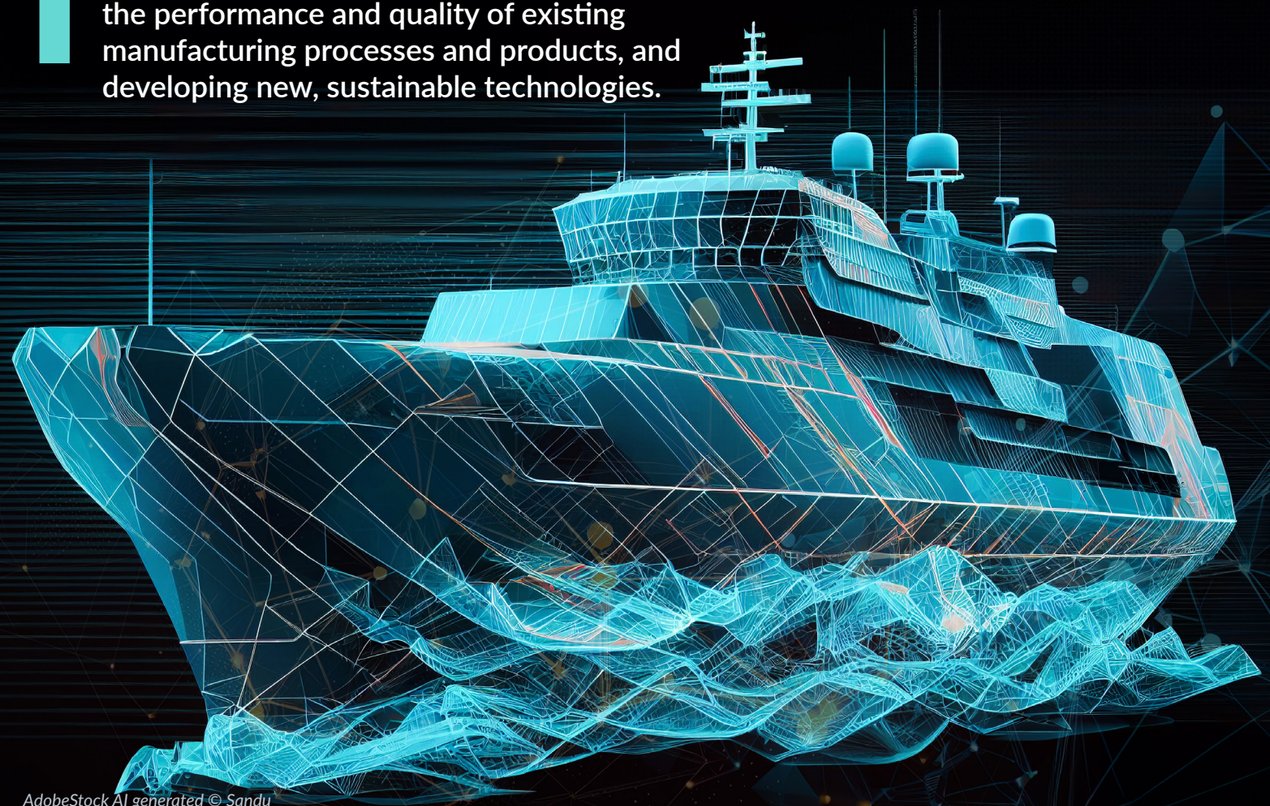
Advancing heavy manufacturing

The ENGINE project is dedicated to advancing the heavy manufacturing industry, with a particular focus on the marine sector. It addresses two key challenges: enhancing the performance and quality of existing manufacturing processes and products, and developing new, sustainable technologies.



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By integrating a comprehensive digital framework called the **ENGINE System**, the project aims to streamline product design, manufacturing and operation through tools like **ENGINE Exchange**, a data management platform and **ENGINE Toolbox**, which supports computational modelling and AI integration. These innovations enable real-time decision-making and defect control, ensuring high efficiency and sustainability across the production lifecycle.

The project also prioritises sustainability, particularly through the transition to green fuels and the decarbonisation of the marine industry. By incorporating lifecycle assessment (LCA) and lifecycle costing (LCC) into the decision-making process, ENGINE ensures that sustainability metrics are integral to design and operational choices.

Furthermore, ENGINE focuses on enhancing production quality control with **ENGINE Production**, which uses advanced sensory techniques and inspection processes to maintain high-quality standards. The project has successfully demonstrated its components, paving the way for implementation in real-world scenarios, particularly in the marine industry.

Overall, the ENGINE project is positioned to revolutionise heavy manufacturing by combining advanced digital technologies with sustainable practices, offering significant commercial value and preparing industries for a competitive and environmentally responsible future.

The ENGINE project focuses on enhancing the heavy manufacturing industry, applying the marine sector as its use case by optimising the supply value chain from start to finish. To do this effectively, the project faces challenges from two main directions—developing and maintaining existing manufacturing processes and products with ever greater performance and quality while also developing new methodologies that deliver more sustainable and greener machines.

