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The Simulation Based Engineering & Sciences Magazine

SPOTLIGHT

Real Virtuality

- Editor's Note

As I was penning the Editor's Note to this edition of Futurities, it struck me that our **Spotlight** in this issue could not be more apt. The beginning of this year has certainly seemed quite surreal as businesses and governments around the world try to keep up with the whirlwind of announcements emanating from the Oval Office in the USA —or, more importantly, try to keep up with modelling all the global implications of these announcements. As an engineer and expert in numerical simulation, it certainly piques my interest as an engineering challenge: trying to find the optimal business model and approach to cost control and business survival with constantly changing tariffs and American presidential behavioural dynamics. Would you opt for a Monte Carlo analysis or a MOGA II algorithm, if this were an engineering challenge? I wish us all the best of luck with it.

Turning my focus to this edition, however, and things more "real" and less fantastical, I mentioned that our Spotlight looks at the role that virtual reality, extended reality, mixed reality, and augmented reality are increasingly carving out in the engineering and industrial realms. They have officially extended their influence out of the gaming sector and are finding real and tangible applications in engineering and industry, where they are helping to save time, cut costs, and optimize performance – the holy grail of any modern technology! Hence our title: Real Virtuality. We explore three separate applications of XR technologies: in aerodynamic design, in geospatial data, and in business process optimization. I hope you find it a stimulating read.

In this issue's **Technology Transfer** section, we introduce a new mini-series on dimensional tolerancing that will continue over the next few editions, and the first article in that series. In our **Know-how** section we have a contribution from Hitachi Rail that examines a basis for analysing the effects of offset impacts in the railway sector and derives key principles for the design of energy-absorbing structures to ensure passenger safety.

The **Research and Innovation** section looks at a series of state- and EU-funded projects in which EnginSoft is deeply involved in various roles. The first article, contributed by the ECOR International Group, is a detailed discussion of research conducted jointly by ECOR and EnginSoft focusing on the application of data-driven digital twins to brazing, additive manufacturing, and manual laser welding. The second piece comes from the aviation industry where the push for greater sustainability has led to the serious consideration of hydrogen fuel cells as a potentially revolutionary solution combining energy efficiency with zero emissions. Obviously, there are multiple significant risk factors to be considered and mitigated, which is what this article from Novotech examines. Specifically, it explores the use of CFD analysis to evaluate and reduce the risk of hydrogen leakage – and combustion – in an aircraft cabin.

The last set of articles provide a brief description of some of the European research projects in which EnginSoft is currently involved across different sectors, including: rEUman which is developing a human-centred approach to remanufacturing, improving sustainability and efficiency at both factory and value-chain levels; GeoS-TECHIS, which aims to decarbonize industrial thermal processes By introducing an innovative thermal system combining a high-temperature heat pump and a heat-driven cooling unit; and SHINE PV which is working on developing alternative technology pathways for advanced photovoltaic (PV) manufacturing to increase the competitiveness of European manufacturers in the global solar market by reducing production costs and improving solar cell efficiency.

The **Product Peeks** in this edition look at a workflow for Ansys Fluent for blood flow simulation and Emulate 3D software from Rockwell Automation which integrates digital twin technology with process simulation and visualization software to streamline installation and commissioning of heat treatment facilities in the automotive sector.

As always, this edition of Futurities offers a diverse and fascinating basket of articles to extend and deepen your knowledge of the world of engineering simulation. Enjoy the read!

Stefano Odorizzi

Editor in chief

"Would you opt for a Monte Carlo analysis or a MOGA II algorithm, if this were an engineering challenge? I wish us all the best of luck with it.

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KNOW-HOW

TECHNOLOGY TRANSFER

SPOTLIGHT

Real virtuality – XR brings a new world to engineering

In a world where business is always rapidly evolving, Covid-19 opened a door into the business world for a new type of technology that was previously mainly used in the gaming industry. XR (extended reality) and VR (virtual reality) technologies have since quickly made their mark as tools that could help to dramatically cut costs and streamline many processes to save significant time.

In our **Spotlight** article the first segment discusses the benefits provided by XR in various fields. This specific research study explores the visualization of geospatial data in XR to assist with clearing debris flows, in this case in the Rovina di Ciancia to facilitate emergency management.

The second segment analyses how, the meeting between VR and ROMs enables engineers to view aerodynamic designs in real time and to adjust them in CAD, without needing to re-mesh, and are provided with instant feedback.

The third segment explores how VR, AR and MR (mixed reality) have changed the way we interact with digital content and how XR helps engineering and design teams to save time and money. XR also helps improve training by providing immersive simulations and reducing downtime. Incorporating AI into XR allows businesses to create smart applications, while the use of AR allows them to provide real-time support, improving collaboration and productivity.

Integrating geospatial data and virtual reality

by Marco Piragnolo[1], Lorenzo Pranovi[2], Alberto Guarnieri[3]
1. Department of Land, Environment, Agriculture and Forestry (TESAF), University of Padua - 2. Laboratori Nazionali di Legnaro (INFN-LNL) - 3. Interdepartmental Research Centre of GEOMATICS (CIRGEO), University di Padua

Maps and cartographic products are produced using geographic information system (GIS) software, which analyses datasets and processes the data into information. Datasets consist of databases and surveys, typically collected using GPS, photogrammetry and laser scanning. Survey techniques, real-time data, IOT sensors, simulations, and CAD modelling are used to create digital twins and three-dimensional models. Digital twins are used in a wide range of industries to monitor, analyse, and simulate the performance of complex systems. The user experience can be radically transformed by applying virtualization and 3D visualization technologies, known as extended reality (XR), which provides a fully immersive, real-time experience. XR is used for training and predictive maintenance, communication, and safety management, especially in high-risk scenarios.
This paper presents a proof of concept for the production and visualization of geospatial data in XR, aimed at exploring the potential and defining a workflow using state-of-the-art 3D viewers of the digital twin of a high-risk area such as the Rovina di Cancia debris flow channel, located near Borca di Cadore in Belluno in the Veneto Dolomites.

Introduction

Digital twins are accurate virtual replicas of physical objects used in various fields to monitor, analyse, and simulate the performance of complex systems. They are based on three-dimensional modelling in CAD environments, real-time data, IoT sensors, simulations, and spatial data captured by photogrammetry and laser scanning, techniques also used in geospatial data collection. Geospatial data refers to data sets that relate to a location in the real world through coordinates, which are often processed into information in geographic information system (GIS) software to create maps and cartographic products. GIS environments typically visualize this dataset in two dimensions, allowing for

3D visualization through an extension that is limited to computer-based content consumption due to the complexity and volume of data involved.

Virtual globes, 3D representations of a planet, are now a common experience through online services. However, immersive and realistic experiences are made possible by extended reality (XR). XR includes virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies, a range of immersive experiences that combine physical and virtual worlds. Each type offers a different level of interaction between the user and the environment, differing in the degree of immersion and the way in which they combine real and virtual elements.

VR headsets fully immerse the user in a simulated environment, isolating them from the real world. Key features include wide field-of-view displays, motion sensors, and controllers for interacting with virtual space. VR headsets, such as the Meta Quest 2, are designed for gaming, training, and simulation experiences, providing full visual and auditory immersion. They aim to create an alternative environment in which the user can move and interact without overlapping with physical reality.

AR headsets superimpose digital objects onto the real world, allowing users to interact with virtual elements while maintaining a clear view of their surroundings. HoloLens 2 uses advanced position and motion tracking sensors to position three-dimensional holograms in physical space. This visualizer is primarily used in professional fields such as industry, medicine, and education, where the visualization of data overlaid on the real world is critical to improving productivity and efficiency.

MR glasses combine elements of VR and AR to create mixed reality experiences. The Meta Quest 3, for example, enables both full immersion in virtual environments and the integration of digital objects into the real environment through advanced pass-through capabilities. This technology enables a smooth transition between the two worlds, giving users the option of interacting with the real environment enriched with digital content, or being fully immersed in simulated worlds.

XR applications can improve data understanding and analysis, facilitate training and collaboration between distributed teams, and provide a powerful tool for training and predictive maintenance. In an increasingly connected and complex world, the combination of XR and digital twins is a key step towards automated, efficient, and safe management of resources and operations, especially in high-risk scenarios [2].

An example of an XR application to create and visualize three-dimensional models of landslide events [3] is based on photorealism, an immersive environment, interactivity, and real-time use. Modelling and animation based on digital terrain models (DTM) enable the identification of damaged areas, emergency management planning, and risk mitigation assessment [4]. DTMs can be produced using a variety of methods, including remote sensing imagery, LiDAR surveys and sensors mounted on satellite, airborne and drone platforms. In geology, the visualization of LiDAR data combined with high resolution spherical imagery is a supporting tool for field surveys [5].
While GIS modelling is mainly statistical and visualization is mainly on a two-dimensional plane, numerical analyses can produce three-dimensional modelling and result in a spatio-temporal domain [6]. Despite the widespread use of XR technology in games, the integration of digital twins with the GIS world is still limited. The integration of modelling and geospatial data in a VR environment is still under development, while the benefits in terms of communication through a realistic experience in an immersive environment are evident [7] [8], for example in scenarios of hydrogeological hazards, floods, and landslides [9] created through graphics engines such as Unity [10] and Unreal [11].

This paper uses a photorealistic approach to reconstruct the landscape of a high-risk area, namely the Rovina di Cancia debris flow channel, located near Borca di Cadore in Belluno in the Veneto Dolomites, based on photogrammetric surveys. The high-resolution textured mesh model could later be used to visualize thematic maps, analysis and simulation results. The following is a proof of concept aimed at exploring the potential and defining a workflow for production and visualization in MR using a Meta Quest 3 viewer and in AR using the HoloLens 2 headset.

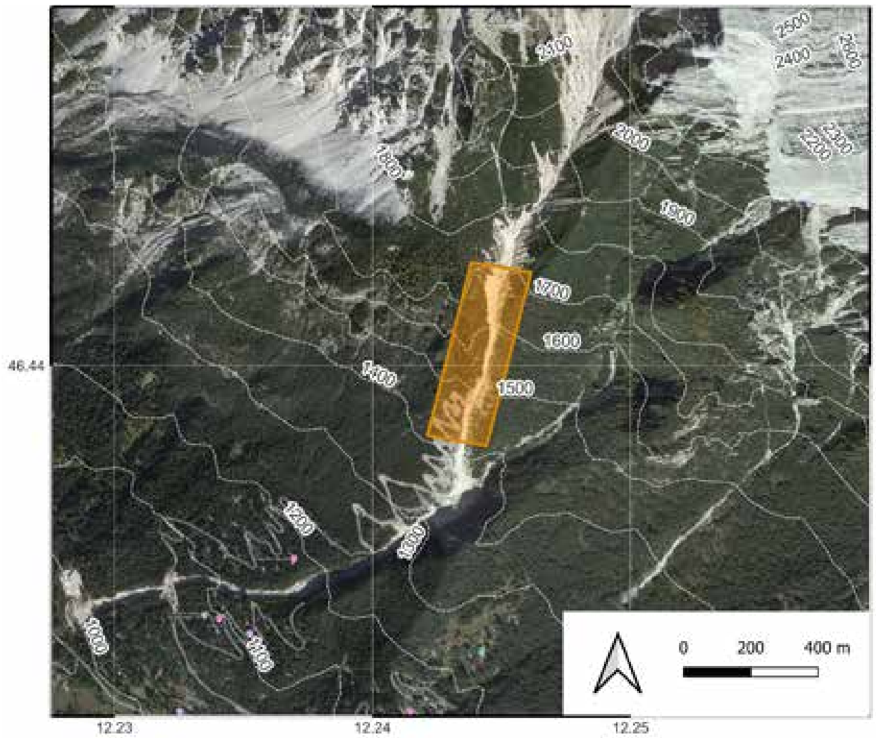

Fig.1. Rovina di Cancia debris flow (Belluno - Italy).

Fig.2. Three different types of drones commonly used for surveying: DJI Matrice 300, Phantom 4 pro and Mavic Mini 2.

Materials and methods

The study area is located in north-eastern Italy in the Veneto Dolomites of Borca di Cadore, where the Rovina di Cancia debris flow overlooks the south-western slope of Mount Antelao (Fig.1). The debris flow is a combination of water and loose materials such as rocks, gravel, and sand triggered by heavy rainfall that rapidly carries a high quantity of sediments.

The erosion channel is divided into three sections, upper, middle and lower, each with its own characteristics. The upper section extends from the head of the cyclopean monolithic boulder at 1,666m above sea level (asl), the formation zone of the debris flows; the width of the bottom of the channel ranges from approximately 1–8m due to the presence of boulders with diameters of 5–6m that limit the accumulation of large sedimentary deposits. The intermediate section extends from the cyclopean boulder area to the depositional platform at 1,344m asl and has a slope of approximately 26° [12]. This section is subject to heavy sediment accumulation and erosion due to bank collapses or low-intensity flows. Finally, the lower section between the deposit area and the gabion wall has a length of 230m with a high inclination, averaging 20°.

The study area has an irregular shape, with a length of about 600m, a variable width between 20–60m at the top, and covers an area of about 10ha at an altitude between 1,400–1,700m.

Good textures are essential for 3D reconstruction, and resolution is dependent on the camera parameters, the weather and lighting conditions, and the flight altitude — less distance between the camera and the object produces more accurate imagery.

Operating a photogrammetric flight can be challenging in morphologically complex areas. Altitude is a critical setting, while the LiDAR flight uses an automatic "terrain tracking mode" due to complex orography and dense vegetation, which often preclude line-of-sight and ancillary data such as morphology and tree height; an additional risk element is the presence of wind channelled onto the slope.

For this study, photogrammetric flights were conducted in August 2022 with a Mavic Mini 2 drone equipped with a 12-megapixel camera and a Phantom 4 Pro equipped with a 20-megapixel camera, and in 2024 with a UAV LiDAR system at different altitudes (Fig.2). The altitude of the flights was approximately 23m for the Mavic Mini 2, which captured 311 images, and about 35m for the Phantom 4 Pro, which acquired 570 images.

To georeference the model, 79 natural and stable ground control points (GCPs) were marked with spray paint on rocky slopes and outcrops and their positions were determined using differential GNSS (global navigation satellite system) in NRTK (network real time kinematic) mode. The photogrammetric reconstruction was performed on an Intel Xeon E5-2620 2.00GHz CPU, 128GB RAM, and a GeForceR GTX 780 Ti GPU in Metashape 2.1, processing the flights individually and obtaining a DTM (digital terrain model) with a GSD (ground sampling distance) of 1.49cm for the Mavic Mini 2 and 1.88cm for the Phantom 4 Pro. The two models were then merged to create a single

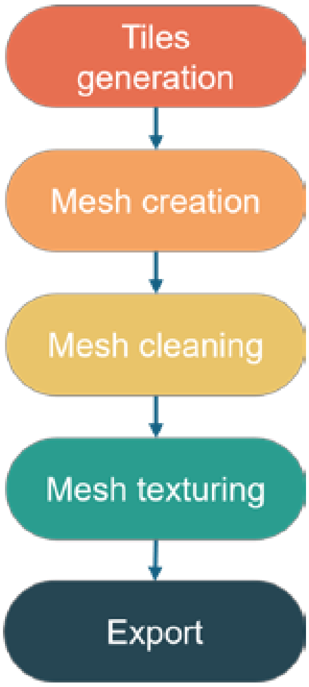

Fig.3. Workflow for creating and cleaning blocks and meshes in Python for Metashape.

dataset of over 3 million polygons to generate high resolution textures and meshes.

Given the size of the study area, applying a single high-resolution texture to the entire mesh would have consumed hardware resources and resulted in poor performance. To overcome this problem, the model was decomposed into tiles using Metashape's native functions and textures were generated for each block. The process shown in Fig.3 was then automated using APIs in the Python language to produce three-dimensional models that could be imported into the graphic engine used: Unreal Engine 5.3 (UE5).

Fig.4. Hologram of a screenshot taken with HoloLens 2 during a test session.

The first part of the process consists of classic photogrammetric processing. The second step is to clean the mesh by eliminating unwanted polygons, such as those that are isolated and separated from the model, polygons that are too small, vertices with low confidence values compared to the model vertices, and finally by closing open and unresolved geometries and correcting topological errors. An iterative process is then used to refine the mesh detail, increasing accuracy, and a decimation and smoothing filter can be applied if required. Thereafter, UV maps are generated, and the model is exported.

Fig.5. Example of the measurement functionality applied to the monolithic boulder in the Cancia channel.

Results

The results of the photogrammetric processing, namely the high-resolution mesh blocks imported into UE5, led to the development of two immersive applications. These applications enable virtual navigation within the Rovina di Cancia landslide using Meta Quest 3 (MR) and HoloLens 2 (AR) headsets, as shown in Fig.4. The experience allows users to immersively explore a photorealistic landscape, add annotations, and conduct metric surveys of the scene geometries, as shown in Figs.5 and 6.

Navigation is first-person and utilizes a "teleportation" function implemented in UE5 to allow movement within the virtual model. An interactive menu allows placeholders with notes to be placed and distance measurements to be taken directly in the virtual environment. Measurement points are determined on the mesh surfaces, providing greater precision than using DTM-based models.

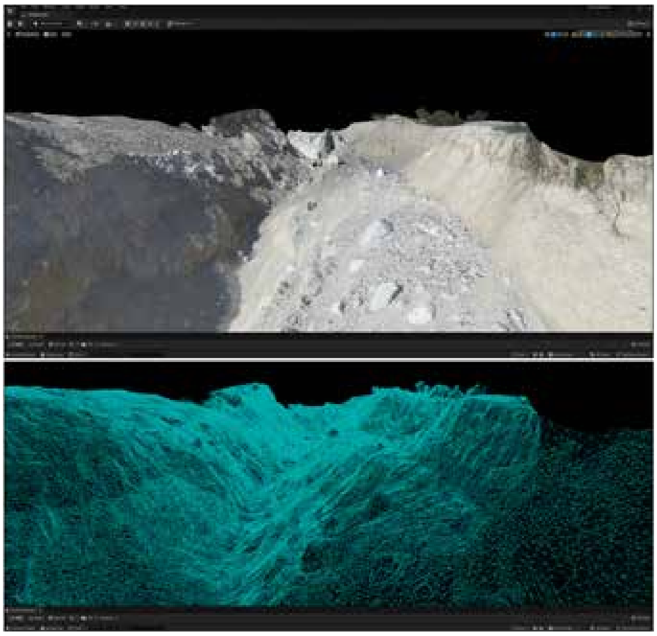

Fig.6. Top: A UE5 visualization of a section of the debris flow at Rovina di Cancia in Belluno; Bottom: The wireframe of the same area.

