort members better, as well as improving post-cohort efforts to create better value for both Hexagon and startups afterwards.

What kind of impact has Sixth Sense had over the last few years?

Milan: I think the best ratification of Sixth Sense's impact is the fact that many different divisions within Hexagon are now asking to launch their own cohorts. There's also a great deal of interest from inside the organisation about many of our start-ups and where there might be opportunities for collaboration.

This has been exemplified by the number of partnerships our finalists from across the cohorts are forging between Hexagon and other industry leaders.

One of note is the landmark partnership between Hexagon and the winner of our second cohort, GelSight. Another is that of ETQ – a part of Hexagon and the leader in enterprise quality management solutions – and Augmentir, also from our second cohort.

Interest in our cohort members' technology shows in other ways, too, with cohort two members Threedy securing $10.4 million in a recent Series A investment round and CASTOR landing a grant from the Israel Innovation Authority.

What makes Sixth Sense different from other accelerator programmes?

Milan: I think Sixth Sense's point of difference is very simple: it has a distinctly transparent, collaborative and human element to it.

We are building relationships between people. We are honest about whether we think something is going to work or not. And we aim to deliver a positive impact on both companies through a growth, collaboration and curiosity mindset.

It's this unique model and approach that resonates with people and makes us different from other programmes. Because of this, I think everybody comes out happier.

Regardless of the outcome, I'd like to see startups walk away from Sixth Sense feeling better than they did when they entered the programme, equipped with new tools that benefit their business in the long run.

What are your main reflections from the Sixth Sense Summit in London?

Milan: After this third iteration, I think we now have a good blueprint of what we want to create with the Sixth Sense Summit. What the London summit highlighted, more than ever, was the golden thread that binds the fabric of our programme and mission: the power of bringing innovators and entrepreneurs together to discuss the future.

With a packed agenda of lively discussions, the London summit convened an impressive group of people from startups, businesses, and Hexagon departments alike. I was particularly pleased to see our series of thematic roundtables broaden the horizons of discussion.

Exploring the challenges and opportunities of an evolving manufacturing landscape, these roundtables were led by Elaine Warburton OBE, Russ Shaw CBE, and Ana Avaliani. They focused on topics including female representation in manufacturing, the current fundraising climate for startups, and how we can better harness the entrepreneurial potential of spin-outs.

It was also great to see Hexagon's Global Internal Communications Manager for Manufacturing Intelligence, Natalie Tellis-James, join us on the day, and I was equally delighted to read her article afterwards, sharing her experience at the summit and how she "ended the day with a true sense of excitement."

All told, the summit provided experts with a unique platform to come together and discuss what the industry's future might look like—and, crucially, how everyone can contribute to it. What's more, it was also a fantastic opportunity to connect our cohort members with potential investors, commercial opportunities, and partners—roll on 2025!

Looking ahead, what's next for the Sixth Sense Programme?

Milan: To take Sixth Sense to the next level, our next phase will see the programme evolve at both ends of the spectrum: zooming both in and out.

Zooming in, we'll be looking at how we can focus cohorts on more specific challenge areas, generating more targeted outcomes rather than the broad approach we've taken thus far.

Zooming out, we'll be looking to replicate the success of our manufacturing intelligence cohorts across more divisions at Hexagon, as well as even broader, with external partners.

We started Sixth Sense with two main goals: one was to bring outside innovation so we could accelerate what we do, and the other was to help facilitate culture change. But culture change doesn't happen overnight; it's an ongoing journey over many years.

We are only two and a half years in, but watch this space. Implementing change may take time, but we'll continue with patience and persistence, and I look forward to talking again in another two and a half years to see where this journey has taken us.

All of this outside interest from other parties indicates that the appetite for Sixth Sense is only growing. The journey is really only just getting started, and the future looks incredibly bright.

System Dynamics

Romax and JMAG develop an end-to-end e-powertrain design and analysis solution

By Dr Rob Holehouse, Shreya Chandrashekhar and Pankaj Pawar,
System Dynamics team,
Hexagon's Manufacturing Intelligence division

Hexagon and JSOL announced a strategic partnership at the JMAG[1] User Conference in Japan in December 2023. This collaboration will deepen the integration between Hexagon's System Dynamics Suite and JMAG[1]. Amidst this exciting development, we are thrilled to announce a new automated workflow between Romax and JMAG (detailed later in this article), poised to make electric machine (e-machine) design and analysis processes more streamlined and efficient.