Challenges in the marine sector

Firstly, there's the performance-oriented challenge: the marine sector deals with costly and technically complex products and components. Any unexpected downtime or unforeseen issues not covered in the design phase of the machine will face significant operational costs while problems are being resolved. Improving the design, manufacture and operation of these large marine components is, therefore, crucial—digitised manufacturing processes will help with this.

Secondly, there's a significant thrust towards sustainability and decarbonisation in the marine industry, which involves transitioning to sustainable fuels such as green fuels and e-fuels. However, integrating these new fuels poses technical challenges for existing technologies, while developing new technologies that use these new fuels and operate more sustainably is also a challenge. To move towards decarbonisation, these technical challenges must be addressed while improving sustainability and circularity in the industry.

The ENGINE project is dedicated to developing methodologies and processes that, while initially targeted at the marine sector, hold potential for broader application across other heavy manufacturing industries. The project aims to not only enhance the performance of existing marine products but also to contribute to a more sustainable future through the creation of eco-friendly technologies.

The ENGINE System: digital innovation and real-time decision-making

At the heart of the ENGINE project lies the ENGINE System, a comprehensive digital framework designed to optimise the processes of product design, manufacturing and operation. This system acts as a digital platform, facilitating seamless collaboration and information exchange throughout the design and production phases. By enabling smooth interactions between various modules, the ENGINE System ensures that every aspect of the value chain is interconnected.

One of the core components of the ENGINE System is ENGINE Exchange, a sophisticated data management solution that integrates research data, production data and real-time analytics. This exchange system empowers decision-makers by providing them with actionable insights, allowing them to make informed choices at every stage of the product lifecycle. The ability to access and analyse data from different sources ensures that decisions are grounded in comprehensive and up-to-date information.

Another critical element of the ENGINE System is the ENGINE Toolbox, which supports the exchange of information through computational modelling and the integration of AI tools. This toolbox enables the tracking of the entire product lifecycle, from raw materials to manufacturing processes and operational use, with a strong emphasis on defect control and zero-defect manufacturing. The toolbox's capabilities extend to simulating steelmaking processes, including continuous casting and hot rolling, as well as product manufacturing steps such as forging. Non-destructive evaluation (NDE) techniques, virtual fatigue testing and assessments of component and product lifetime under specific operational conditions are also incorporated, allowing for thorough evaluation and optimisation.

Life cycle assessment and costing

The ENGINE project's approach to decision-making is deeply integrated with LCA throughout the workflow. By covering the entire process with LCA, design changes and future usage

decisions can be based on sustainability metrics across the value chain. Additionally, the integration of LCC allows for comprehensive business analysis, optimising supply chain decisions for better business outcomes. For example, a forging shop, a key supplier in the marine industry, can evaluate components early in the process to determine their optimal end use, assessing whether they meet tolerance limits or require adjustments. This approach not only informs decisions about material performance but also provides the flexibility to repurpose materials or scrap them, depending on the information derived from LCA and AI models, ensuring real-time decision-making on the shop floor.

Production quality control

Beyond these advancements in design and manufacturing, the ENGINE project also focuses on enhancing production quality control through ENGINE Production. This aspect of the project integrates sensory techniques and inspection processes, such as phased array ultrasonic testing and surface quality measurements, across the entire supply chain. By linking these sensing data sources directly to ENGINE Exchange, the project ensures that quality standards are consistently met and any issues are identified and resolved in real time. This comprehensive approach allows for immediate feedback and adjustments based on observations from actual production, ultimately ensuring that the entire production process is optimised for quality and efficiency.

Successful demonstration and implementation

ENGINE has successfully demonstrated its core components, including the development of ENGINE Exchange, ENGINE Toolbox, and ENGINE Production, with minimum viable products (MVPs) established for each. This accomplishment highlights the project's dedication to turning initial efforts into concrete technical innovations.

The project is now working on its implementation phase with its use cases and demonstrating the whole ENGINE System to showcase its comprehensive capabilities, serving as the foundational framework that integrates various elements and functionalities. The ENGINE System, with its digital workflow for product manufacturing and online monitoring, represents a leap beyond current industry standards. This has opened new technical, business and sustainability avenues, demonstrating ENGINE's ambition and potential for a defect-free manufacturing paradigm.

Collaboration and industry impact

Industry partners, ranging from major players to SMEs, can leverage this system in diverse ways tailored to their needs. Major players can use the entire value chain to enhance product design and value creation over the product's lifetime and leverage sensor data for technical solutions. Meanwhile, SMEs will be able to contribute to specific aspects of the system, such as developing AI tools or sensor capabilities and providing business opportunities for them.

ENGINE's progress underscores its beyond-state-of-the-art approach, especially in the domains of data management (ENGINE Exchange) and modelling and simulation (ENGINE Toolbox). The project has established a comprehensive workflow that, for the first time, allows for tracing material and product manufacturing causality across all critical manufacturing steps, a key outcome for advancing and deploying ENGINE's capabilities.