Conclusions

This work presents a workflow used to process and import a mesh derived from photogrammetric UAV flights over the Rovina di Cancia debris flow. The virtual environment generated using Unreal Engine 5 allows users to have an immersive experience within the high-resolution digital model. An automated workflow developed in Python for the Agisoft Metashape photogrammetric software allows users to segment the model into tiles (high-resolution mesh blocks), and to apply high-resolution textures. A dedicated tool allows measurements to be taken on the triangular faces of the model and annotations and placeholders to be inserted.

Future developments will focus on implementing advanced functionality for metric analysis of 3D models in XR, integrating these models with other geospatial data sources such as cartography and maps, and creating panels to visualize information from local and cloud databases.

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About INFN-LNL

The INFN is the national public research laboratory located in Legnaro, about ten kilometers east of Padua, supervised by the Ministry of Education, University and Research (MIUR), dedicated to the study of the fundamental constituents of matter and the laws that govern them. It carries out both theoretical and experimental research, in the fields of subnuclear, nuclear and astroparticle physics.

About University of Padua

Founded in 1222, the University of Padua is one of Europe's oldest and most prestigious institutions. With over 70,000 students (including 7,000+ international students) and 2,200 teaching staff across 32 departments and 8 schools, it offers a wide range of academic programs. The university boasts over 100 bachelor's and master's degrees, 40 PhD schools, and 60 specialization schools. It awards 13,000 degrees and 5,000 scholarships annually, supported by 29 libraries housing over 2 million books. The University of Padua continues to uphold its reputation for excellence in education and research, attracting students and employers alike with its esteemed qualifications and multidisciplinary approach.

About TESAF

The Department of Land, Environment, Agriculture, and Forestry (TESAF), founded in 1987, is a modern and multidisciplinary department within the University of Padua, one of the oldest universities in the world. The department's activities are strongly oriented towards the study, conservation, effective management, and sustainable use of agricultural, forest, and natural resources. TESAF's structure reflects its diverse range of expertise, including ecology, hydrology and water resource management, geomatics, silviculture, agricultural and forestry mechanization, land appraisal, and agri-food and forest economics and policies.

About CIRGEO

CIRGEO was established as the Centre for Research on Geomatics at the University of Padua. It provides support for stakeholders involved in Geomatic applications in academia, including various departments and projects, both within the University of Padua and across other higher education institutions. The multidisciplinary committee of CIRGEO comprises faculty members from several departments of the University of Padua, spanning diverse fields such as civil engineering, computer science, forestry and agriculture, archaeology, hydraulic engineering, and many others.

Revolutionizing aerodynamic design with a VR-enabled workflow

by Andrea Lopez[1], Marco Camponeschi[2], Marco E. Biancolini[1,2]
1. University of Rome Tor Vergata - 2. RBF Morph

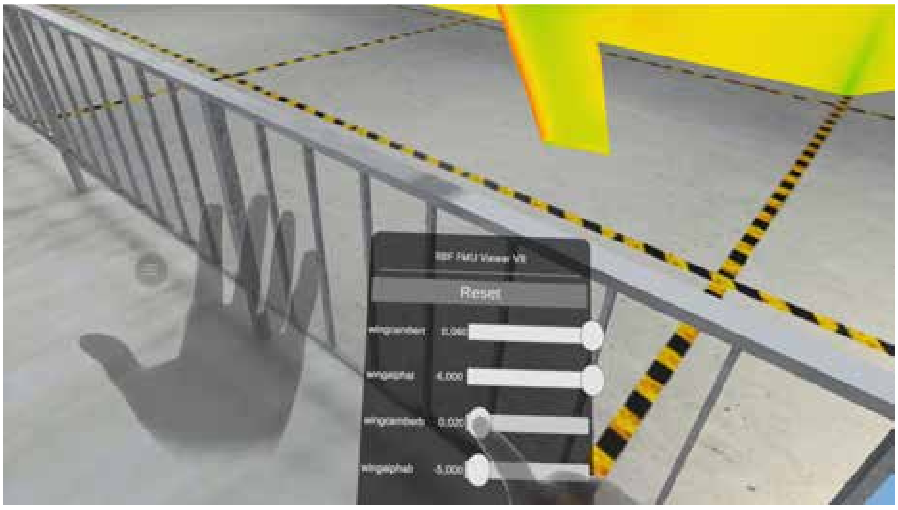
The aerospace industry is undergoing a rapid digital transformation, embracing innovative technologies to streamline design workflows, increase efficiency, and drive innovation like never before. One of the most exciting breakthroughs is the integration of virtual reality (VR) with reduced order models (ROMs), to enable real-time aerodynamic design exploration.

Traditionally, engineering workflows have been slow and resource-intensive, with design iterations relying on lengthy computational fluid dynamics (CFD) simulations. This article presents a game-changing approach – one that seamlessly links CAD modelling, CFD, and ROMs within an interactive VR dashboard. The result? A fast, immersive, and intuitive tool that allows engineers to explore designs in real-time, making the whole process more dynamic and efficient.

Bridging the gap: from CAD to VR

Aerodynamic performance optimization has traditionally been a highly iterative process. Engineers must analyse multiple design variants using high-fidelity CFD simulations, which are accurate but computationally expensive and time-consuming. Integrating VR and ROMs into the workflow helps overcome these challenges by providing a real-time design environment with interactive parameter exploration.

By incorporating CAD parameterization and mesh morphing, engineers can seamlessly



adjust shapes without the need for repeated re-meshing. This not only streamlines the design process, but also reduces computational delays, allowing for faster and more efficient iterations. The idea is to create a direct link between CAD and the mesh, so that shape modifications are defined at the CAD level while the numerical analysis model is updated via mesh morphing. This ensures excellent shape control, with the mesh automatically updated and computational times significantly reduced.

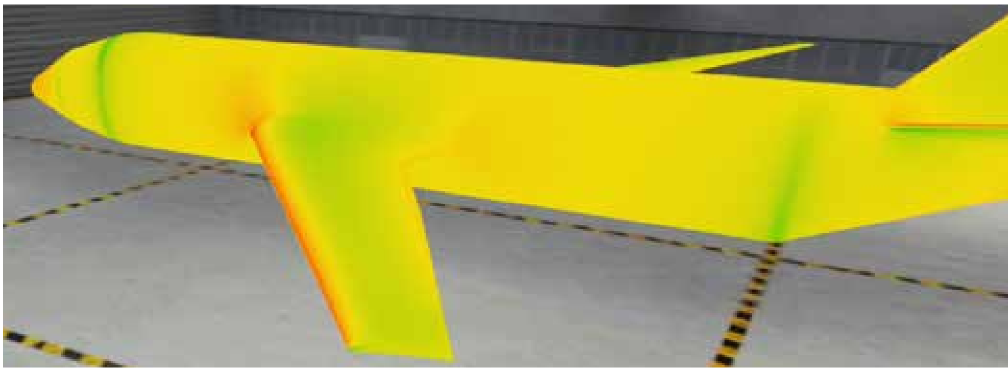
To enable this CAD-mesh link, we have created a tool (based on the OpenCASCADE engine) that generates two isotopological point clouds – one on the baseline and one on the modified variant. These point clouds are interpreted as an RBF field, which can then be used to transfer shape modification data from the CAD model to the mesh.

Another key benefit of using mesh morphing is that it ensures that each design point maintains an isotopological mesh, i.e. the same number of nodes and elements across all variations. This consistency is crucial for developing POD-based reduced order models (ROMs). ROMs provide compact yet highly accurate representations of high-fidelity CFD results, preserving predictive accuracy while drastically reducing simulation time.

Functional mock-up units (FMUs) enable standardized data exchange, ensuring compatibility between different simulation tools and digital twin environments. FMUs have been adopted as the standard for transferring information and integrating ROMs into the VR framework.

The virtual reality interface revolutionizes the way engineers interact with aerodynamic data, providing an immersive environment where they can visualize the impact of design changes and make informed decisions in real time.

By integrating these technologies, engineers can instantly adjust design variables and see the impact on aerodynamic performance in real time – all within an interactive 3D environment. This direct approach makes the design process more intuitive, efficient, and engaging.



Industrial applications and benefits

The effectiveness of this workflow was demonstrated using the open parametric aircraft model (OPAM), a simplified representation of a Boeing 787. This test case clearly demonstrated how the combination of ROMs and VR can revolutionize the aerodynamic design process. One of the most significant benefits is the dramatic reduction in the time required for design iterations, allowing engineers to explore more possibilities more quickly and easily. Traditional CFD-based workflows often take days or even weeks to generate results, whereas this approach allows for real-time modifications and evaluations, enabling much faster decision-making.

Another key benefit is the improved engineering insight. The immersive capabilities of VR provide an intuitive understanding of complex aerodynamic effects, allowing engineers to see firsthand how changes in shape affect airflow and performance characteristics. This, in turn, promotes more informed decision-making and greater confidence in the final design results.

The collaborative potential of this workflow is substantial. By enabling engineers, designers, and decision-makers to interact with the same 3D model in a shared virtual space, cross-discipline collaboration is enhanced, communication barriers are broken down and the development process is streamlined. Additionally, the use of FMUs ensures seamless integration with existing CAE (computer-aided engineering) and PLM (product lifecycle management) tools, making this approach easy to adopt within established workflows.

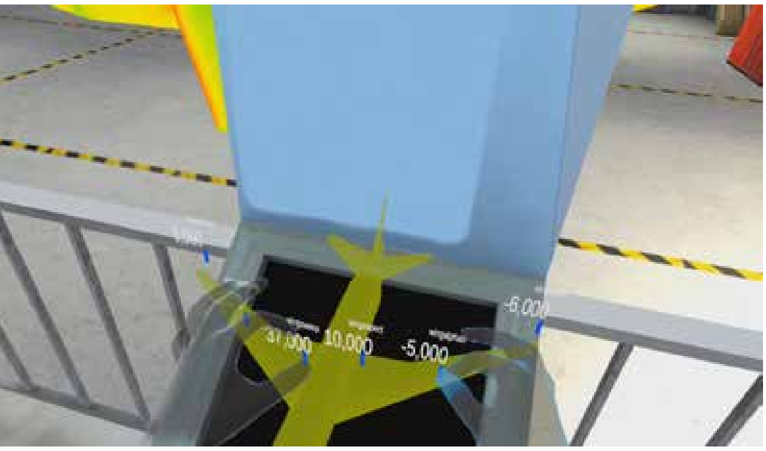
The VR-enabled dashboard

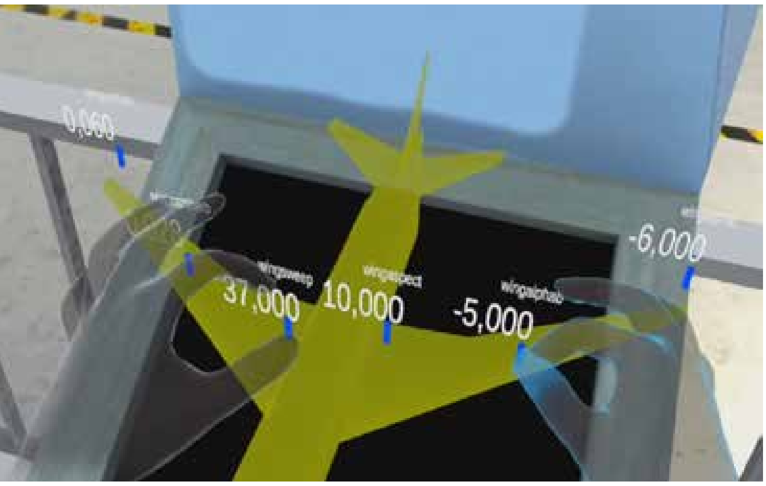
Developed in Unity, the VR-enabled dashboard introduces a powerful interface that allows engineers to manipulate aerodynamic parameters in real time and receive immediate feedback on performance. The Meta Quest 3 headset was chosen for its high-resolution display, intuitive interaction features, and, crucially, its ability to operate in a wireless configuration.

Unlike research VR applications that require a connection to a powerful workstation, our solution runs as an on-device application, providing greater flexibility and enabling collaborative experiences without the need for tethered setups.

We are also actively developing an app for Apple Vision Pro, bringing this innovative technology to an even more immersive platform. The expected release is imminent, promising an exciting leap forward in interactive aerodynamic design. This expansion will significantly broaden the accessibility of this innovative workflow, making it available across multiple innovative VR platforms.

The system provides a dynamic and responsive environment where users can control aerodynamic parameters through intuitive interfaces. Instead of relying on traditional numerical input methods, engineers can use sliders and handles to precisely adjust design variables and receive immediate feedback as changes take effect.
For those who prefer a more tactile approach, the system allows direct manipulation of 3D model control points, providing a more interactive way to modify aircraft geometry. Furthermore, real-time data overlays provide continuous insights into critical aerodynamic





metrics, including drag, lift, and pressure distribution, ensuring that design choices are always backed by data-driven analysis.

This reimagined design process represents a significant departure from traditional simulation-driven workflows, shifting towards a more intuitive and immediate method of performance evaluation.

Expanding the potential: future applications

Although originally designed for aerospace applications, this VR-integrated ROM workflow has the potential to revolutionize various other industries.

- In the medical field, this approach is being adapted to support surgical planning, allowing medical professionals to interact with the patient's anatomy in a virtual environment. By visualizing and optimizing procedures before they take place, surgeons can increase precision, reduce risks, and improve patient outcomes.
- In automotive design, similar approaches can be used to optimize vehicle aerodynamics, leading to improvements in fuel efficiency and overall performance.
- In marine engineering, streamlined hull designs can be tested to minimize hydrodynamic drag and improve overall vessel efficiency.
- In wind energy, turbine blade designs can be rapidly adjusted to maximize power generation while maintaining structural integrity.
- In industrial aerodynamics, applications range from optimizing HVAC (heating, ventilation, and air conditioning) systems to analysing urban wind flow dynamics and improving industrial cooling solutions.

The flexibility and scalability of this approach makes it incredibly adaptable to industries where real-time design evaluation and optimization are essential. By allowing engineers to interact with complex aerodynamic data in an immersive and intuitive way, this technology can revolutionize not just aerospace design, but a wide range of engineering disciplines.

Conclusion

This VR-enhanced aerodynamic design workflow represents a ground-breaking shift towards interactive, high-speed, and highly efficient engineering processes. The combination of ROMs, FMUs, and immersive VR is transforming the way engineers interact with simulation data, providing a level of insight and engagement that was previously unattainable.

As industries place greater emphasis on faster, more cost-effective, and data-driven design cycles, the role of real-time simulation and VR will become increasingly important. Future advancements will expand the dataset, integrate AI-driven optimization techniques, and explore even broader engineering applications. This will further refine and enhance the workflow, pushing the boundaries of what is possible and enabling engineers to solve complex problems with greater efficiency and precision.

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About RBF Morph

RBF Morph is a cutting-edge company specializing in advanced mesh morphing technology powered by Radial Basis Functions (RBF). Our flagship solution, seamlessly integrated with Ansys, enables fast, precise, and efficient shape modifications for CAE simulations—eliminating the need for remeshing. This breakthrough technology accelerates design optimization, parametric studies, and real-time shape adaptation, making it an essential tool for engineers and designers. Widely adopted across the aerospace, automotive, and biomedical industries, RBF Morph empowers companies to push the boundaries of innovation, enhancing performance, efficiency, and reliability in product development.

The new industrial role of spatial computing

An overview of the integration of immersive reality and artificial intelligence in industrial processes

by Giulio Cenci
Vection Technologies

VR immerses people in fully virtual environments, AR superimposes digital elements on the real world, and MR blends the two to create interactive experiences where physical and digital objects coexist. In design and engineering, XR enables teams to visualize and interact with prototypes in a virtual space, reducing costs and accelerating product development. In training, immersive simulations improve learning retention and provide direct experience without real-world risks. In customer support, AR-based remote assistance helps technicians diagnose and fix problems more efficiently, minimizing downtime.

The integration of AI into XR is a major step forward. AI algorithms enhance the XR experience through intelligent environmental mapping, natural language processing for voice commands and personalized content delivery. As these technologies converge, businesses will benefit from more intuitive interfaces, predictive capabilities, and context-aware applications that adapt to user behaviour and environmental conditions.

This paper explores some industrial and engineering applications of Vection Technologies' suite of spatial computing software solutions within various business processes.

Introduction

In today's rapidly evolving business landscape, organizations are constantly looking for innovative solutions to improve their processes and gain a competitive edge. XR technologies, including VR and AR, have emerged as powerful tools with the potential to revolutionize various aspects of business operations. Vection Technologies, a leading provider of spatial computing solutions, offers a range of software products designed to address specific business needs in different domains. This paper examines the applications of spatial computing technologies to key industry-specific business processes, highlighting their unique capabilities and potential benefits.

Virtual reality for technical training

Immersive VR training experiences for technical procedures related to commissioning, operations and maintenance are among the most mature. By simulating

Fig. 1. Not only 3D CAD models can be experienced in VR; now, immersive reality enables the visualisation of structured and unstructured procedures for technical training, design review, assembly and operation scenarios.

Fig. 2. Multi-channel (mobile, tablet, desktop, VR and AR headset) and collaborative scenarios can be easily set up with no-code software.

real-world scenarios, employees can acquire practical skills in a safe and engaging environment. The integration of AI enhances the training process by providing document analysis, troubleshooting support, and assisted virtual navigation. This results in better knowledge retention, reduced training time and increased employee competence.

Augmented reality for technical support

AR technology provides real-time support for technical procedures such as assembly, commissioning, quality control, checklists, and maintenance. By overlaying digital information on the real-world environment, technicians can access step-by-step instructions, detailed procedural guidance, and automated report generation according to job specifications. AI integration further improves efficiency by providing contextual assistance and streamlining documentation processes. Powerful integration with remote assistance using visual holograms and vocal online help from a technician can be activated for specific requests.

Virtual reality for design review and product presentation

Multidisciplinary design reviews of CAE campaigns in VR can help engineers evaluate product performance in different configurations and boundary conditions. This promotes team collaboration and facilitates early identification of design flaws. In addition, VR visualization of CAE results can be used for product and design presentations in VR, providing decision makers with an immersive experience that effectively displays technical content and company expertise.

Virtual reality for "lightweight" DFMA processes

Lightweight design for manufacturing and assembly (DFMA) processes, which eliminate the traditional loop between CAD design and prototyping, are supported by specific VR applications with a new and disruptive process that enables tangible assembly scenario evaluation and VR design optimization with the following benefits:

- Managing 1:1 ergonomics, spaces, and tooling workflows
- Identifying every detail, error, gap, and mechanical interference with infinite zoom
- Enabling virtual perceived quality and precise measurement
- Ensuring complete safety by avoiding real resources and workshops
- Reducing prototyping and design costs through continuous technical collaboration
- Creating a new, simple, and intelligent framework for suppliers, customers, and engineers

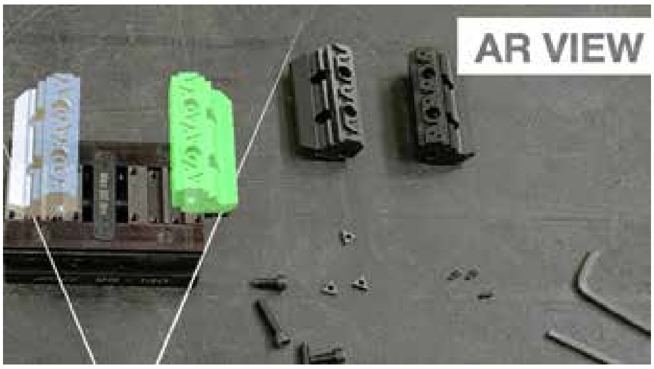

Fig. 3, Fig. 4, and Fig. 5. A complete process can be set up in the same editing software, from VR training sessions to AR operations support with 2D and 3D procedures, remote assistance and AI troubleshooting, and manual integration.

