Large-Scale WAAM Manufacturing of Marine Gear Systems

The Purpose of the elaborated Case Studies

Case studies are structured examinations of real-world situations or challenges designed to bridge theory and practice. They are developed both as a research method and as a learning tool to strengthen analytical and problem-solving skills. By engaging with authentic industrial scenarios, students gain practical insight into complex professional environments.

The purpose of this case studies is to encourage active, learner-centred engagement. They support approaches such as problem-based learning by enabling students to work independently or collaboratively, with or without instructor guidance. Through analysing theoretical concepts within realistic contexts, students learn to interpret data and test results, evaluate alternative courses of action, and develop well-reasoned, creative solutions.

This approach is particularly valuable in sectors such as aerospace, defence, and advanced manufacturing, where challenges are multifaceted and solutions are rarely singular. Because multiple valid solutions often exist, guided facilitation is frequently beneficial to help students structure their reasoning, assess trade-offs, and justify their decisions effectively.

Large-Scale WAAM Manufacturing of Marine Gear Systems

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XXL3DDRUCK – Energy- and Resource-Efficient Additive Manufacturing of Large-Scale Marine Gearbox Housings,

IPH– Institut für Integrierte Produktion Hannover gGmbH
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Background:

- Large marine gearbox housings are usually manufactured using casting processes. Although these methods are well established, they require large amounts of material, energy and production time.
- The XXL3DDRUCK project, funded by the German Federal Ministry for Economic Affairs and Energy (BMWE) under funding reference number 03ET1644C and managed by Project Management Jülich (PtJ), investigated how large-scale metal components could be manufactured more sustainably using additive manufacturing technologies. The project developed and validated a complete process chain for producing gearbox housings up to four metres in size using laser-assisted wire arc additive manufacturing (WAAM). The consortium comprised IPH – Institut für Integrierte Produktion Hannover gGmbH and four further companies and research institutes. REINTJES GmbH coordinated the project and hosted the large-scale 3D printer, which was built by EILHAUER Maschinenbau GmbH. Laser Zentrum

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Hannover e.V. (LZH) developed the laser-assisted arc welding process, while TEWISS GmbH was responsible for constructing the print head and developing the machine control system.

- The project combined additive manufacturing, inline metrology, adaptive process control and lightweight design methods to reduce resource consumption and increase manufacturing flexibility.

Illustration of the case study



Figure 1: Additively manufactured marine gearbox housing demonstrator produced within the XXL3DDRUCK project.

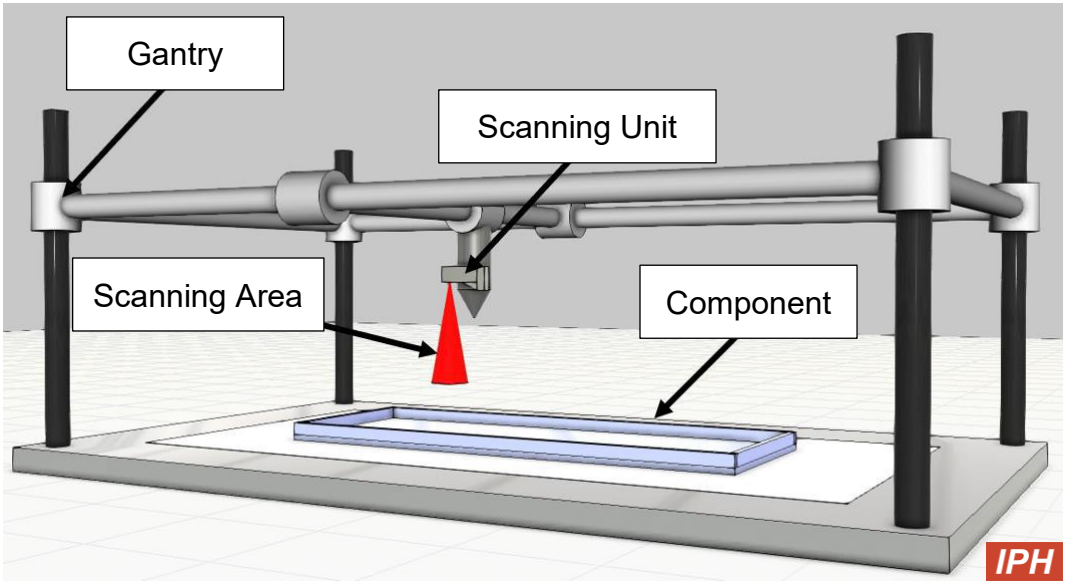


Figure 2: Inline measurement concept developed by IPH.