The rapid electrification of industries like automotive and aerospace has created a demand for simulation technologies that enable cross-functional teams to understand the impact of component-level design choices on system-level performance. With the increase in the production of electric vehicles, e-machines which are an integral part of the system, have come to the forefront of design efforts. Consequently, the interactions between the e-machine and the broader powertrain have garnered significant attention among all industry players striving to stay competitive in this landscape.

Figure 1. The partnership with JMAG complements Hexagon's wide spectrum of capabilities and partner ecosystem.

However, the ever-evolving challenges facing the CAE industry extend beyond the shift to electrification. OEMs and suppliers are under pressure to bring new designs to market faster than ever. This drives a requirement to minimise development time, reduce the number of prototypes, and reduce the reliance on physical prototyping. It is no longer sufficient for the designer and CAE analyst to purely consider the 'nominal design'. Analysts also need a better understanding of design variability, and to be able to understand the impact that small design changes or manufacturing tolerances have on broader system behaviour. Considered together, these trends highlight the need for a simulation tool-chain offering efficient workflows, delivering faster insights & the ability to run simple and robust "what-if" analyses.

The partnership with JMAG complements Hexagon's wide spectrum of capabilities and partner ecosystem.

Addressing these industry challenges, Romax, part of the Hexagon System Dynamics Suite, stands out as a comprehensive solution. It offers efficient modelling workflows and fast analysis of conventional and electrified powertrains (e-powertrains), which find applicability in a lot of domains, from automotive to aerospace, and renewable energy to industrial machinery. Romax specialises in advanced drivetrain analysis critical for e-powertrain design and performance optimisation. The Romax product line includes capabilities for gear and bearing durability and efficiency analysis, best-in-class tools for detailed bearing design and powertrain NVH simulation, from calculating gear mesh transmission error to predicting noise radiated from the powertrain.

A key part of any analysis involving the e-machine is the consideration of the electromagnetic field. For the e-machine designer, a trusted electromagnetic analysis tool is needed to evaluate machine performance and efficiency, ensuring that all design targets are met across the complete operating window. In the context of noise, vibration and harshness of the e-powertrain (commonly referred to as eNVH), the electromagnetic analysis tool is needed to predict the forces in the machine (torque ripple and radial forces on the rotor, and radial and tangential forces on stator teeth), and these forces are subsequently applied to the structural model as part of the vibration analysis. The task of predicting the tooth forces, although a key part of the NVH process, cannot be considered in isolation. For analysts to trust the results of the NVH analysis, it necessary to not only trust the underlying solver technology, but also trust that their model definition represents their design intent.

To fit into our customers' trusted processes, Romax has always aimed to develop simple and reliable workflows with leading electromagnetic analysis tools. In 2019 Romax introduced an interface with JMAG which employs a proprietary file format to call data required for drivetrain-level eNVH analysis from JMAG to Romax via a single data file. This simple workflow was ahead of its time; by minimising the risk of user error, and reducing the effort required to pass data between tools, users could focus their efforts on generating results and making informed engineering decisions and could therefore better leverage the strengths of both tools.