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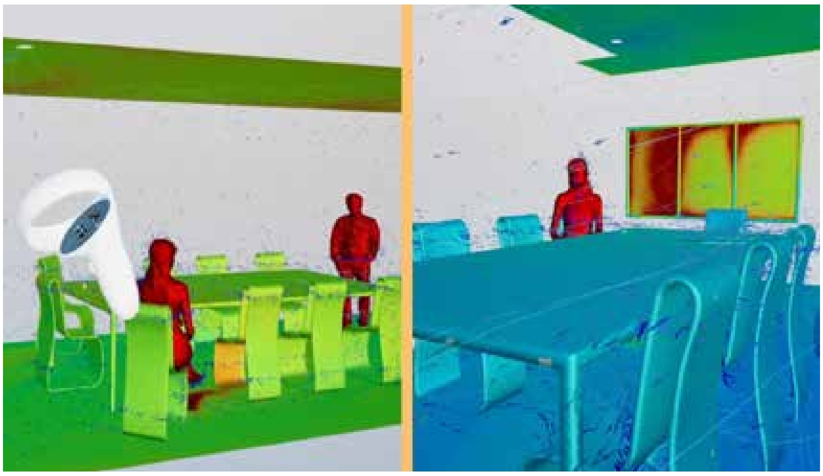

Fig. 6. X-RHEA is designed to easily create customer experiences focused on the immediate and immersive presentation of multi-disciplinary structural mechanical, thermo-fluid dynamic, and electromagnetic analyses campaigns, as well as other engineering data related to components or systems. The observer's viewpoint can be external or internal, offering immediate visualization, understanding and decision-making capabilities even for top managers, entrepreneurs and customers.

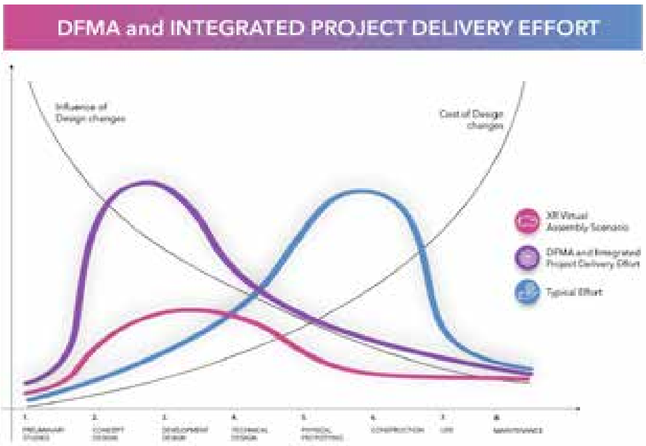

Fig. 7. The light purple curve represents a disruptive, lightweight XR virtual assembly scenario that addresses a sustainable trade-off for SMEs to implement a lightweight DFMA process focused on reducing the design and prototyping cycle through a new collaborative XR assembly evaluation and communication process.

By promoting and facilitating en efficient and inclusive communication between designers and prototypers from concept to critical design, VR significantly reduces development time, investment, and costs compared to traditional DFMA approaches, especially when applied to small and medium-sized companies.

Conclusion

Spatial computing solutions (XR & AI integration with specific hardware appliances) provide a complete ecosystem of software solutions for a transformative approach to various business processes. By harnessing the power of VR, AR, CAE and integrating them via AI, these tools improve efficiency, collaboration, and decision making across a wide range of industries.

From technical training and support to design review and product presentation, Vection Technologies' software enables organizations to optimize their operations and achieve new levels of productivity.

Collaboration with EnginSoft and the development of X-RHEA

Vection Technologies, an ASX-listed company focused on spatial computing solutions and the full integration of XR and AI technologies, is partnering with EnginSoft, an Italian engineering simulation boutique that provides cutting-edge CAE software and specific high-level services, to develop X-RHEA.

This collaboration aims to increase the communicative and commercial value for customers using engineering simulation expertise in their product development processes.

With their combined technical expertise, Vection and EnginSoft will enable customers to rapidly develop multi-disciplinary design reviews in virtual reality using X-RHEA. These reviews can then be presented to their own customers, providing a compelling and informative customer experience that effectively demonstrates the value of their products, processes, and expertise to increase value, branding, and competitive advantage.

This strategic partnership enables customer companies to bridge the gap between complex technical data, simulations, and effective communication, driving business growth and strengthening customer relationships. The future of computational engineering is closely linked to emerging technologies such as XR and AI, which can unlock the full value of our customers' technical expertise.

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TOLERANCING MINI-SERIES

Tolerances are a fundamental part of modern product design and manufacturing. They affect not only the quality and performance of a product, but also its cost, manufacturability and time-to-market. Poorly defined tolerances, inadequate reference patterns, or inefficient assembly sequences can lead to high production costs, higher rework and scrap rates, and delays in product launch. It is therefore critical for engineering organizations to have a clear understanding of the impact of tolerance decisions throughout the product development process (PDP).

In today's increasingly complex and multi-functional design environments, tolerances must be precisely defined, managed, and communicated. This ensures that critical dimensional information flows seamlessly from design to production to quality control, and back to engineering. Whether documented in 2D engineering drawings or incorporated into 3D CAD master files, tolerances and reference structures are the backbone of design intent and product quality assurance.

This series of articles explores four key aspects of modern tolerance:

1. Dimensional Management (DM)
2. ISO GPS – Geometrical Product Specifications
3. Statistical Simulation of 3D Tolerance
4. QIF format for model-based definition (MBD) and digital continuity

Each article aims to provide insights into how tolerance can be systematically implemented in PDP, using simulation, standards, and digital tools to improve product quality and reduce manufacturing costs.

Dimensional Management (DM)

by Florian Weidenhiller
EnginSoft

What is dimensional management?

Dimensional management (DM) is a simulation-based engineering methodology that analyses and ensures dimensional quality throughout the product lifecycle. It aims to minimize variation in parts and assemblies through robust design, manufacturing, and inspection processes. By controlling variation early in the product development process (PDP), DM supports the creation of products that meet quality requirements while reducing costly rework, scrap, and delays in production and/or time-to-market.

More than just a quality control tool DM is an integrated framework that links design, manufacturing, and quality teams, within a company and with suppliers/customers, promoting collaboration and data-driven decision-making. It acts as a vital interface between the PDP and the production planning process (PPP), ensuring that product and process designs are compatible, feasible, and verifiable.

The role of dimensional management in the product development process

Dimensional management plays a central role in the entire PDP, serving as a common thread linking all disciplines involved from initial concept to full-scale production. Rather than treating dimensional quality as an afterthought, DM brings it into the initial stages of development, allowing teams to anticipate challenges and control variation before physical prototypes are built.

At each phase of the PDP, DM allows dimensional requirements to be clearly defined and evaluated. This includes setting quality limits, planning assembly sequences and analysing how design choices affect overall build precision. With this insight, teams can make informed decisions that balance functionality, manufacturability, and cost.

One of the main functions of DM is to create robust reference diagrams and tolerance definitions that are both technically valid and achievable. These definitions are created with an understanding of how parts will be assembled and inspected, ensuring alignment between digital models and real-world production. Critical characteristics, those that have a direct impact on performance or assembly, are identified early on, enabling the development of targeted inspection and verification strategies.

DM also guides the creation of measurement plans, ensuring that dimensional checks focus on what really matters. This includes identifying not only where to measure, but also how to measure, with what equipment, and under what conditions. By considering inspection requirements alongside design and manufacturing, DM ensures that quality assurance is not an afterthought but an integral part of the product lifecycle.

Most importantly, DM facilitates smooth communication between functions. It creates a common language for dimensional quality, enabling design, manufacturing, and quality teams to work in a coordinated way. This alignment reduces ambiguity, avoids costly iterations, and ensures that the product performs its intended function with a high degree of confidence, on time and within budget.

Systematic approach to dimensional management

The implementation of dimensional management follows a structured, step-by-step methodology that is aligned with the key stages of the product development process: concept, design, prototyping, and production. Rather than relying on disconnected quality control at a late stage in the process, this approach integrates dimensional thinking from the very beginning.

The concept phase focuses on defining and documenting the dimensional requirements of the product. Initial considerations include the evaluation of possible assembly and design alternatives, with the goal of minimizing complexity and variation. A key part of this phase is establishing clear parts and assembly location diagrams, which form the basis for downstream production and quality assurance processes.

As the project matures, more detailed activities will be undertaken. These will include the definition of ISO GPS-compliant reference structures and feature controls to communicate tolerance information. Design optimization will be conducted using 3D tolerance simulations to predict and control variation between assemblies. Critical functional characteristics and relevant measurement points are identified to guide both production control and inspection planning. An optimized measurement strategy is also developed at this stage to ensure that subsequent inspection can be carried out efficiently. In the prototyping phase, the focus shifts to the validation of processes and physical tools. Measurement devices and equipment are assessed and verified for suitability in both design and production contexts. Statistical techniques such as gauge repeatability and reproducibility (Gauge R&R) studies are used to ensure that measurement systems are consistent and reliable. In addition, capability studies are used to assess the dimensional stability of parts and assemblies under real-world conditions.

Finally, during the production phase, dimensional management supports the implementation of statistical process control and continuous quality monitoring. This includes not only the detection of variation, but also the active management of improvement initiatives. Root cause analysis is conducted to resolve any dimensional issues that arise during assembly. Information from production is fed back into the design and manufacturing processes, enabling continuous optimization throughout the product lifecycle.

This holistic and iterative approach to dimensional management ensures that tolerances and reference schemes are not only theoretically valid, but also practically viable, traceable, and measurable throughout the product's journey from concept to reality.

Key principles and emphases

The successful application of dimensional management depends on a set of foundational principles that guide its implementation across all disciplines. At its core, DM is a collaborative process that requires the active involvement of design, manufacturing and quality experts. All decisions regarding tolerances, reference structures and measurement strategies must be discussed, validated, and agreed upon by the relevant stakeholders to ensure alignment and consistency.

A critical starting point for DM is the geometry of the product itself, which serves as the basis for defining both functional requirements and quality criteria. The orientation and sequence of assembly steps are logically derived from this geometry. These assembly considerations are not developed in isolation but are deeply connected to the dimensional stability and inspection feasibility of the product.

Reference patterns and tolerances are determined based on part orientation and functional features. Specifically, the orientation of parts in an assembly is guided by principles such as degrees of freedom and the function of mating surfaces or critical elements. This structured derivation ensures that references are both logically chosen and meaningful, supporting robust assembly and inspection.

To optimize these definitions, DM relies heavily on 3D statistical tolerance simulations. These simulations allow teams to evaluate different scenarios, identify variation risks, and make informed decisions on where to tighten or loosen tolerances. This not only supports better product quality but also reduces overengineering and unnecessary manufacturing costs.

Finally, it is essential that all optimized tolerance and reference information is accurately documented and communicated. This is typically done through 2D engineering drawings or embedded directly into 3D CAD master models, ensuring that design intent is preserved and accessible throughout the product lifecycle, from design to manufacturing, and even into inspection and quality feedback loops.

Why DM matters

DM is not an optional add-on, but a fundamental element of modern engineering workflows. In a world of shrinking development cycles, complex supply chains and increasing quality demands. DM enables companies to deliver the right products first time. It reduces ambiguity in design intent, aligns teams across disciplines and minimizes surprises in production and assembly.

Integrating simulation, standards and measurement, dimensional management is the backbone of digital product quality, from the first conceptual sketches to full-scale production.

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Railway-vehicles crashes: A study on energy absorbers in offset conditions

by Luca Buoncristiani, Alberto Perticone, Giuseppe Occhipinti
Hitachi Rail

Recent growth in railway traffic has resulted in several accidents and casualities that in turn have jeopardized one of the safest means of transport to date. Energy absorbers, the devices designed to absorb impact energy during a collision to protect passengers and preserve cabin integrity, play a critical role in mitigating collision impacts by dissipating kinetic energy and safeguarding structural integrity and, therefore, passengers. However, increasingly, public and regulatory authorities are requesting that their reliability also be guaranteed under off design conditions.

One of these off-design conditions is the offset or eccentric impact, where vehicles collide without perfect frontal alignment, introducing a degree of eccentricity.

Nevertheless, despite the growing importance of eccentric impact scenarios for railway vehicle homologation, the open scientific literature offers limited studies on energy absorbers in this off-design condition. Energy absorbers, such as crash buffers and crumple zones, were first introduced in railway vehicles in the mid-20th century as part of efforts to improve crashworthiness.

Early developments in crash energy management (CEM) systems began in the 1960s and 1970s, particularly in high-speed rail applications and heavy freight railcars. The mandatory implementation of energy absorbers in railway vehicles has varied by country and region. In Europe, crashworthiness standards were significantly reinforced with the introduction of EN 15227 in 2008, last updated in 2024 [1], which mandated energy absorption structures and eccentric scenarios.

This study provides the basis for analysing the effects of offset impacts in the railway sector and derives key principles for the design of energy-absorbing structures in metal alloys, such as steel or aluminum typically used in these applications.

A numerical simulation was performed on various types of tubular absorbers (hereafter referred to as "tubes"), including simple tubes (TWS, thin-walled structures), conical tubes (TWDTS, thin-walled double tapered structures), tubes with internal longitudinal septa (TWMCS-LS, thin-

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walled multi-cell structures – longitudinal septa), and tubes with an additional inner tube (TWMCS-BT, thin-walled multi-cell structures – bi-tubular tubes), see Fig.1.

All these configurations operate on the principle of energy dissipation through controlled crushing (or folding): when subjected to axial compressive loading, the tube forms plastic hinges that progressively create folds. This process allows irreversible energy dissipation through plastic deformation of the material. The correct and controlled formation of these folds is essential to ensuring efficient energy absorption during a collision.

The energy absorber models investigated in this study were developed using finite element (FE) analysis and evaluated through 240 simulations in which several geometric parameters were varied, including tube and septum thickness, external and internal dimensions, number of septa, conicity (ratio between the front and rear sections), and cross-sectional shapes.

The simulations were conducted with the explicit solver LS-DYNA R12.2.1, on HPC cluster using 128 CPUs and 185GB memory. All geometries adhere to a maximum cross-sectional dimension (or maximum footprint) constraint of 300 mm × 300 mm and a tube length of 400 mm, in line with typical applications for Metro C-II category vehicles (Standard EN 15227). All analyses were performed using a 10 mm mesh size, employing fully integrated shell elements for the plates and solid elements for the anticlimbers, in turn positioned with a vertical offset of 40 mm, in accordance with the eccentricity condition defined in the standard [1].

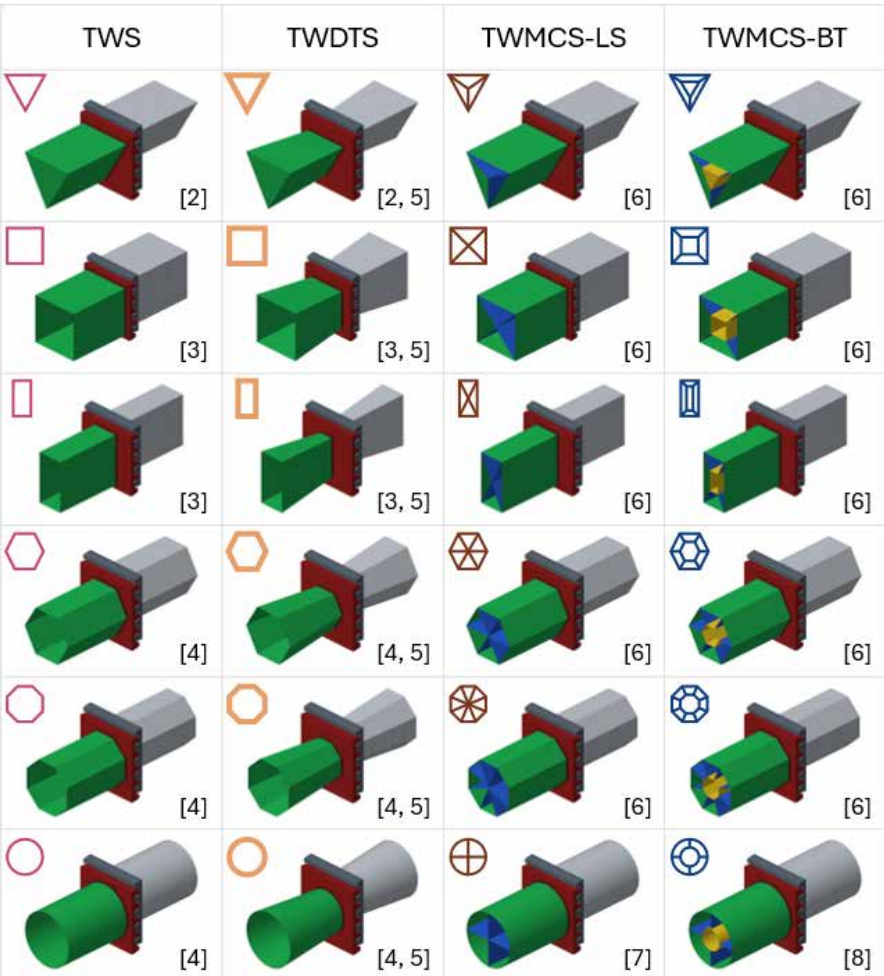


Fig.1. Type, shape, and references [#] for all the analytical formulations in this study.

Each configuration under offset impact conditions was evaluated using the energy ratio indicator R, which expresses the ratio between 1) the energy absorbed during an offset impact, as determined by numerical simulations, and 2) the energy that the absorber would dissipate under ideal, purely axial impact conditions.

The latter was calculated using theoretical analytical formulations available in the literature (Fig.1) and implemented in MATLAB to account for all parameterized variations in the offset scenario.

These analytical formulations enable the estimation of the energy absorbed during the plastic formation of folds, under a perfectly axial and stationary crushing mechanism. This approach ensures that for each offset simulation, the corresponding energy value under purely axial conditions is available, allowing an accurate determination of R among all the considered geometric variations.