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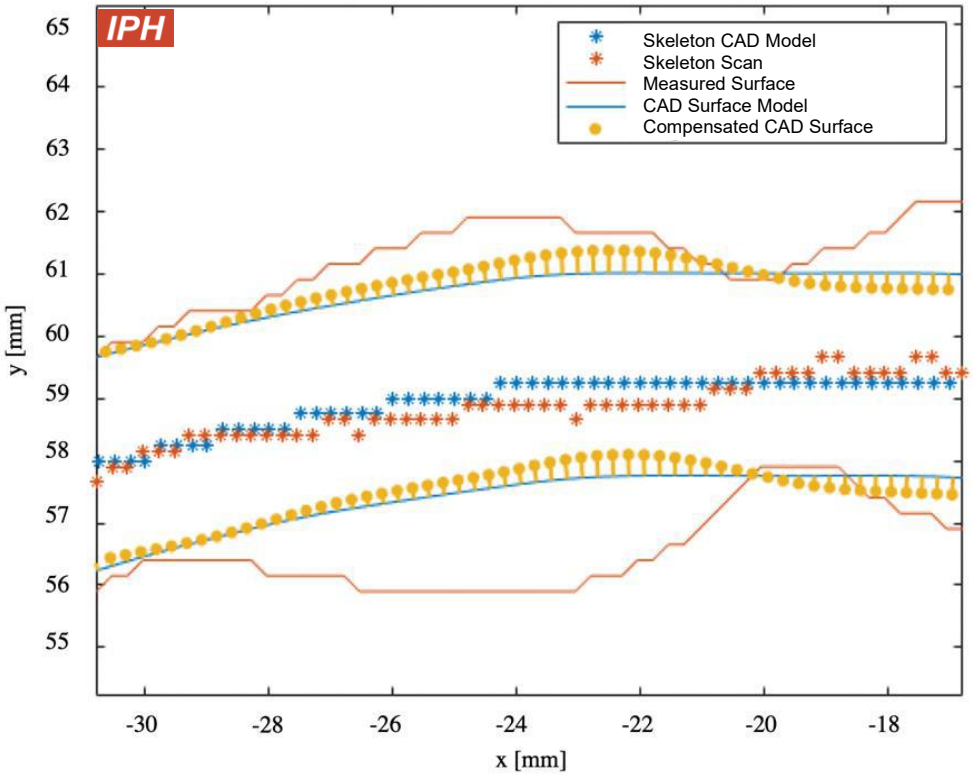


Figure 3: Geometric Comparison between CAD model and measured geometry.

Technical challenge

- How can large-scale metal components be manufactured additively while maintaining dimensional accuracy?
- How can thermal distortion during the WAAM process be reduced and compensated?
- Which inline measurement technologies are suitable for monitoring XXL additive manufacturing processes?
- How can real-time measurement data be used to correct manufacturing deviations automatically?
- How can additive manufacturing reduce material consumption, energy demand and CO_2 emissions compared with conventional casting processes?
- Which design adaptations are necessary to exploit the full potential of large-scale additive manufacturing?
- What are the potential industrial applications of large-scale WAAM technology beyond marine gearbox housings?

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Detailed solution/ process

- Development of a laser-assisted Wire Arc Additive Manufacturing (WAAM) process for large metal structures.
- Integration of an inline 3D measurement system developed by IPH using laser line scanning technology.
- Continuous comparison between measured geometry and CAD model.
- Automatic generation of correction values to compensate manufacturing deviations.
- Development of adaptive process control for improved dimensional accuracy.
- Manufacturing of overhang structures up to 30° and lightweight hollow-wall structures.
- Achievement of deposition rates of up to 5 kg/h.
- Successful production of a marine gearbox housing demonstrator.

Key Results:

- Material savings up to 36 %
- Energy savings up to 51 %
- Deposition rates up to 5 kg/h
- Successful validation of inline metrology and adaptive process control

Literature:

Kriwall, A.; Janson, N.; Heineking, O.; Küster, B.; Stonis, M.: Die additive Fertigung von Großbauteilen überwachen. In: QZ - Qualität und Zuverlässigkeit, Carl Hanser Verlag, 67. Jg. (2022), H. 4, S. 54-56. ISSN: 0720-1214.

Competence unit coverage:

	AILEEN competence units	Covered CU
AI_01	Inspection: NDT in Additive Manufacturing	✅
AI_02	Metrology in Additive Manufacturing	✅
AAM_02	Quality Assurance & Quality Control	✅
AD_02	Data Acquisition and Analysis	✅
AD_05	Automation	✅
AG_02	Sustainable Design and Environmental Compliance	✅

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