ENGINE's achievements demonstrate the viability of advanced digital workflows and provide policy-relevant evidence supporting the development of future manufacturing strategies, digitalisation, standardisation and best practices. This positions ENGINE as a pivotal project in advancing sustainable and defect-free manufacturing in Europe.

Training and VR for skill development

Additionally, ENGINE has developed thorough training and skill development plans that can be provided to industry personnel, with comprehensive documentation and specialised training materials targeting R&D engineers and designers also available. This approach aims to facilitate the adoption and effective utilisation of the technology. The ENGINE project has achieved a significant milestone in developing and deploying an interactive website and comprehensive training materials for plant workers. This initiative focuses on enhancing skills development.

During the initial stages of the project, the requirements for training and upskilling materials were clear, as it was identified that employees involved in the production process performed various tasks. The required training materials range from general skills in key material production areas, such as occupational safety and health, fire safety, electrical safety and workplace organisation, to more specialised knowledge and skills crucial for specific manufacturing stages utilising the ENGINE System.

VR simulations are a key feature of the training programme, providing immersive and interactive experiences for complex tasks. These simulations allow workers to practice tasks in a safe environment, thereby increasing efficiency and reducing errors during actual production.

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The interactive training webpage, integrated into the vocational training partner's VALTEH home page, features a course catalogue and a learning management system. This platform provides a detailed overview of each course, including abstracts, target audience descriptions, prerequisites, objectives and materials. The webpage also hosts an introductory video explaining the importance and complexities of material testing, emphasising the significance of each step in the manufacturing process.

The training content is available in multiple formats, including video tutorials, lectures, courses and virtual reality (VR) simulations. VR simulations are a key feature of the training programme, providing immersive and interactive experiences for complex tasks. These simulations allow workers to practice tasks in a safe environment, thereby increasing efficiency and reducing errors during actual production.
One example of a course that utilises VR technology is the simulation that trains workers on the main steps of the specimen marking procedure to ensure traceability in materials testing. Trainees carry out the procedure on the connecting rod big end bearing head (BEBH), following guidelines from the Department of Industrial Engineering at the University of Padova. The simulation includes step-by-step instructions and error prevention measures, providing an immersive learning experience.

As the ENGINE project progresses, additional training videos and materials will be developed to further support the implementation of the ENGINE System. Upcoming content includes training on the usage of the ENGINE Exchange software, which will be particularly beneficial for employees working with industrial data.

Conclusion

The ENGINE project is centred on applying its innovative system to complex and critical components, particularly in large marine engines. These real-world applications serve as crucial testing grounds, providing valuable insights and validation for the system's effectiveness. The ENGINE System's practical application demonstrates its reliability and underscores its significant commercial value for various industries.

The adoption of this technology offers multiple benefits, including cost savings, improved efficiency and enhanced sustainability. With regulatory changes on the horizon that increasingly favour sustainable solutions, industries that embrace the ENGINE System early on stand to gain a considerable competitive advantage in the marketplace. The system's integration into the evolving market landscape aligns closely with industry-driven needs, ensuring that businesses are well-prepared for the future. By addressing the gaps identified by industry stakeholders, the ENGINE project aims to deliver lasting value that extends beyond the initial implementation, fostering continuous evolution and innovation.

The overarching objective of the ENGINE project is to develop a comprehensive methodology that meets the complex demands of heavy manufacturing. The digital framework provided by the ENGINE System offers robust technical capabilities, while collaboration with industry partners ensures that these methodologies can be adopted and implemented effectively, tailored to the specific needs of each sector.

The project's focus on heavy industry, particularly in the utilisation of metallic alloys, means its scope extends across various value chains within manufacturing. By embracing cutting-edge digital technologies and sustainable practices, the ENGINE project is poised to chart a new course that balances high performance with environmental responsibility, paving the way for an exciting and sustainable future in manufacturing.

ENGINE
ZERO-DEFECT MANUFACTURING FOR GREEN TRANSITION IN EUROPE

PROJECT SUMMARY

The main objective of ENGINE is to develop a first-time-right (FTR) and zero-defect metal product design and manufacturing system, then demonstrate it on the marine engine supply chain. Our ambition is to increase the competitiveness of industry and SMEs, reduce manufacturing defects and waste, create new business cases and improve employee well-being.

PROJECT PARTNERS

Technology Research Center VTT Oy, Universität für Bodenkultur Wien (BOKU), Tampere College of Education Sr., University of Oulu, University of Padua, Wärtsilä Finland Oy, Wärtsilä Italia SpA., Siderforgerossi Group SpA, Acciaierie Bertoli Safau SpA, AeonX AI, Advantic Sistemas y Servicios SL, Global Boiler Works Oy, Nome Oy, RTD Talos Ltd, GreenDelta GmbH and Valmieras Tehnikums.

PROJECT LEAD PROFILE

Anssi Laukkanen is a Research Professor in Computational Materials and Data Sciences at the VTT Technical Research Centre of Finland O. and the coordinator of ENGINE. At VTT, Laukkanen specialises in computational modelling and AI activities related to materials science and engineering. Laukkanen leads VTT's research efforts, including the application of integrated computational materials engineering in industry collaborations.

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