The results indicate that increasing the cross-sectional dimensions leads to a higher energy ratio R. Conversely, variations in thickness do not have a comparable effect. Although thickness is a critical parameter for the total amount of energy dissipated in both axial and eccentric impact conditions, its variation

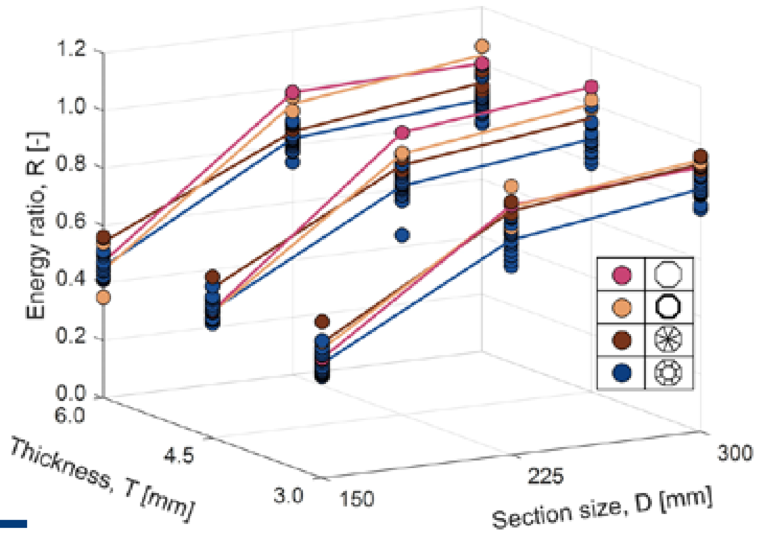


Fig.2. Influence of section size and thickness on energy ratio.

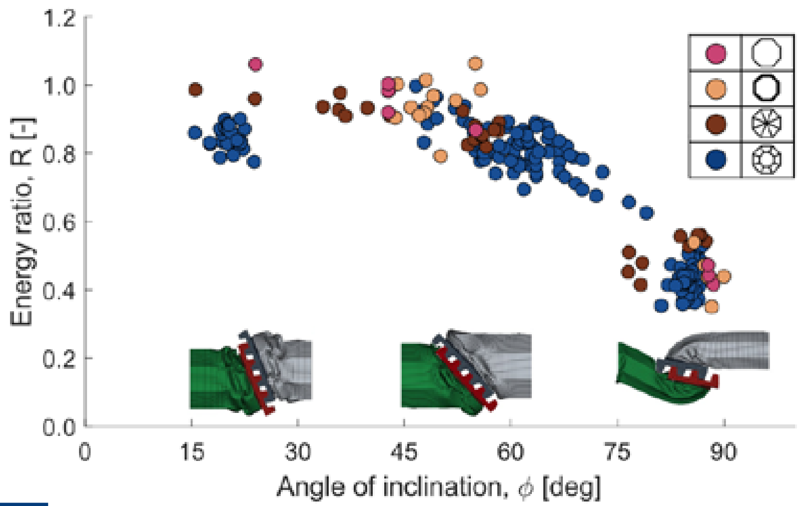
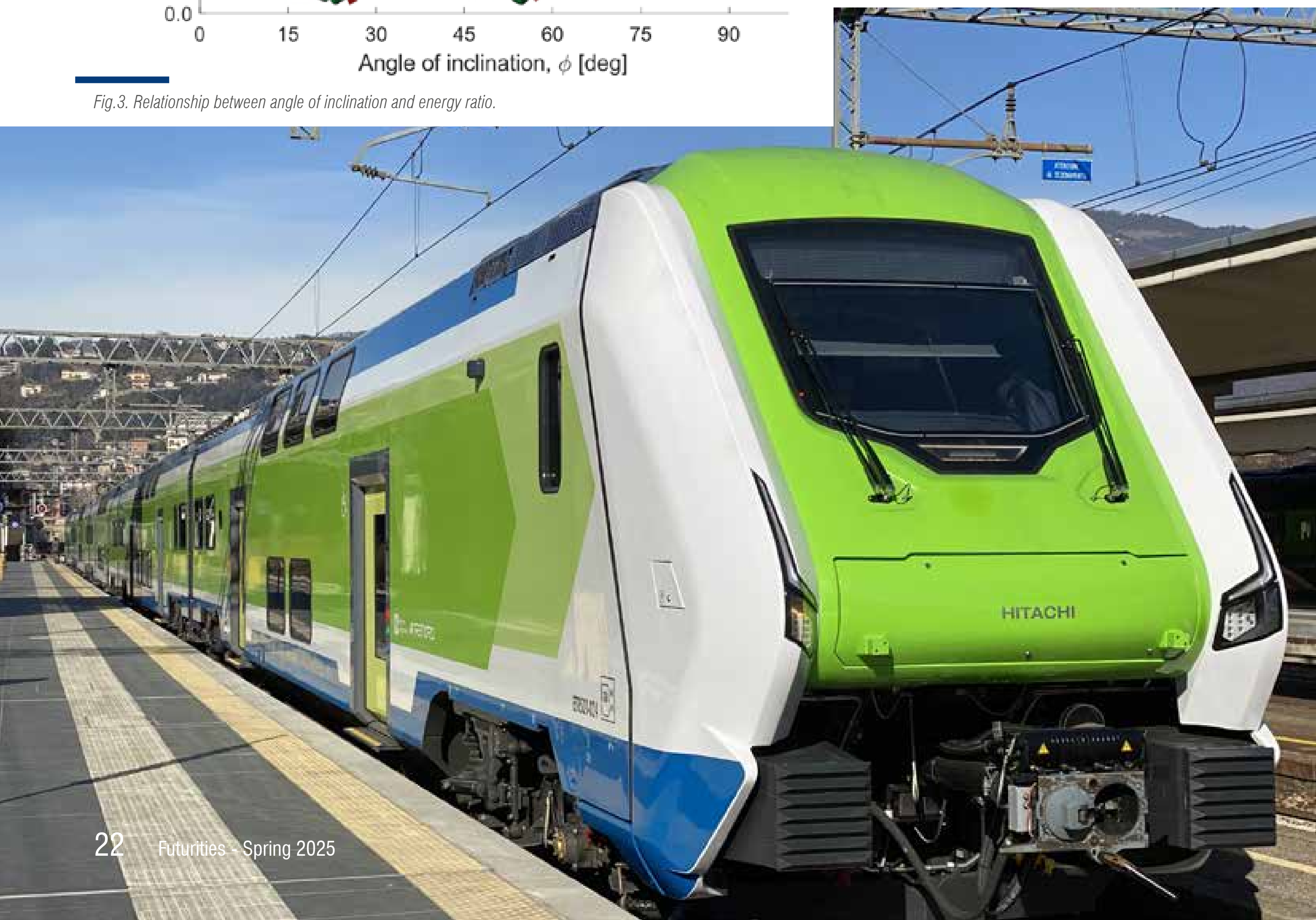


Fig.3. Relationship between angle of inclination and energy ratio.

does not improve the energy ratio R (Fig.2). Similarly, no specific absorber type outperformed the others in terms of the energy ratio R.

Further analysis of the absorption phenomenon revealed the existence of a minimum cross-sectional dimension below which buckling instability occurs, leading to significant rotations between the two absorbers and a loss of energy dissipation efficiency.

However, by correlating the energy ratio R with the angle of inclination ϕ between the absorbers (Fig.3), it was observed that the inclination — outside the instability region associated with buckling instability — does not serve as an effective indicator of the absorber dissipation capacity. In this region, indeed, the energy ratio R remains almost constant even for large angles of inclination between the two absorbers, leading to a suitable energy dissipation albeit the incompleteness of folds.



In addition, the use of cross-sectional shapes with acute or right-angled vertices (Table 1), such as triangles, squares, and rectangles, has been shown to limit the absorber inclination ϕ and increase the number of complete folds — a key parameter for the energy absorption efficiency of these devices (Fig.4). A section with acute or right-angled vertices produces higher resistances near these points, in accordance with analytical formulations of absorber dissipation.

These higher resistances contribute to more controlled crushing, facilitating the formation of complete folds and allowing a deformation mechanism like that observed under purely axial impact conditions.

In conclusion, this study highlights the crucial role of the cross-sectional dimensions of the energy absorbers: increasing this parameter improves the energy ratio R. The buckling instability only occurs below a certain minimum cross-sectional dimension, leading to significant rotations between the two absorbers (over about 70 degrees) and a notable loss of energy dissipation efficiency.

However, it is worth noting that a certain inclination between two absorbers does not necessarily result in significantly lower energy absorption compared to axial conditions even in presence of incomplete folds — outside the buckling instability region.

Besides, the absorber type (TWS, TWDTS, TWMCS-LS, and TWMCS-BT) and wall thickness have no significant effect on the energy ratio R. Conversely, cross-sectional shapes with acute or right-angled vertices effectively minimize the angle of inclination ϕ between absorbers for all the typologies, ensuring a crushing mechanism equivalent to purely axial scenarios with the formation of complete and controlled folds.

Special thanks to the University of Florence and the MOVING research group, with special recognition to Professor Niccolò Baldanzini, for their collaboration with Hitachi Rail STS in promoting research on finite element numerical simulation and passive safety in the railway sector.

TWS			TWDTS			TWMCS-LS			TWMCS-BT		
Shape	R (-)	ϕ (deg)	Shape	R (-)	ϕ (deg)	Shape	R (-)	ϕ (deg)	Shape	R (-)	ϕ (deg)
	1.01	7.9		1.04	5.7		0.94	9.2		0.98	7.9
	0.96	4.7		0.95	3.5		1.02	5.2		0.99	5.8
	1.03	2.4		0.95	4.9		0.96	2.2		0.96	5.1
	0.95	25.8		0.96	43.1		1.04	9.7		0.92	50.6
	0.97	41.8		0.96	49.1		0.92	38.4		0.89	60.1
	0.95	52.1		0.95	48.7		0.89	52.5		0.85	63.4

Table 1. Relationship between shapes of different typologies, inclination angle and energy ratio.

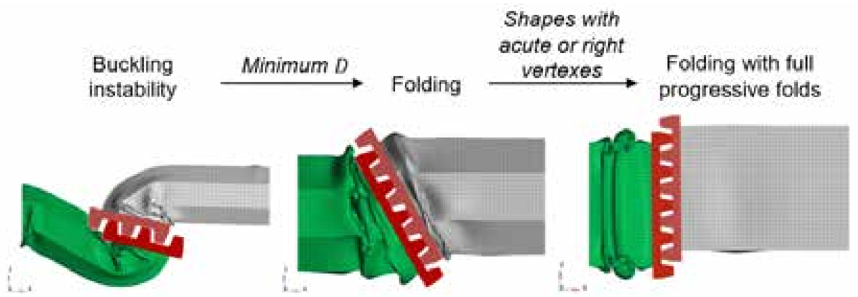


Fig.4. Summary of the main conclusions.

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About Hitachi Rail

Hitachi Rail is committed to driving sustainable mobility transition and helping every passenger, customer and community enjoy more connected, seamless and sustainable transport. Hitachi Rail is a trusted partner to operators around the world with expertise across every part of the rail ecosystem – from manufacture and maintenance of rolling stock to digital signalling and smart operational systems. In FY23, the company had revenues of €7bn and 24,000 employees across over 50 countries. It invests in its diverse and talented teams. Drawing on the wider Hitachi group companies, Hitachi Rail furthers the development of digital innovation and new technologies to help pioneer resilient and sustainable solutions. For more information, visit hitachirail.com

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Evaluating and reducing the risk of hydrogen leakage in an aircraft cabin using CFD analysis

by Marco Corti[1], Leonardo Lecce[2]
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Introduction

The transition to more sustainable aviation is driving the industry to explore new technological frontiers, with hydrogen emerging as one of the most promising candidates for future propulsion. Hydrogen fuel cells represent a potentially revolutionary solution that combines energy efficiency with zero emissions. However, implementing this technology in a specialized sector such as aviation that has multiple risk factors raises important safety issues which require in-depth analysis to prevent and mitigate accidents. Several projects have been developed and are underway to implement fuel cells in the aviation sector in aircraft ranging from small two-seaters to large commercial aircraft.

SERENA, an abbreviation derived from the Italian name of the project (Sviluppo di architetture propulsive ad Emissioni zeRo per l'aviazione gENerAle), thanks to the joint efforts of Distretto Tecnologico Aerospaziale (DTA), EnginSoft, Novotech and Università del Salento – Department of Innovation Engineering, focuses on the development of zero-emission propulsion architectures for general aviation and aims to develop an all-electric propulsion system using a combination of batteries and fuel cells for the Seagull, a VDS (recreational or sport flight) category aircraft manufactured by Novotech. The aircraft stores hydrogen gas in a 350-bar cylinder located in the fuselage behind the pilot seats. The use of pressurized gas, combined with the fact that hydrogen has a low activation energy and a wide range of concentrations (from 4% to 75%) to form an explosive mixture with air, requires careful risk assessment and mitigation. Databases such as HIAD 2.1 provide an overview of the accidents caused by hydrogen usage in different industries which offers a statistical sample and reference for risk reduction.

When hydrogen tanks are used, the malfunctioning or rupture of the gas supply valve is a frequent cause of accidents. With this in mind, the CFD (computational fluid dynamics) activity within the SERENA project focused on simulating a valve rupture scenario resulting in the release of hydrogen into the aircraft cabin during flight.

The aim of the CFD modelling was to assess whether the average hydrogen mole fraction in the cabin would remain below 1% and whether the combustion danger zone (identified as the area with a hydrogen mole fraction greater than 4%) would remain confined to a small area near the leak.

Design requirements and reference standards

Starting from the definition of a series of typical missions (take-off, climb, cruise, descent) of the Seagull aircraft and the data available on its aerodynamic and propeller characteristics, a specific "Mission Performance Calculator" procedure was developed. The power requirements, the total energy required to carry out the various missions, the autonomies, and the mission times were calculated by modifying the main parameters (speed, pitch, cruising altitude, and duration) that uniquely identify each mission. Using this procedure, twelve different typical missions varying in duration (between 30' and 90'), cruising speed, flight altitude, etc. were analysed, after which the power requirements for each flight phase, and for the mission as a whole, were derived.

Project partner UniSalento used this data to define the propulsion system based on an electric motor powered by a suitable fuel cell and a corresponding hydrogen gas tank. It also addressed the certification and safety issues relating to the use of hydrogen to power the fuel cell. In this regard and due to the absence of legislation applicable to light aircraft, UniSalento examined the available regulations (ISO/TC 197, EC ATEX and EU TPED directives) governing the use of hydrogen in other sectors, as well as recent FAA and EASA reports on the use of fuel cells and hydrogen tanks.

Modelling of the cabin housing the propulsion system

A preliminary analysis was performed assuming a cylindrical tank and the presence of two openings at the top and side of the aircraft to provide natural ventilation. Bodies in the vicinity of the tank were also considered as they significantly influence the movement of the fluid. The exit velocity of the leak was estimated using FLOWNEX software for a tank with a known pressure of 350 bar, assuming a cabin pressure of 1atm and a leak diameter of 2.5mm. The exit velocity of the tank leak is u=1,103m/s. The analysis, performed using Ansys Fluent, has the following physical modelling characteristics:

- **Transient**: the analysis evaluates the temporal evolution of the gases within the domain. At the initial moment, a volume consisting only of air is considered, while at later moments the cabin begins to contain hydrogen due to the outflow from the tank.
- **Multicomponent**: a multicomponent simulation, i.e. which evaluates the model as a mixture of fluids, is necessary to evaluate the hydrogen concentration. In the case of the actual simulations, the mixture considered consists of air and hydrogen. The mole fractions X_{H2} and X_{air} are the quantities considered to evaluate the composition of the mixture in the different regions of space
- **Gravitational**: air and hydrogen have quite different densities, so the gravitational field must be considered as it has a significant effect on the dynamics of the gases inside the cabin.
- **Turbulent**: the jet of the leak exiting the tank has a very high velocity due to the considerable difference between the pressure in the cylinder and the pressure in the cabin, resulting in turbulent flow. The difference in density between air and hydrogen is another factor that causes turbulent flow even in regions far from the leak, so appropriate modelling was introduced to account for this physical aspect. Fluent has a variety of models for turbulence. We used the k-ω SST model for this simulation. This method of turbulence resolution belongs to the family of URANS (unsteady Reynolds averaged Navier Stokes) models and is optimal among URANS models because it provides accurate values for many flow regimes. It is the most robust URANS turbulence model because it combines the k-ε and the k-ω standards: the former gives good results at a distance from solid walls (e.g. free jets) but loses accuracy near objects, whereas the k-ω standard provides a hybrid solution between k-ω and k-ε weighted by the distance from the wall. The k-ω prediction outweighs k-ε at proximity, and vice versa at distance. The merits of the two models are thus combined into one.
- **Isothermal**: heat exchange with any heat sources inside the aircraft or with the external environment is assumed to be negligible. The temperature is therefore constant at 15°C, while the surfaces defining the volume are adiabatic.

We used Fluent meshing to discretize the geometry. We paid special attention to mesh densification to accurately represent the complex hull surfaces and the very small size of the leak. We used a poly-hexcore mesh with multiple layers of prisms to accurately capture the velocity gradients present near the walls. The polyhedra provide a transition layer between the prisms and hexahedra.

The hexahedra fill the rest of the volume and are the main cell type in the analysis. We filled the volume with hexahedra instead of polyhedra and, simultaneously, we thickened the computational grid area in front of the fuel tank leak in order to minimize the numerical diffusion error and to optimize the accuracy of the calculations. A sensitivity analysis of the results with respect to the number of elements was conducted using different mesh sizes for the computational grid. A mesh of 4,634,968 cells provided values that were independent of the size of the computational grid and was therefore chosen to illustrate the results of the analysis.

CFD simulation of hydrogen dispersion

The results of the analysis show that the hydrogen jet emerging from the leak is limited in extent by the object situated in front of it. As the jet hits the surface of this object it shows an abrupt change in flow direction and a loss of momentum. As a result of the sharp reduction in the jet's inertia, buoyancy forces dominate the flow dynamics and tend to push the hydrogen into the upper region of the hull. Buoyancy also causes a recirculation zone below the tank. The speed of the hydrogen jet exiting the leak reduces sharply from a velocity of 1,102m/s to a velocity of 100m/s in a distance of 40cm. The hydrogen escaping the tank sets the surrounding air in motion, causing it to expand and simultaneously reduces the velocity of the jet. The reduction is very

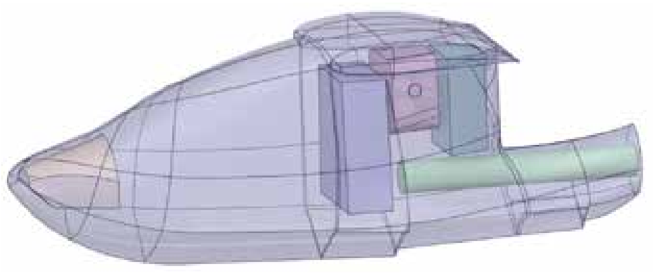

Fig.1. The Seagull's geometry with natural ventilation used for analysis.