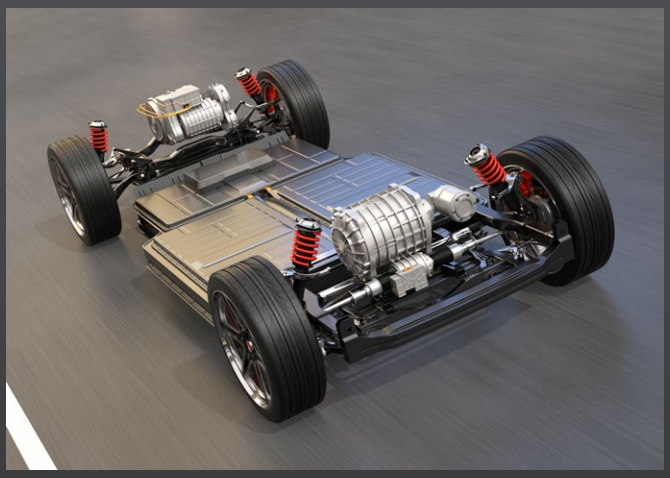
This year, Romax is taking this collaboration a step further by incorporating a capability to run JMAG analysis from within the Romax environment using a newly developed automation code. This automation allows the Romax user to vary e-machine parameters and call JMAG to generate e-machine excitations for each design iteration, all from within the Romax environment. Thus, the Romax user can run a study to investigate the impact of changes in the e-machine geometry on the system vibration response. Multiple design candidates can now be rapidly assessed in context of the system performance, empowering the user to understand how design sensitivities and manufacturing tolerances may affect the system.

The new automated coupling between Romax and JMAG will enable rapid investigation and optimisation of how electric machine parameters affect e-powertrain vibrations.

By enabling these seamless, rapid design studies and further removing the reliance on repeated, manual data transfer between tools, Romax has significantly improved the way the e-machine designer and the powertrain analyst collaborate.

As this exciting development nears completion, the Hexagon team is working closely with Powersys, a global provider of design and engineering solutions for electric vehicles and grid applications. Powersys is Hexagon's go-to-market partner in the US, EU and India. Combining the cross-functional expertise of Powersys and Hexagon will accelerate the delivery of the best-in-class e-powertrain simulation capability to our customers. The teams have been working on joint case studies and plan to present resulting conference papers throughout the year.

As pioneers in their respective fields, the new coupling between Romax and JMAG will minimise design time, enhance design quality, and decrease reliance on physical prototyping through simulation using trusted tools and reliable results.



[1]JMAG from JSOL Corporation is a specialised simulation software for electromechanical design and development. It accurately grasps complex physical phenomena inside of equipment and performs high-speed analysis. It has been used as a product development and design tool for motors, transformers, actuators, sensors, and other electronics and power electronics.

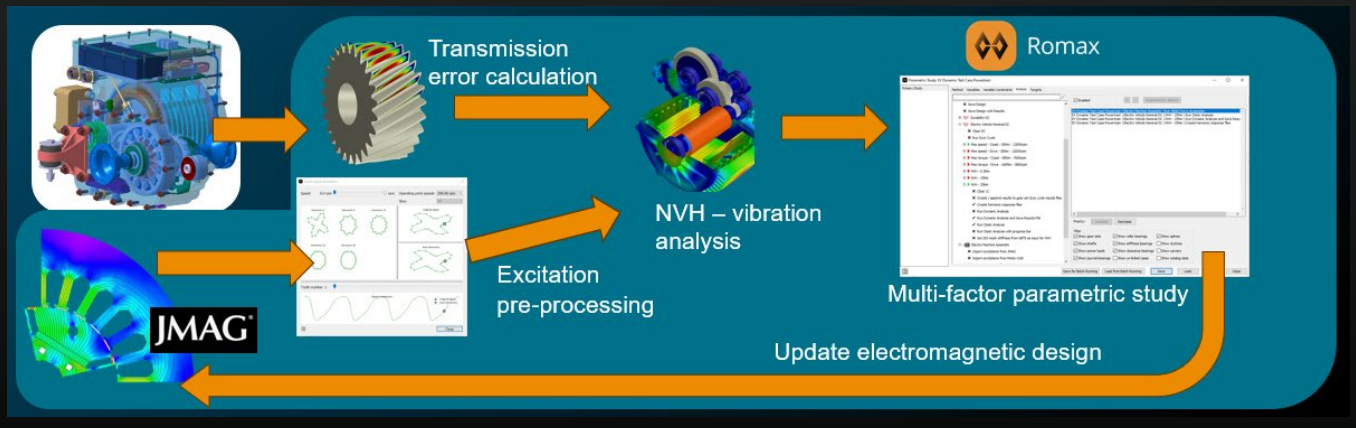


Figure 2. The new automated coupling between Romax and JMAG will enable rapid investigation and optimisation of how electric machine parameters affect e-powertrain vibrations.

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