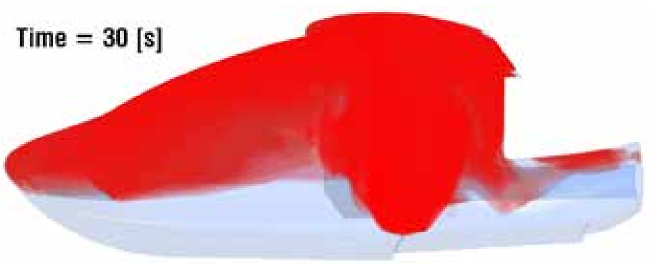

Fig.2. Combustion risk at instant t = 30, region s (natural ventilation case).

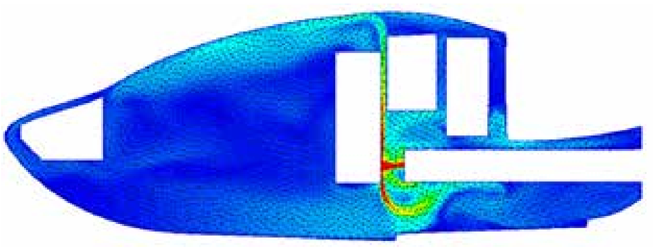

Fig.3. Velocity field in the plane of symmetry (scale limited to 2m/s) for the case with natural ventilation.

abrupt up to a distance of 10cm from the leak and then follows a linear law. The velocity field does not vary significantly over time but remains practically the same at different times, especially in the region of higher velocities, where the motion is caused by the jet.

Analysing the average mole fraction of hydrogen, we see that the concentration of the hydrogen gas increases significantly with time according to a linear law. In just over 5 seconds, it exceeds the target value of an average mole fraction of less than 1%. After 30 seconds, 4.8% of the gas in the cabin is hydrogen. At 2s the concentration is closely tied to the jet dynamics. In the subsequent instants, the hydrogen tends to occupy the upper region of the domain and then moves towards the front region of the fuselage. In the instants that follow, a progressive stratification is observed, with hydrogen also significantly occupying the lower region of the cabin. The results show that after 30s, approximately 70% of the cabin is at risk of combustion.

Risk analysis and mitigation

The results showed that the natural ventilation could not cope with the high flow of hydrogen into the cabin, leading to unacceptable conditions after a few seconds. It was therefore necessary to modify the scenario by considering forced ventilation.

In the new configuration, one of the surfaces that allowed the mixture to exit the domain was modelled as an inlet and the flow rate was set to simulate forced ventilation. Geometrical changes were also made to the initial analysis considering the tank provided by Novotech, modifying the layout of the internal bodies, and introducing baffles in the cabin. The new analysis was carried out in several steps:

- The variation in results with or without the baffles inside the aircraft was evaluated at a ventilation flow rate of 1,500m^3/h. Two different diameters for the ventilation inlet and outlet (160mm and 240mm) were tested for the different cases, as well as two different placements: a "front" placement between the two baffles and a "rear" placement behind both baffles. The diameters of the vents considered are larger than those previously defined for the natural ventilation to reduce the flow velocity in and out of the vents. The forced ventilation significantly improves the results compared to natural ventilation by allowing the average

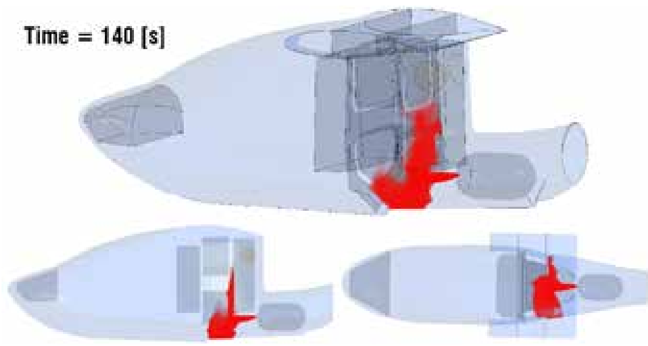

Fig.4. Combustion risk region after 140s with forced ventilation (Case D=240mm, and rear position).

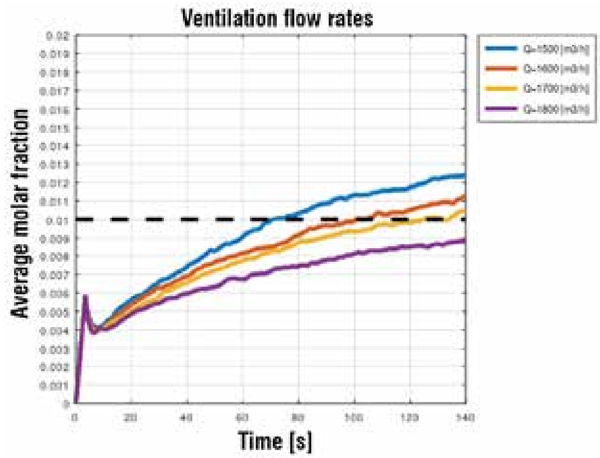

Fig.5. Average hydrogen concentration in the cabin at different forced ventilation flow rates.

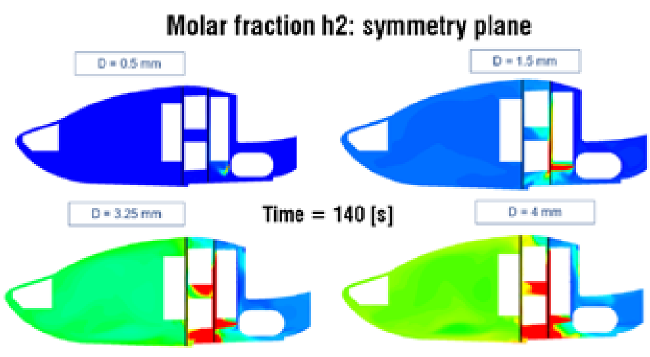

Fig.6. Hydrogen mole fraction for different leak sizes (forced ventilation).

hydrogen concentration to tend towards an asymptote after the initial increase. The area at risk of combustion also remains confined in a time-constrained space. Comparing the various cases, the baffles have a beneficial effect on the amount of flammable gas dispersed in the cabin. The best case achieved is a setup with baffles and a ventilation inlet/outlet diameter of 240mm in a rear placement position. This setup exceeds the target limit of 1% later than the other cases (79s) and remains below 1.2% at 140s. This geometric configuration will be considered for further work.

- The analysis performed in the previous step assumed that the ventilation was already active at the time of tank rupture. We then wanted to introduce a model into the analysis in which the ventilation only activated after a pair of sensors detected the hydrogen leak. The sensors were modelled as point detectors positioned close to the fuselage walls and mirrored with respect to the aircraft's plane of symmetry. Four different sensor placements were considered. Ventilation was activated at time instant t_v, given by the sum of the sensor leak detection time t_s and a system response delay Δt of 3s. The best position for the sensors was "B", which allows the ventilation to be activated after only 3.5s, thus preventing the concentration from exceeding 1% before ventilation intervenes. The results show that positioning the sensors in front of both baffles, as in case D, should be avoided. In this scenario, ventilation activation does not take place until one minute after the situation in the zone has deteriorated (the average hydrogen content is higher than 9%). Sensor position B is used for the rest of the activity.
- Once the geometry and position of the sensors had been determined, the minimum ventilation flow rate was assessed so that the average hydrogen concentration would always remain below 1%. A ventilation system with a flow rate of 1,800m³/h meets this criterion by keeping the value below 1%, even after a 30-minute time window.

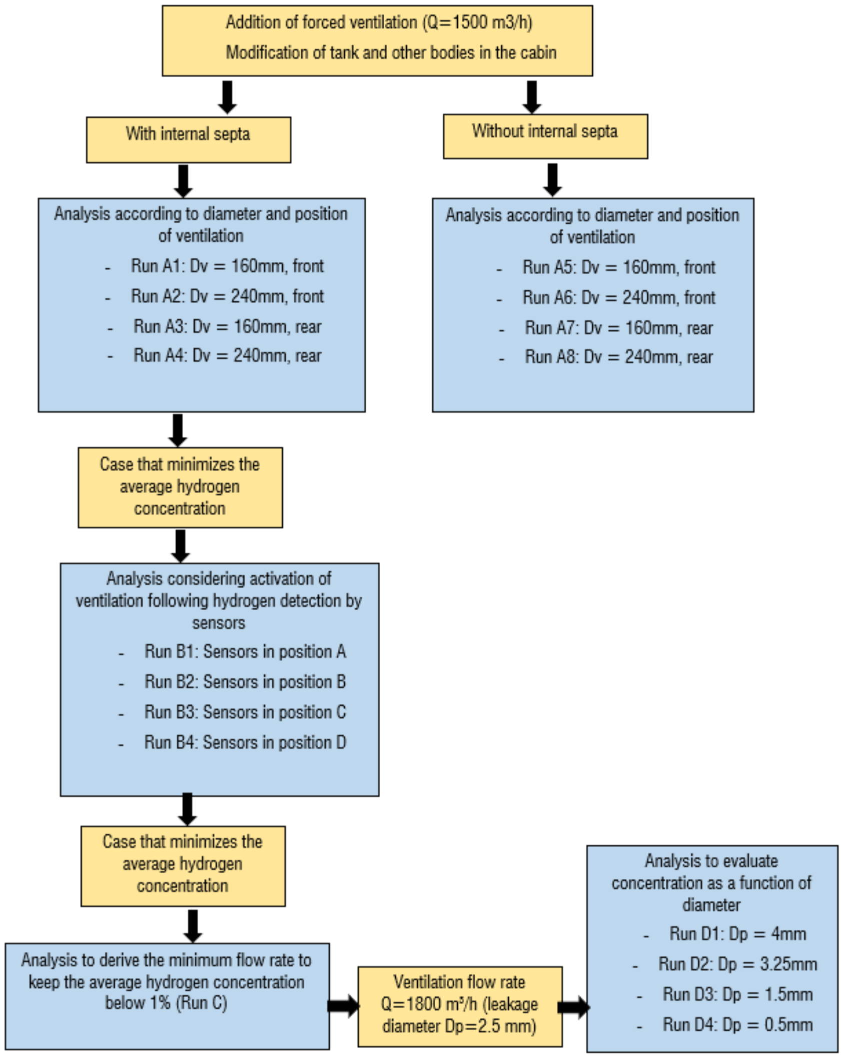

Fig.7. Logical scheme followed to carry out the simulations.

- After defining this new value for the ventilation flow rate, a sensitivity analysis was carried out by evaluating different hydrogen leak sizes, both larger and smaller than the nominal leak used (2.5mm)

A mesh of 4,634,968 cells provided values that were independent of the size of the computational grid and was therefore chosen to illustrate the results of the analysis.

Conclusion

The CFD analyses conducted assessed the risk of hydrogen leakage inside the Seagull cabin following the rupture of a gas fuel tank valve. The analysis of the case with natural ventilation showed that a large area was at risk of combustion after a few seconds. By switching to forced ventilation and following a strategy of optimizing ventilation geometry and sensor response times, it was possible to maintain a hydrogen concentration of less than 1% at a flow rate of 1,800m3/h. Lastly, a sensitivity analysis was carried out to compare the results for leaks with larger and smaller diameters.

Acknowledgement

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MINISTERO DELL'AMBIENTE E DELLA SICUREZZA ENERGETICA

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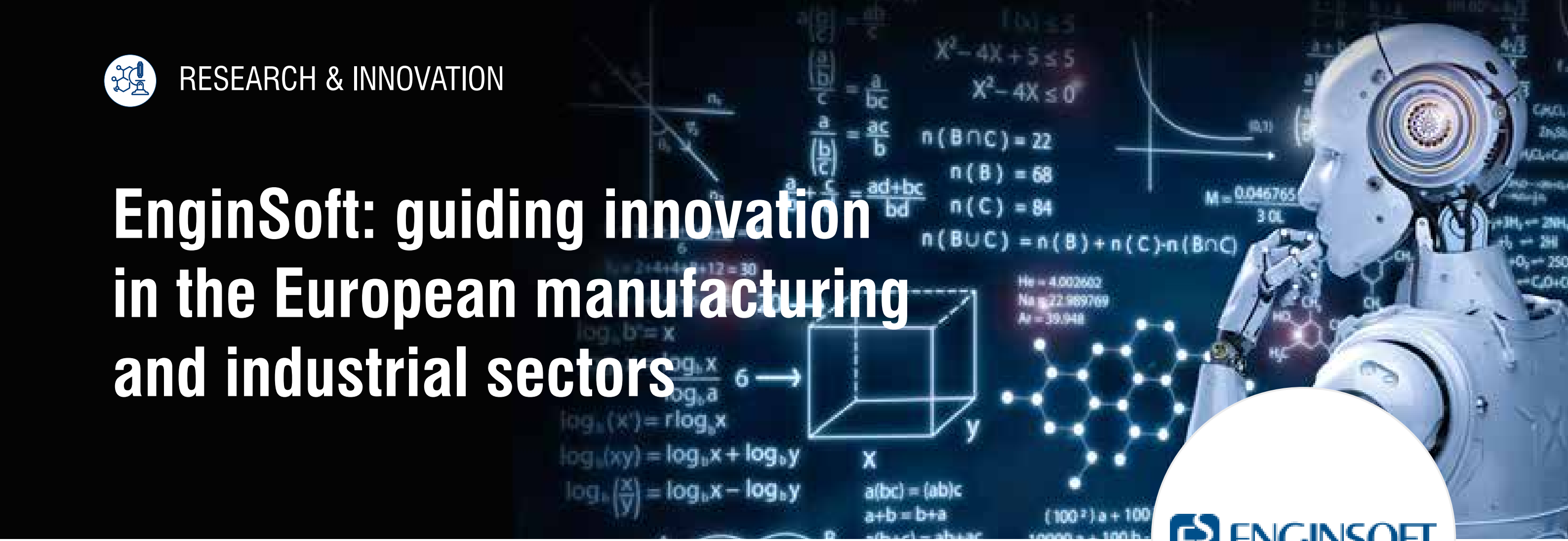

EnginSoft: guiding innovation in the European manufacturing and industrial sectors

During the course of its 40-plus-year history, EnginSoft has participated in a great number of European co-funded projects. What follows are three examples of EnginSoft's ability to focus on twin transition, namely the digitalization of production environments and the decarbonization of industry, and to apply its technical and numerical simulation skills to projects looking for efficiency optimization.

The **rEUman** project aims to improve sustainability and efficiency at both factory and value-chain levels. EnginSoft's contribution is three-fold: creating a digital tool suite to optimize factory setups, helping to identify the remanufacturing skill gaps, and launching the APRA Academy to train future professionals in the necessary competencies for the project solutions.

The **GeoS-TECHIS** project was created to decarbonize industrial thermal processes by introducing an innovative thermal system combining a high-temperature heat pump and a heat-driven cooling unit. EnginSoft is playing a key role in the project as coordinator, providing engineering services and simulation expertise across several work packages.

The goal of the **SHINE PV** project is to develop alternative technological pathways for advanced photovoltaic production. In this project, EnginSoft is providing its simulation expertise to virtually optimize and validate the project's performance.

rEUman

A digitally enhanced multi-level solution for smart human-centric remanufacturing

The rEUman project aims to improve European remanufacturing by developing a human-centred approach to remanufacturing, improving sustainability and efficiency at both factory and value-chain levels. The initiative focuses on creating systems that are human-safe, ensuring reduced risks and increased worker satisfaction, while improving the regeneration rates of remanufactured products. The approach is flexible enough to adapt to different product post-use conditions and is designed to be robust and replicable across different sectors.

The main objective of the project is to increase energy and material savings, thus contributing to a sustainable transition in Europe. In addition to environmental benefits, remanufacturing brings significant socio-economic benefits such as job creation, skills development and technological advancement. At the factory level, the key challenges are to ensure high regeneration rates of remanufactured products and traceability of the process, while at the value-chain level the focus is on maintaining stable volumes and product quality.

rEUman will demonstrate a new remanufacturing paradigm that incorporates innovative technologies, including digital product passports (DPP) for traceability. The approach will be applied in three sectors — automotive, home appliances, and optoelectronics — and will include the development of new business models and training materials for industry adoption.

As a partner in the project, EnginSoft is leading two key activities: creating a digital tool suite to optimize factory setups and identifying skills gaps in remanufacturing. EnginSoft is also playing a key role in setting up the APRA Academy to train future professionals in the skills required for the project's solutions.

By developing flexible, scalable, and secure solutions that address both operational challenges and the skills gap in the industry, the rEUman project aims to set new standards in remanufacturing.

This project received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101138930.

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GeoS-TECHIS:
Geothermal source thermal energy for cooling and heating in industries with steam

The GeoS-TECHIS project aims to decarbonize industrial thermal processes, which account for about 20% of global energy consumption and rely heavily on fossil fuels. By introducing an innovative thermal system combining a high-temperature heat pump and a heat-driven cooling unit, the project aims to reduce carbon emissions by 60–75% compared to current fossil fuel-based methods. The system uses geothermal resources as a heat source, sink, and storage and is targeted at industries that require heating below 200°C and cooling above 0°C.

Key initiatives include the development and field-testing of a versatile thermal system (R718) using water as the working medium, which can efficiently integrate geothermal sources, industrial excess heat and renewable energy such as solar thermal. The project also explores high-temperature thermal energy storage (TES) to improve operational flexibility and creates hybrid digital modelling tools to optimize industrial thermal processes and support decarbonization with customized roadmaps.

GeoS-TECHIS aligns with Europe's green transition goals and contributes to the EU's "Fit for 55" climate targets by integrating renewable energy, increasing efficiency and promoting the circular economy. It follows the European Commission's "Do No Significant Harm" principle, ensuring environmental sustainability, innovation and economic growth.

EnginSoft plays a key role in the project as coordinator, providing engineering services and simulation expertise across multiple work packages. These include project management, computational fluid dynamics (CFD) and exploitation to ensure effective project delivery, quality assurance and overall success. In addition, GeoS-TECHIS aims to boost public engagement by promoting transparency and community involvement, thereby increasing societal acceptance of geothermal energy solutions.

This project received funding from the European Union's Horizon Research and Innovation Programme under Grant Agreement No. 101172928

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SHINE PV:
Sustainable, high-throughput, industry-ready, next-generation technology for European manufacturing leadership in photovoltaic

The SHINE PV project aims to develop alternative technology pathways for advanced photovoltaic (PV) manufacturing, thereby increasing the competitiveness of European manufacturers in the global solar market. The project focuses on reducing production costs and improving solar cell efficiency through innovations in three key back-end manufacturing steps: metallization, post-processing, and interconnection. The goal is to increase solar cell efficiency by 0.5% in absolute terms, which translates into a 2% increase in module power, while reducing the cost of ownership (CoO) by 4–10%. This will be achieved by reducing material costs and increasing equipment productivity.

The project will investigate two solar cell technologies — heterojunction (SHJ) and tunnel oxide passivated contact (TOPCon) — and evaluate their synergies and differences. The project will demonstrate integrated manufacturing processes with a focus on high-volume production readiness. It will identify the most cost-effective and efficient production flows for these two technologies, with the aim of establishing a solid and sustainable European PV manufacturing capability.

The project will also develop and demonstrate complete back-end PV manufacturing lines, contributing to a more secure and resilient European solar energy sector. The aim is to establish a strong European base for PV innovation and production, thereby strengthening the sustainability of the PV value chain.

EnginSoft is playing a key role in the project, focusing on process integration, demonstration, and evaluation. EnginSoft will create simulation models of the SHJ and TOPCon processes to virtually optimize and validate their performance. The team will develop digital manufacturing models to demonstrate the equipment and production chains to further explore alternatives for improving efficiency and reducing costs in PV production.

This project received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement No. 101172902.

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The FFplus Project: A decade of enhancing the innovation potential of European SMEs

by Tina Crnigoj Marc
Arctur, FFplus Communication Lead

Building on the methods and achievements of the Fortissimo project series, FFplus, with a total budget of €30m, will continue to support and empower SMEs and start-ups to innovate. With more than a decade of history and a strong reputation in Europe, the Fortissimo projects (Fortissimo, Fortissimo 2, FF4EuroHPC) received a budget of €42.8m and successfully executed more than 130 experiments involving more than 300 partners. These efforts have resulted in 120 success stories from more than 20 EU countries where SMEs have used HPC (high performance computing) and AI to develop new products and services, boosting the EU economy.

Ahead of the launch of the second open call, we spoke to project coordinator Dr Bastian Koller, deputy director of the High-Performance Computing Centre Stuttgart, and open call lead Dr Guy Lonsdale, CEO of scapos, who gave us valuable insights into the world of Fortissimo.

Dr Bastian Koller

Dr Guy Lonsdale

The iconic Fortissimo project series has been running since 2014, spanning more than a decade. How did its success story begin?

Dr Bastian Koller: Well, at that time, the European Commission had increasingly focused on onboarding SMEs to HPC in order to increase the competitiveness of European SMEs. This opened up an opportunity and the University of Edinburgh's Supercomputing Centre (EPCC) took a leading role in bringing together the key players to manifest the Fortissimo concept in a first project. These key players already had good experience of working with industry, particularly SMEs, and of setting up and running open calls within projects.

What has made this series of projects so successful and effective that it continues to be funded after all these years?

Dr Bastian Koller: I would say the key words are "success stories". Since Fortissimo (I), the success stories speak for themselves and inspire the industry as well as the entire HPC landscape. Fortissimo has evolved to include success stories that demonstrate the benefits of an open call experiment in a way that industry can understand. At the same time, it has always been important to us to give the funding agencies something in return for the trust (not just money) they have placed in us. The Fortissimo series has thus become an important part of the EU's SME strategy.

The Fortissimo projects have had a profound impact on the adoption of HPC by European SMEs. How does FFplus build on this legacy and what new dimensions does it bring?

Dr Bastian Koller: FFplus is an evolution of the previous projects. On the one hand, it continues the classical path of business experiments with HPC, but at the same time it addresses the ever-growing need to make AI technologies usable for SMEs. As a result, for the first time, there are two tracks in the open calls: a classical one, which deals with the use of HPC as in the previous projects, and a new one, which uses generative AI to realize innovation studies for SMEs and start-ups using AI.

As coordinator of the FFplus and EUROCC2 projects, what are the main objectives of the collaboration among FFplus partners and the NCCs from 33 European countries?

Dr Bastian Koller: The classic saying is "do good and talk about it". However, this is easier said than done as the target groups of SMEs and start-ups are not always easy to reach. With the network of National Competence Centres (NCCs), EuroHPC has created a multiplier that ideally sits directly with SMEs and start-ups and can promote the FFplus opportunities (open call, funding, HPC, and AI) to them. At the same time, the NCCs can offer support to SMEs and start-ups, ranging from assistance in writing applications to help with onboarding to the EuroHPC systems.

How does FFplus contribute to the EU economy and innovation landscape?

Dr Bastian Koller: I see FFplus as a kind of accelerator. It speeds up processes without creating total dependency and, by supporting SMEs and start-ups, it unlocks potential that would otherwise be difficult for them to exploit. For the experimentation/innovation study partners, it is primarily about their business model, but at the same time we show similar SMEs and start-ups what is possible through the success stories. This can have a multiplier effect, making it clearer to companies that it is worth investing in this area.

What is your vision for the future of projects like Fortissimo and FFplus? How do you see them shaping the course of industrial digitalization and Europe's competitiveness on the global stage?

Dr Bastian Koller: Of course, I am biased and therefore say that projects like Fortissimo must always continue. After all, activities such as FFplus can provide targeted support to companies in order to exploit the full potential of technologies. In this way, Europe can gradually put its companies in a much better competitive position. At the same time, there is great potential for start-ups to become champions, especially in the field of AI, and get a quick boost from a programme like ours.

Looking at it from a more distant perspective, I see it the same way, but with the clear premise that it will continue to evolve based on the needs of the target groups. Even now, in FFplus, we are constantly learning from the experiments/innovation studies we have carried out: what was well planned/defined by us, what might still be missing, or what does not work as we had imagined. And yes, we can gradually improve this with open call 2 and 3. The open call system has been used in other projects in a similar way to FFplus, so our experience can help here too.

Let us take a closer look at the proposals selected in the first open call. What are the most common technologies used? Which sectors are leading the way? Are there any "hot topics" or key challenges that companies are particularly focused on? What about the EU countries? Are there certain countries that stand out as leaders in submitting proposals to the call?

Dr Guy Lonsdale: As mentioned, we have two types of proposals: using HPC to address any type of SME business challenge, and using HPC to develop or tune/adapt generative AI methods and tools. For the latter, we see a range of technologies and approaches, depending on a variety of specific application targets. But one of the striking things – and a change that gained momentum with the previous FF4EuroHPC project – is that the AI/ML topic is present in the majority of proposals selected in the first type of proposals. Where modelling and simulation play a key role, this is often combined with the use of AI/ML approaches or integrated in digital twins.

Regarding the "EU demographics" of proposal submissions and selection, while a small number of countries was particularly well represented in terms of the number of proposals submitted (I would like to highlight Germany, Italy, and Spain), we are proud to see that a large number of EuroHPC member states is represented in the set of sub-projects that will be implemented as a result of the first call.

SMEs often face technical and financial barriers to adopting HPC and AI. What are some of the key strategies FFplus is using to overcome these challenges and demonstrate tangible business benefits?

Dr Guy Lonsdale: The key approach of FFplus (and indeed Fortissimo in general) is to design the experiments or studies in terms of scope and timeframe to address a very specific business challenge. An open-ended research objective is not appropriate. Each of the sub-projects will receive funding that should be commensurate with achieving the objectives of the experiment/study. Obviously, it is not possible under FFplus to provide funding to SMEs to support their post-project exploitation path. As regards the provision of the necessary technical support, each business experiment or innovation study may comprise a small consortium where the technical competences of the SME are complemented by supporting partners bringing in the necessary technical expertise (whether in the targeted application area or in the key HPC/IT/software technology).

Are FFplus partners likely to use state-of-the-art EuroHPC JU systems for their business experiments and innovation studies?

Dr Guy Lonsdale: There is a slightly different answer to this question depending on the type of FFplus sub-project. For the business experiments, there is the opportunity to use leading-edge systems to explore the potential of using HPC to address their business challenges. The scale of the resources to be used may not be such that such a system would not otherwise be available, but the EuroHPC JU systems are provided free of charge, allowing the experiments to make the most of the budget provided by FFplus to address their business challenges. For the innovation studies, where the development of generative AI technology, such as the training of LLMs, requires extremely large resources, the EuroHPC JU systems represent a unique opportunity in Europe. The EuroHPC JU systems can be the vehicle through which the FFplus sub-projects generate their success stories, building the innovation potential of the participating SMEs and promoting HPC as an innovation vehicle for European industry as a whole and SMEs in particular.

About FFplus

FFplus builds on the methods and accomplishments of the Fortissimo project series, which have left an invaluable legacy in the European HPC and business landscapes. Starting with Fortissimo (2013-2016), Fortissimo 2 (2015-2018) and FF4EuroHPC (2020-2023), more than 130 experiments involving 330 partners have been executed, resulting in 120 success stories. The FFplus project will support and empower SMEs by addressing technical aspects, facilitating access to EuroHPC resources, and highlighting the adoption of HPC and AI for SMEs and Startups across Europe, showing the business benefits and impacts of adopting HPC and AI in real business models. Learn more: www.ffplus-project.eu

Data-driven digital twin and digital shadow applied to brazing, additive manufacturing, and welding

by Nicola Gramegna[1], Giovanni Paolo Borzi[1], Domenico Stocchi[2], Silvia Tiberi Vipraio[2], Alberto Chiarello[2]
1. EnginSoft - 2. Gruppo Ecor International

Digital transformation is making revolutionary history in industry. Industry 4.0 technologies are spreading at an unexpected pace and sectors are consolidating around areas where the necessary tools can be used more effectively thanks to processes that more easily capture data directly (automation, robotics, CNC machines, etc.).

Thermal process simulation is well known and used in many industries for tool design and product optimization. The results of process simulation usually remain in the CAE department, although some limited possibilities can be used on the production line, even if the process setup has also been optimized virtually. The simulation-based digital twin is a new approach to linking the physical domain with the reduced order model (ROM) to quickly gain benefits in the product life cycle.

In this context, there is a need to integrate the real world with digital models using an increasingly popular digital twin methodology. Real-world manufacturing data, collected from different sources, can be structured and developed using different approaches. This paper introduces and describes a data-driven Digital Twin (ddDT) and Digital Shadow (ddDS) approach where a web-based monitoring platform can be functionally tailored to industrial applications based on processes and data received in real time. Each industrial case presented in this paper has specific objectives, but all share common challenges represented by the requirement to manage real-time data to support human monitoring, traceability and decision making. The ddDTs and ddDS connected to the thermal metalworking system allow a continuous and just-in-time monitoring of the process and are a valid method to track the events and quality indices of the component to be produced. A machine learning approach integrating supervised or deep learning models can be applied to the acquired data set, extending the data analysis with advanced meta-models.

The AGILE and AMQ_TOOLS research projects applied the ddDS approach to brazing thermal treatments and manual welding processes, the ddDT to additive manufacturing L-PBF. In all these cases, the thermal process transforms metals by influencing their microstructure, quality, and mechanical performance. A common technological approach was implemented using virtualization and digitalization with monitoring, modelling, and simulation.

In addition, process results can depend not only on the machine involved and the process parameters, but also on human variables.

For example, an innovative augmented reality environment has been developed for the manual welding process to monitor the human process variables. This virtual industrial space allows the integration of the operational setup and human gestures, generating useful data to monitor, visualize and configure the process, to support the analysis and development of the most appropriate process parameters, and to support operator training. This demonstrates a new paradigm of Industry 5.0, in which digital technology is used to improve the skills of human resources.

Introduction

Differential equations are often used to describe the fundamentals of mathematical modelling of phenomena occurring in thermal processes. The finite difference method (FDM) and finite element method (FEM) solutions to differential equations are well known, well established and implemented in simulation tools using computational solutions managed by workstations and, in some cases, high performance computing (HPC).

Some challenges remain in the CAE modelling of time and materials to represent multi-scale transformations in thermo-mechanical processes. Recent advances in emerging topics in modelling and simulation of advanced thermal processes find fertile ground in the development of advanced modelling of innovative materials and processes. While these sometimes remain at the laboratory or pilot demonstration level, they capture a current context of strong digital transformation of the factory environment where these processes are actually used. This context creates the need to integrate the real world with digital models, using an increasingly prevalent digital shadow methodology.

This paper focuses on manufacturing and thermal processes, which are often an integral part of the production chain and which use thermal energy to transform matter and product into the designed object. Where analytical or differential equation solutions are available, using the reduced order model (ROM) for fast response, simulation-based digital twins can be used to study the evolutions of material to achieve maximum quality and performance. In parallel, the real monitoring data of the production processes and their correlation with the qualitative results measured in the field also constitute a wealth of information of considerable value when managed and processed by a monitoring system such as a data-driven digital shadow. The acquisition of large amounts of data, now possible thanks to the connectivity of Industry 4.0 machines, and its processing with machine learning (ML) algorithms, makes it possible to identify the impact of deviations in the process that can lead to defects and production inefficiencies.

Recent research carried out by EnginSoft and Ecor International on metalworking processes has focused on virtualization and digitalization through monitoring, modelling and simulation, techniques that have been developed and implemented to study different processes such as brazing, additive manufacturing, and manual laser welding.

A web-based platform called "smart prodactive", already used in Foundry4.0 and in plastic injection moulding, has been extended and applied to similar thermal processes.

The thermo-fluid dynamic simulation of a TAV heat treatment furnace, such as the brazing case study in the AGILE project, is certainly not new, but the data-driven digital shadow, based on advanced sensing and real-time data collection to track any deviations from the ideal setup, introduces an innovative solution that makes it possible to predict the impact of such deviations on the various parts inserted into the treatment grid of the entire batch.

An important transformation from melting to solidification of metal alloys occurs in the additive manufacturing L-PBF process, which is managed by increasingly powerful, automated and sensor-rich machines. The 3D printing process provides layer-by-layer temperature-time results depending on the laser path, power and speed, and the monitoring platform collects data from the machine and in-process sensors. Again, even small variations in the many process variables can affect the quality of the product, which is sometimes unstable and unrepeatable even with identical machine configurations. The same data-driven digital shadow platform used for the TAV oven was then connected to an EOS M290_OT machine as part of the activities foreseen in the AMQ_TOOLS project supported by HubCup.

It is not always easy to monitor the process variables of a manufacturing process, especially when the human-machine combination is critical. This was the case for the manual welding cell, digitized by tags on the operator's hands, used in the AGILE and SMACT projects, where monitoring via a VR system is synchronized with the laser source signals and the operator's execution times.

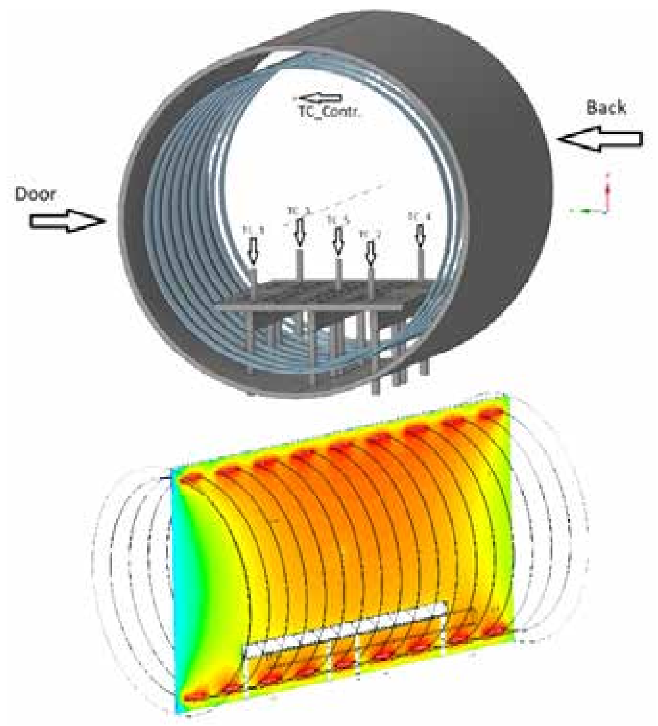

Fig.1. Diagram of the digital platform and its integration into the production line.

Fig.2. Diagram of the digital platform and its integration into the production line.

All this is integrated into a digital shadow platform that processes the data and provides the right information to support decisions. This benefit is further enhanced by the tracking of welding processes, which are highly operator-dependent.

The optimal paths can now be used as best practice to standardize and plan the training of new resources.

Digital Shadow Case Studies

Case study 1: Brazing furnace monitoring and simulation

Brazing is a well-known technological process for joining two or more materials by melting and adding a filler metal, called braze, which is a eutectic alloy that melts at a lower temperature. The feedthrough is a special type of electrical capacitor consisting of conductive elements (copper/steel) and other insulating elements (typically ceramics). As with any mass production, quality control is a very laborious task and does not always understand the causes of defects. A possible improvement could be achieved by fully tracking the processed parts to identify process variations that could cause defects in individual parts.

The first step towards digitalization was the creation of a virtual study of the oven which made it possible to identify the furnace zones of maximum efficiency and stability, both in a steady state (static) and transient (dynamic) situation (Fig.1). The CFD modelling of a TAV oven now makes it possible to analyse the different usage scenarios with even the smallest deviations and allows the possible creation of reduced order models (ROMs), useful for a future simulation-based digital twin. The static and dynamic simulations confirm the temperature uniformity in the oven, suggesting the study of possible deviations in the positioning matrix and in the geometric conformity of the assembly.

The FEM study contributes to the important goal of moving from traditional methods to a virtual approach where information can be managed in an integrated way. The availability of a predictive simulation tool increases the agility and speed of the design phase, for example for new products. To be competitive, it is necessary to know how to innovate the product quickly and adapt the production system accordingly. The tool can also support decision making.

In this case, given the efficiency of the furnace, a different approach was taken and implemented with a data-driven digital shadow that collects process data in real time via the OPC-UA protocol to create a control optimization algorithm, predictive data-driven control of the model, robust/optimal control, and a decision support system. This integrated quality-process management system is designed to manage both thermal data with possible historical processing and quality data from process controls in a single system (Fig.2).

The GUI integrates process data (pressures, temperatures, etc.) with production data (batches, product codes, etc.) and with quality data. The database allows searches and extractions to identify any problems in the process.

It is only with this information can that we can talk about process control and monitoring, component traceability, and the implementation of improvement actions to reduce waste (towards zero waste). The system developed allows an in-depth analysis of quality data and the production of a report with detailed process tracking.

As part of the quality study for the digital platform, quality and functionality analyses were performed on each component of the experimental campaigns. The tests were all non-destructive due to the small number of defects found and consisted of visual inspection, tomography, optical scanning, CMM inspection, and a leak test.

The measurement campaigns also included the analysis of a number of specimens with varying degrees of weld defect to which a specific misalignment (concentricity) value was assigned. A correlation analysis was then carried out between these two aspects. Preliminary information confirmed a relationship between the degree of defect in the components and the misalignment between the components of the assembly.

Optimization of the mathematical model using physical parameters, vacuum temperature laws and dynamic regimes under both static and dynamic conditions results in a good agreement with the experimental data.

As part of the agility concept, the main objective was to monitor, track and intelligently manage process data (part position, reference times compared to recorded times for each individual process, cell availability, tracking of any criticality and its resolution) with the digital platform.

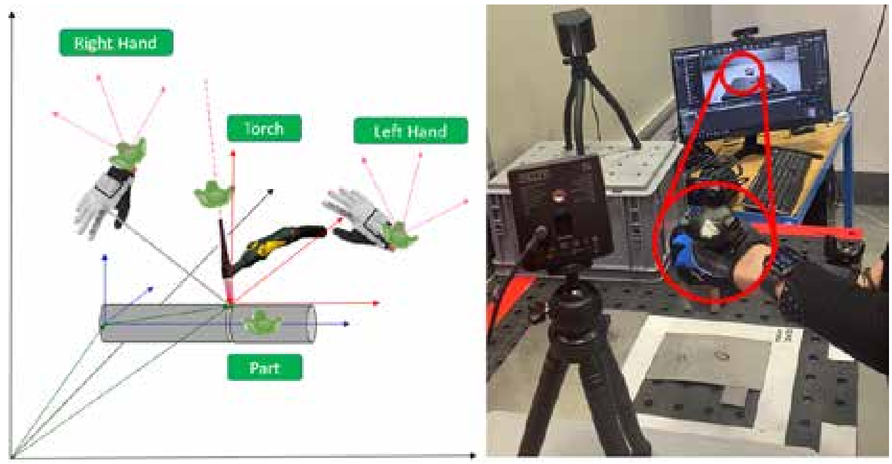

Fig.3. Human sensors for manual welding and system configuration.

Remote management of the system and design has been achieved, minimizing low-value human activities. The platform makes it possible to digitize and integrate quality data to perform searches and extracts to identify any problems in the process.

Case study 2: Virtualization and data management of the manual welding process

Controlling processes that are affected by direct human interaction, such as the manual welding process, can have a significant impact on continuous improvement by reducing defects. Predicting quality and controlling the joining process can greatly influence production efficiency, process repeatability and the reduction of production costs towards a "zero defect" approach.

Product development mainly involves the pre-assembly of the parts to be welded, spot welding, and then in manual Tungsten Inert Gas (TIG) welding of the joints. NDT and visual inspection are used for quality control and defects are classified into porosity, slag inclusions, bite edge, weld pit and linear defects such as incomplete penetration, incomplete fusion, etc. The quality problems encountered were related to process variables such as welding voltage, welding current, wire feed rate, welding speed, and bevel angle. A second set of process parameters were identified as human process variables. (Industry has shown that different technicians using the same set of parameters and welding procedure specifications (WPS) to produce the same specific part can produce results of varying quality.)

The method designed and developed to design and digitalize the manual welding process aims to create a mixed reality-oriented digital shadow (MR-DS) framework to detect defects and configure the process according to the most appropriate parameters.

Motion capture (MOCAP) was used to monitor the welding process. This system allows real-time monitoring and subsequent data storage. It was equipped with two cameras for a complete welding plate scenario. Trackers in wearable gloves and on the forearms of the operators tracked all their movements to detect the manual dexterity of the welders.

The same types of sensors are also found on the weld part, torch, and worktable. An offset was added to centre the table tracker. Details of the organization of the equipment to generate the virtual welder are shown in Fig.3, along with details of the sensors to capture the spatial variables of the entire welding environment. The complete set of variables monitored is reported in Table 1.

Data from the welding station is fed into a unique data management system (DMS). It is exchanged between the Unreal Engine tool and the data logger. Data from the physical and virtual systems needs to be stored and processed in the communication layer (Fig.4).

Item instrumented	Parameter monitored	Associated functionality
Welding unit	Current	Influence on seam heat input
Welding unit	Voltage	Influence on seam heat input
Right and left hand	3 translations and 3 rotation angles	Manual dexterity of the operator
Fingers	3 rotations for each finger	Manual dexterity of the operator
Welding torch	3 translations and 3 rotations	Management of the torch during welding
Welded part	3 translations and 3 rotations	Spatial position of the piece
Welding table	Reference plane	-

Table 1 – Set of parameters monitored to develop the virtual model.

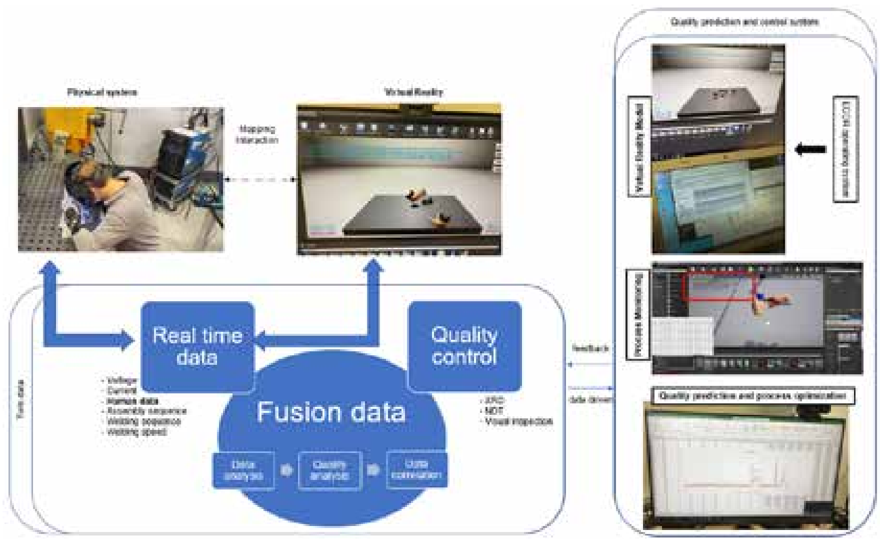

Fig.4. Digital Shadow model to predict and control manual welding quality.

Internet of Things (IoT) technology enables interactions between different layers of embedded systems for real-time data transfer. The IoT provides bi-directional synchronization of physical and virtual systems, providing data for virtual system updates. Real-time control commands are executed based on the past and present state of the physical system to ensure the consistency of the manufacturing process and the quality of the manufactured parts [1].

The main objective of the research is to improve the efficiency of the process by monitoring and controlling its variables in real time, and to achieve better and more consistent product quality. This will be achieved through a dynamic industrial virtual reality scenario in which the simulation will replicate the main variables of the production process. All the variables collected (big data) will be processed by a digital software platform.

The interaction between the physical entity and the hybrid twin data model is actually managed by a software structure and the process technologist and welding operator who distribute the sensor data represented by the welding process database. The tool used for this specific purpose is an intelligent cloud platform specifically integrated with the Enterprise Resource Planning (ERP) system.

The digital tool allows the process to be monitored in real time. Its configuration can support comparative analysis of the reference process and the current welding phase: quality data for each welding phase is stored to ensure process traceability of parameters and time-space variables. Prediction of process quality is then obtained by processing and analysing large amounts of data, which the platform supports by refining the pass/fail criteria.

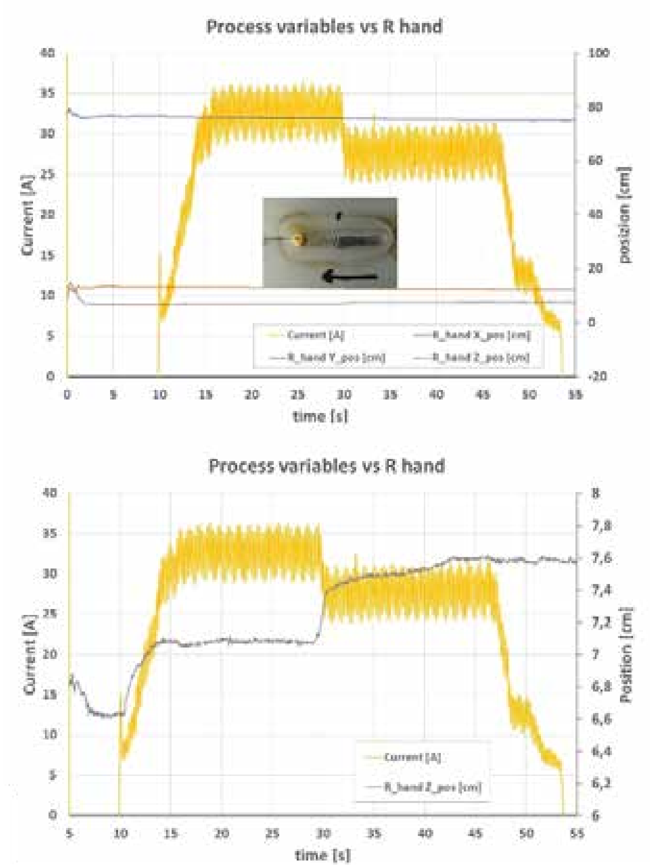

Fig.5. Reduction in bead size due to movement of torch hand in z-direction.

There was a good correlation between the data and the real conditions in terms of physical changes being reflected in the virtual system. Fault detection and validation of the sensor data was carried out by inducing faults to assess both the ability of the virtual system to adapt to changes in the real environment and to measure its sensitivity.

Fig.5 shows the monitored data output (current, voltage, z-displacement of the torch hand) after the operator induced a reduction in the seam size. The operator's movement caused a z-displacement of 6mm, which is perfectly acceptable in the range of potential errors during welding.

The digital shadow is a digitalized, data-based system for smart decision making and quality forecasting. Once data from different part number jobs has been imported into the digital platform, the correlation between the influencing variables of the physical unit and the virtual model can be efficiently analysed for real-time information analysis and decision making.

The research framework is fully integrated into the Industry5.0 model. The (human) technician of the welding unit (the industrial machine) and the virtual machine work together with the common goal of improving industrial production efficiency and operator skills.

The training of human resources is managed by the data-based platform. The entire production team (consisting of the welding operator, welding engineer, and process technologist) is then involved in interactive upskilling sessions via virtual on-the-job training. Predictive quality can be achieved through the benchmarking phase for data-driven decisions.

In addition, young welders or engineers can be kept up to date through virtual training sessions that implement distance learning on real industrial cases. Instruction is provided through safe training that avoids exposing workers to unnecessary problems during these phases [4].

Traceability of process quality is ensured by the availability of data that can be analysed and processed efficiently and intelligently by the data platform. The data analysis experience has been greatly improved by the implementation of a customized tool for industrial welding.

A new concept of human efficiency and productivity is being developed. Skills are the driver of business productivity. Human resources are directly involved in improvement activities through the support of innovative digital technologies, and this can create a virtuous circle of engagement [5].

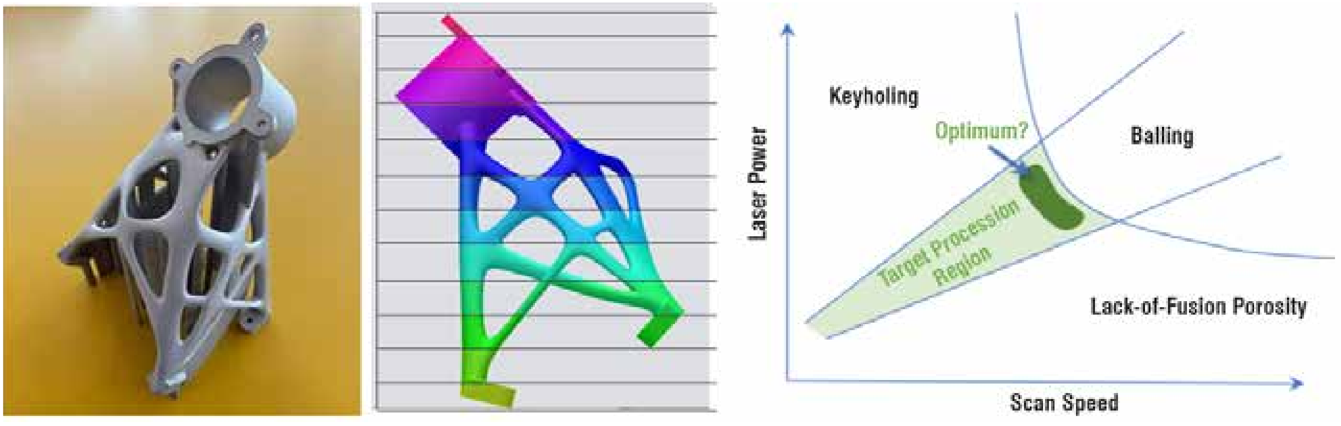

Fig.6. Final demonstrator with scan plan and typical AM defects with optimal setup.

Environmental control through smart, networked, and customized sensors that work together to provide a real-time picture of the industrial scenario from different angles. In the search for sustainable processes, the aim is to reduce production time and minimize material and energy wastage in re-manufacturing by minimizing defects resulting from poor production quality control. Corrective and preventive actions can be implemented by using the digital tool in the process optimization phases.

It also has a major impact on the productivity and business efficiency of the entire production system, as the process can be adjusted based on the direct results of the quality checks.

Digital twin case study

Case study 3: Monitoring and data management of the additive printing process

Metal additive manufacturing (AM) is a complex process that requires the fine-tuning of hundreds of process parameters to achieve repeatability and good design quality at the dimensional, geometric and structural levels. Among the key technology challenges, many recent reports have highlighted the need to achieve intelligent metal AM process control so to ensure quality, consistency, and reproducibility across AM machines.

A huge amount of data can be collected in metal AM processes, as most industrial AM systems are equipped with sensors that provide log signals, images, and videos. However, there are no consolidated solutions in industrial practice capable of analysing this data in real time for quality control. The HUBCAP programme (www.hubcap.eu) aims to develop and promote European cyber-physical systems (CPS) technology. Within this programme, the AMQ_TOOLS (additive manufacturing quality and monitoring control system) project developed a platform for technology providers and users to collaborate and access tools and services for model-based design (MBD) of CPS.

In particular, the validated quality control methodology consists of the combination of a) a model-based tool that adapts the design for additive manufacturing (DfAM) using a process simulation software solution (Ansys Additive Suite) based on technical and quality requirements (Fig.6) and b) a cyber-physical system that connects the EOS M290 machine with newly developed process monitoring software to control the quality of the parts during the printing phase.

The four key parameters, namely laser scanning speed (LSS), laser power (LP), hatch distance (HD), and layer thickness (LT), are directly related to the energy transferred to the powder bed, expressed as volumetric energy density (VED), by the equation:

$$\mathbf{VED} = \frac{\mathrm{LP}}{\mathrm{LSS} * \mathrm{HD} * \mathrm{LT}}$$

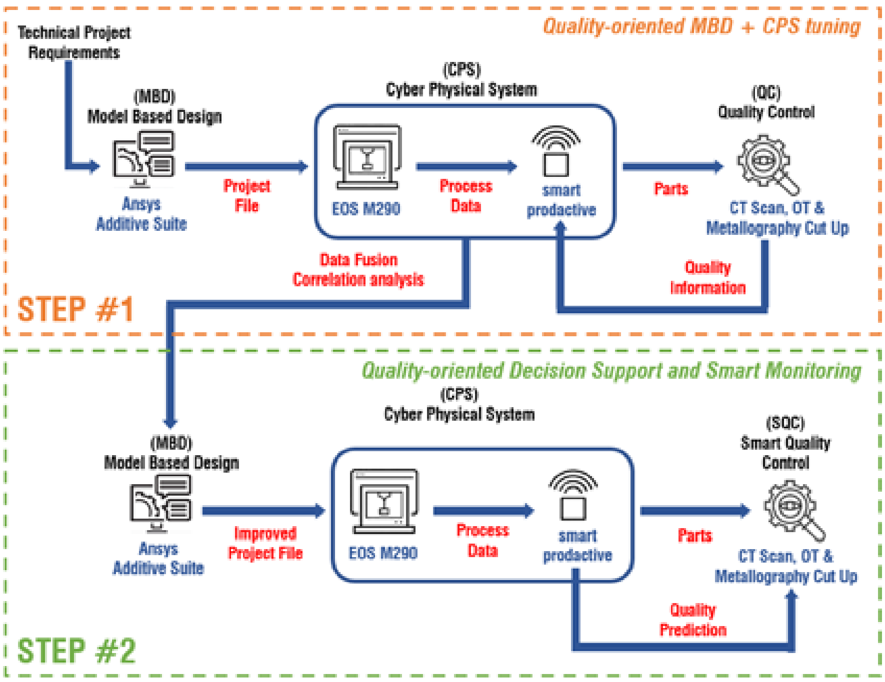

Fig.7. Quality-oriented approach with MBD and CPS tuning.

The VED is related to the measured density studied during the experiments.

Quality control in additive manufacturing involves a decision support framework that integrates a design for AM (DfAM) with the digital platform that connects AM machines (in this case an EOS M290) with quality assurance requirements and quality control data.

smart prodactive is a fully integrated system that links production processes with data sources (machines, sensors, HMIs) and uses traceability information to correlate this data with output quality. smart prodactive thus enables intelligent monitoring of additive manufacturing processes by applying quality-oriented predictive models and machine learning algorithms in real time. These models predict defects by category, area and quality. Process simulation identifies macro-scale defects, while advanced modelling with real-time process data is used to analyse, model, and predict meso- and micro-scale defects.

The overall solution proposed is based on a two-step methodology (Fig.7):

- **Step 1:** Defects are categorized and a catalogue is created. An MBD tool then translates the technical requirements into part geometry, machine and process parameters to identify defect risks. The AM process then starts and the CPS collects the process data. The OT and CT scan collects the quality information and links it to the relevant process step, batch and part number.
- **Step 2:** Process parameter optimization is applied to provide decision support for part and process design. The detailed information generated by the CPS is integrated into the MBD to define quality-oriented product and process design practices. The AM process is initiated, and data is collected and the model estimates quality compliance in real time.

The quality-focused AM solution supports quality compliance by estimating the real-time impact of:

- Monitoring DMQ (maximum density achieved/target density) quality improvement during the print phase.
- Reducing lead time by up to 20% using online quality process monitoring to reduce the number of the quality checks.
- Minimizing design complexity using simulation tools to validate process set-up.

Uses cases referenced

The use cases described are the results of the recent research projects AGILE (funded by the Veneto Region through the POR-FESR 2014-2020 programme), AMQ_TOOLS (funded by the HUBCUP programme), and the EFFIMEC – "Sistemi di produzione ad alta efficienza per componentistica meccanica speciale" (or high-efficiency production systems for special mechanical components) project funded by IT MIMIT within the framework of the "Accordi per l'Innovazione – 2019" (or innovation agreements).

Acknowledgements

The authors would like to thank Dr Shahram Roshanpour for his valuable contribution to the brazing furnace modelling research, which has significatively improved the depth and quality of this research by contributing to the availability of an industrial tool for the efficient optimization of the brazing process. We would also like to express our appreciation to the dedicated teams from the companies who provided unwavering support and direct involvement in all the research activities.

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About Ecor International

Ecor International is a reference company for the manufacturing of highly functional components made of steel, aluminium, titanium and special alloys for the food packaging, pharma, advanced mechanics, aerospace and defence sectors.

Guided by the awareness that innovation represents the strategic value to increase the company's competitiveness in current and future markets, its business model is now oriented towards the world of applied industrial research.

Advanced materials and advanced (digital) production technologies are the strategic guidelines for maintaining competitive technological industrial standards.

Workflow for blood flow simulation in Ansys Fluent

by Ji Won Kim
Tae Sung S&E

In many industries, product design, stability evaluation and experimental processes are often costly and time consuming. Consequently, there is a growing tendency to use virtual environments to create desired experimental settings and achieve targeted outcomes. There is an increasing interest in using these tools even in areas where simulation has not been widely adopted. The biomedical sector is a notable example of this trend, with growing demand for simulations such as blood flow analysis and implant evaluations based on patient CT data. By comparing simulation results with clinical outcome data, these analyses improve safety assessments and structural performance evaluations. In this article, we present a workflow from vascular modelling to blood flow analysis using 3D Slicer and Ansys Fluent, showing how these tools contribute to advancing the biomedical industry.

The integration of simulation technologies is a key trend in today's business environment, driven by the growing demand from the biomedical sector for blood flow analysis based on patient CT data. This analysis provides a new approach to assessing the structural performance and stability of vascular stenosis, artificial blood vessels, and other related conditions. The convergence of fluid dynamics and medical research is facilitated by advancements in CT and MRI imaging, which now allow internal structures to be visualized in 3D.

Blood flow analysis is increasingly being used to investigate the causes of vascular diseases by analysing hemodynamic characteristics. Additionally, non-invasive methods for diagnosing and assessing a patient's blood vessels are gaining attention. This article explores vascular modelling techniques using the main software tools for blood flow analysis, focusing on vascular extraction methods, blood material properties, and boundary condition settings.

Pre-processing

Modelling based on 3D CT images of the aortic vessel

The Ansys modelling tools currently do not provide the ability to directly extract 3D CT images of patients directly into STL files. Therefore, we used commercial software called 3D Slicer for this article. 3D Slicer is an open source software platform for visualizing and analysing medical imaging data. It is professional medical imaging software with comprehensive image analysis, 3D modelling and design, and 3D structure extraction from DICOM files.

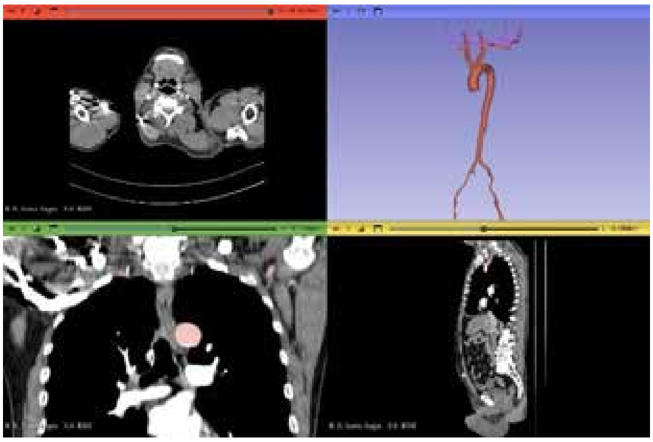

Fig.1. Extraction of blood vessels from a CT scan in 3D slicer.

As shown in Fig.1, the process of extracting blood vessels with 3D Slicer requires the administration of a contrast agent during the CT scan to enhance the visibility, calculated in Hounsfield Units (HU), of the vascular structures. This makes it easy to extract vessels within a specified HU range. Smoothing options can also be applied to the facets during the modelling process to refine the geometry before generating a mesh for flow analysis. Once the vessel modelling is complete, the DICOM files are converted to STL format.

Modelling with SpaceClaim

When you import a converted STL file into Ansys SpaceClaim, you can inspect the facets of the model. The next step is to convert these facets into volumetric shapes. However, as shown in Fig.2, some areas of the model, such as protrusions and open facets, can make this transformation difficult.

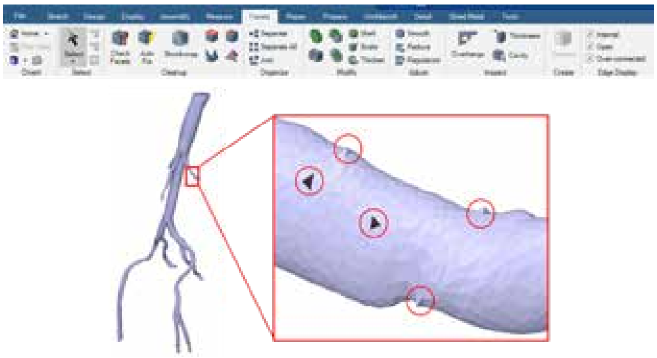

Fig.2. Faulty facet areas.

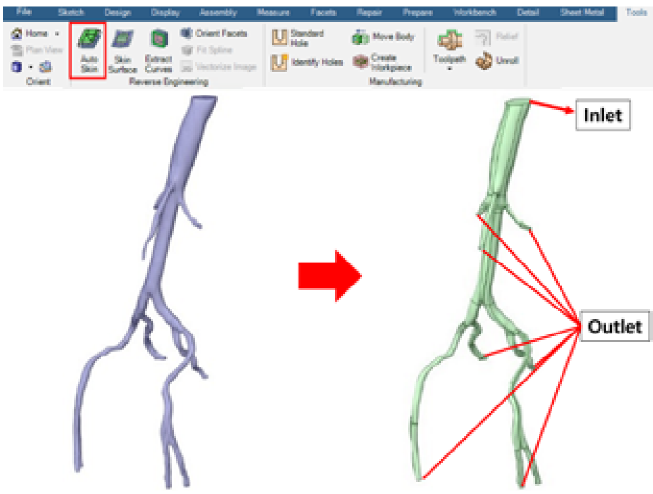

Fig.3. Converting from facets to volumetric shapes.

Ansys SpaceClaim's automatic clean-up functions, located on the Facet tab, solve these problems by refining the model. Next, select Tools - Auto Skin to convert the model into a volumetric shape, as shown in Fig.3. This correctly prepares the model for mesh generation.

Solve

Blood properties

This study used Ansys Fluent to analyse the blood flow. To numerically simulate blood flow, we need to specify the density and viscosity coefficient of the blood. Since blood is a non-Newtonian

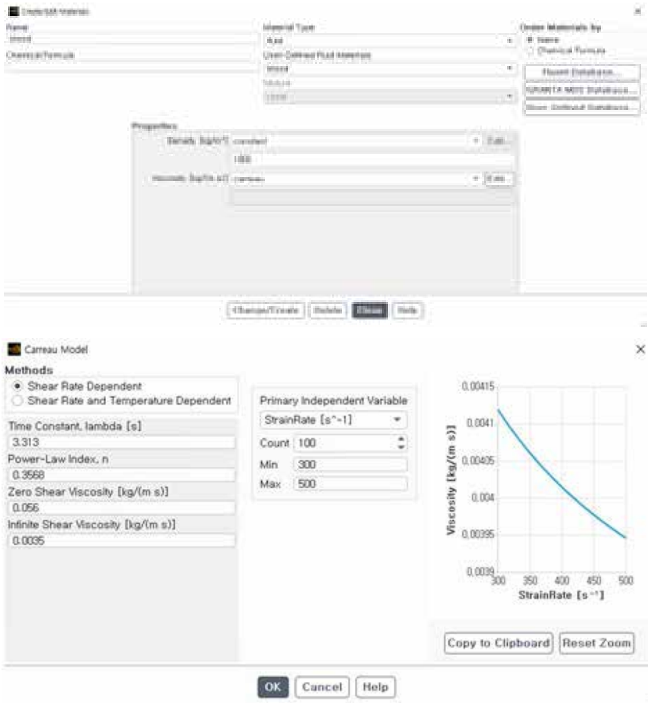

Fig.4. Blood properties.

fluid, its viscosity varies depending on the shear stress. To accurately represent this flow, we used the Carreau model, which is known to effectively describe the viscous properties of non-Newtonian fluids. Carreau's model is the constitutive equation that defines the viscous behaviour of these fluids and is calculated as shown in Equation 1.

$$\eta = \eta_\infty + (\eta_0 - \eta_\infty)[1 + (\lambda\dot{\gamma})^2]^{\frac{n-1}{2}}$$

Equation 1. Carreau Model

Ansys Fluent displays the Enter Properties tab for blood (see Fig.4). The density is set to 1,060kg/m^3 and the viscosity model is converted to the Carreau model. The parameters of the Carreau Model are applied according to the values found in the relevant research papers.

Boundary conditions

The inflow (velocity) and outflow (pressure) conditions of the blood flow are defined. A pulse velocity profile is applied to the time-dependent inflow conditions using an expression (see Fig.5).

Defining the initial pressure conditions is difficult due to the complexity of real physiological phenomena, but remains one of the most important factors. In this study we used an average blood pressure of 13,332Pa.

Iteration setting

The total simulation time for the specified phenomenon is set to one second. As shown in Fig.6, the Run Calculation settings are configured to 200-time steps with a time-step size of 0.005 seconds.

Fig.7 shows the blood flow velocity and wall shear stress (WSS) on the vessel walls once the simulation is complete. Blood flow velocity

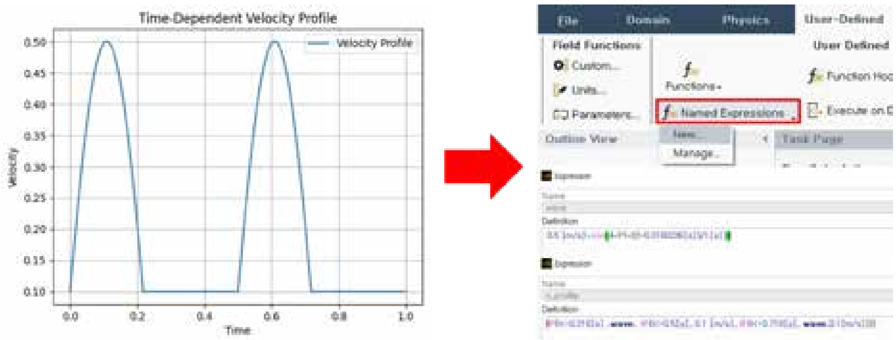

Fig.5. Boundary conditions.

and wall shear stress vary depending on the vessel's cross-sectional area. Additionally, in regions with relatively high velocity distribution, the shear stress acting on the vessel walls increases, potentially affecting the vascular structure.

As shown in this example, blood flow analysis can help assess the hemodynamic characteristics in stenotic vessels, which are the primary focus of these studies. This analysis can provide insights into whether vascular interventions, such as angioplasty or stent placement, may be necessary for the stenotic region.

Conclusion

This article presented a workflow for blood flow analysis using Ansys Fluent together with a vascular modelling tool such as 3D Slicer.

CT-based 3D modelling and simulation demonstrates the effectiveness of numerical analysis in medical applications. As shown in this study, numerical simulations can be used in the biomedical industry (including medical device development and clinical medicine) to optimize the design of medical devices by considering various design parameters and integrating limited data from clinical trials.

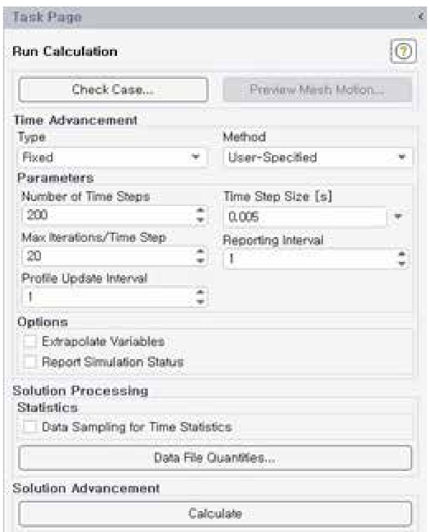

Fig.6. Iteration setting.

Simulation results can also be used to develop personalized treatment plans based on a patient's unique vessel geometry and degree of stenosis. Further research is needed to improve the accuracy and reliability of blood flow analysis through validation and calibration studies. We look forward to future developments and successful case studies in this area, illustrating the potential applications of blood flow analysis in the biomedical field.

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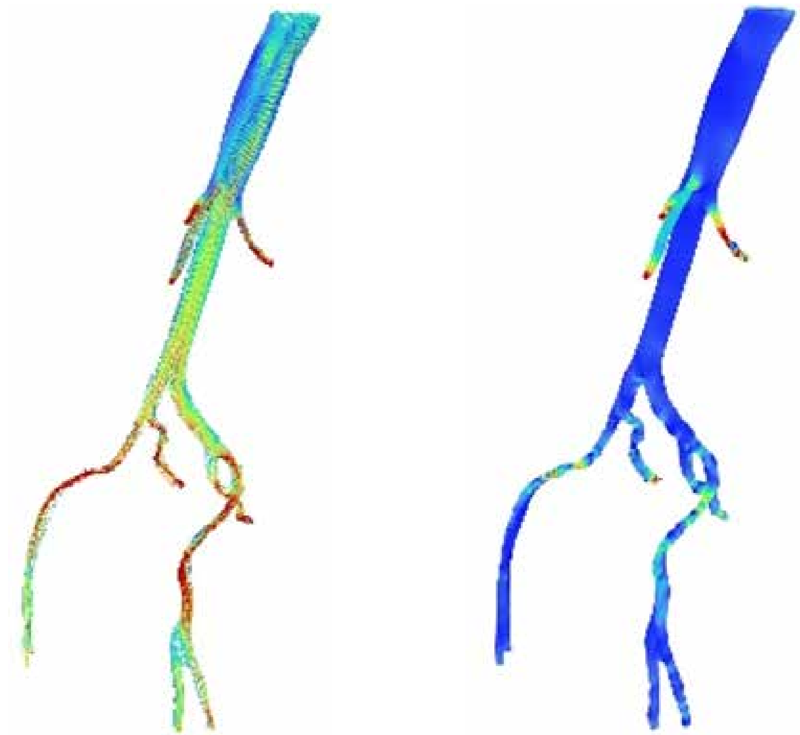
Fig.7. Blood flow velocity and wall shear stress results.

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ECM Technologies reduces installation and commissioning time by 50% using digital twin technology

Virtual commissioning and parallel work streamline automotive heat treatment plant timeline with Emulate3D software in industrial processes virtual environment: reproduction of real road and off-road conditions.

by Arianna Locatelli
Rockwell Automation

By integrating digital twin technology with advanced process simulation and visualization software, ECM Technologies has found a way to significantly simplify the design, installation, and commissioning of large-scale heat treatment facilities for the automotive industry.

Through the use of Emulate3D software, ECM Technologies, a world leader in the design and manufacture of innovative and modular low-pressure carburizing industrial furnaces, has developed a solution that eliminates many of the traditional installation and commissioning challenges associated with the design, testing and deployment of large-scale heat treatment facilities.

The challenge: complexity of heat treatment at scale

Heat treatment is a complex, multi-stage process with many variables that must be precisely controlled to ensure product quality and consistency. ECM Technologies specializes in low-pressure carburizing, a process that infuses steel with carbon to increase its wear resistance and fatigue strength. The company's vacuum process allows operators to control the diffusion of carbon into the metal by managing several variables, including the duration of each stage and the critical vacuum pressure.

Christian Dugit-Pinat, Automation Expert at ECM Technologies, explains: "There are several steps in the process. The parts are washed, heat treated, and carburized in a vacuum, a process that can take up to six hours. They are then rapidly cooled by gas or oil quenching, followed by tempering and final machining. The total process time for a typical automotive gearbox component is between ten and 13 hours."

"Our heat treatment facilities are of multi-chamber design," continues Dugit-Pinat. "This allows us to process several parts in parallel, each often with its own unique heat treatment recipe, with between 50 and 80 loads moving through the line at any one time. Each load must be individually controlled to ensure the highest quality."

The solution: virtualization and digital twins

Modern automation systems can efficiently manage heat treatment facilities within optimized parameters, but the design, installation, and commissioning process presents unique challenges that often become apparent during the start-up phase. To address these issues, ECM Technologies turned to digital twin technology.

Philippe Reymond, Project Manager at ECM Technologies, explains, "When we were asked to install one of our ICBP Jumbo vacuum carburizing systems at a large automotive plant in Mexico, we were faced with additional challenges. Not only did we need to get production up and running quickly, but the customer also required us to use their software standard, which meant rewriting our existing code. Given the complexity and tight timeline, we knew we had to find a way to streamline the project and speed up the implementation."

The company decided to use Rockwell Automation's Emulate3D software to run some simulations and optimize the design before physical installation. "By using virtualized models, we were able to test and fine-tune the PLC code in parallel with production, saving a significant amount of time," adds Reymond.

The software's ability to integrate with other systems, such as MATLAB for thermodynamics and process physics simulations, made it an ideal solution for ECM Technologies' needs. "We were able to simulate the mechanical design while simultaneously taking into account other critical factors such as process flows and thermodynamics," explains Reymond.

The results: significant time and cost savings

Using Emulate3D, ECM Technologies was able to fine tune and finalize much of its PLC code before the line was delivered. The company estimates that by debugging the code in parallel with production — rather than after installation — it saved up to five months of lead time on the ICBP Jumbo project.

"We completed a similar installation seven years ago without the aid of Emulate3D or other Rockwell Automation control solutions, and although the software used was our own, the project was still very complex," adds Reymond. "However, this new project was not only delivered on time, but we also reduced the commissioning time by 50%. Even though we were using the customer's code, we were able to complete this second project more quickly. Fewer on-site meetings also meant less travel to and from North America."

ECM Technologies has since received a follow-up order from the customer and has been asked about other opportunities. "The customer was impressed with the speed of the installation and commissioning," says Reymond. "We are now looking to use Emulate3D on other projects, three of which are currently underway, and we will continue to implement digital twins as part of our internal procedures."

Looking ahead: streamlining more projects with digital twins

Reymond concludes, "Virtualizing our projects has allowed us to manage multiple projects simultaneously, thanks to the quality and speed of the output. By spending less time at a client's site, we have reduced the pressure on the team and eliminated many of the stress points traditionally associated with on-site work. We are also much more confident about meeting deadlines. When we say the first of July, we really mean it!"

Nicola Iovine, Strategic Business Developer for EMEA of Digital Designs and SaaS at Rockwell Automation, comments, "Emulate3D is quickly becoming a leader in industrial design as more companies recognize the incredible benefits of digital twin technology. This application with ECM Technologies is a prime example of how design and commissioning can be streamlined. We look forward to supporting ECM Technologies as they continue to innovate and expand further into the digital realm."

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About Rockwell Automation

Rockwell Automation, Inc. (NYSE: ROK), is a global leader in industrial automation and digital transformation. We combine the imaginations of people with the potential of technology to expand what is humanly possible, making the world more productive and more sustainable. Headquartered in Milwaukee, Wisconsin, Rockwell Automation employs approximately 27,000 problem solvers dedicated to our customers in more than 100 countries as of fiscal year end 2024. To learn more about how we are bringing the Connected Enterprise to life across the industrial enterprise, visit www.rockwellautomation.com.