NEPTUN

NEW APPROACH TO INNOVATIVE TECHNOLOGIES
IN MANUFACTURING

Deliverable 5.9

Publication of co-authored book about Industry 4.0 topics

Work package No. 5 – Visibility & Social Media

Prepared by: Marek Chodnicki (Gdańsk Tech)

Lead participant: Gdańsk Tech

Delivery date: 31.10.2025

Dissemination level: Public

Type: DEC

Project: 101079398 — NEPTUN — HORIZON-WIDERA-2021-ACCESS-03

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Revision History

Author Name, Partner short name	Description	Date
Marek Chodnicki (Gdańsk Tech)	Creating a report	30.10.2025

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1. Executive summary

D5.9 is fulfilled through **two complementary, co-authored publications** addressing Industry 4.0/5.0 themes and good manufacturing practice:

- **(A) Edited volume (journal special issue):** an **Open-Access Special Issue** of the *International Journal of Manufacturing Research (IJMR)* titled **"New Approaches to Innovative Technologies in Manufacturing"**, guest-edited by representatives of Gdańsk Tech, NTUA and KTH. The SI is organised and managed under Inderscience's special-issue framework, with double-blind peer review, OA APC, and international scope. It compiles **8 accepted articles** (from 9 submissions) and will be published as a thematically coherent issue (book-like edited volume).
- **(B) Public e-book (compendium): Neptun Ebook 2025 — The Book of Trends and Good Manufacturing Practices** (PDF), aggregating methods and case-based good practices derived from WP2–WP3 and partner expertise. It serves both as a readable monograph and a practical compendium (also referenced under D5.7).

Together, these outputs meet the D5.9 objective by delivering a co-authored, peer-reviewed **edited volume** plus a **public e-book** that translates project know-how into broadly accessible guidance for academia and industry.

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2. Publication A — IJMR Open-Access Special Issue

2.1 Scope, governance and OA terms

- **Title:** *New Approaches to Innovative Technologies in Manufacturing* (IJMR OA Special Issue). **Guest Editors:** Gdańsk Tech, NTUA, KTH. Topics include process planning, innovative processes, metrology, digital twins, HRC, AM/advanced materials, AI/ML, VR, sustainability, and I4.0/5.0 applications.
- **Editorial process & standards:** Double-blind review in Inderscience's online system; two (preferably three) referees per paper; independence rules for editors' own submissions; quality and international balance requirements; OA.
- **Key dates (current plan):** CfP/Invitations, submissions mid-2025; decision & finalisation per IJMR SI timeline; target publication in the current calendar year.

2.2. A.2 Article set — examples of accepted manuscripts

(Titles abbreviated to illustrate thematic coverage; final line-up and pagination as per IJMR production.)

- **3D printing head changer for extrusion printers** — device concept, prototyping, tests; print-time reduction without loss of geometry quality.
- **DRIFTS analysis of phenol-formaldehyde resin crosslinking** — monitoring concomitant curing (resole+novolac) and temperature effects for abrasive manufacturing.
- **Impact of PCD cutting-edge shaping on milling forces** — laser-vs-ground DP edges; lower forces with laser-shaped edges in face milling of Al alloy.
- **Digital Transformation of Manufacturing Companies** — mapping 24-area cross-domain interactions; mixed-methods case studies; I4.0 tooling linked to I5.0 principles.
- **Operational efficiency of industrial hydraulic drives** — operating-efficiency coefficient combining energy, lifecycle and cost for schematic selection.
- **mSLA-printed micro-abrasive tools for 41Cr4 steel** — resin-diamond tools; precision finishing; topography changes vs. cutting depth.
- **Model & strength assessment of a multifunctional freight wagon** — concept and FEM-based evaluation (manufacturing innovation in rail).
- **FEM of anti-vibration coatings on a gondola car** — modal/harmonic analysis; localised damping zones; vibroacoustic improvement.

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- **Adjustable conical air bearings for non-contact direct drives** — analytical model, test rig; weight −11%, size −17.3%, air consumption −25%. *(1 of 9 total; one manuscript may be held/withdrawn per reviewers' outcome.)*

2.3. Compliance with D5.9

- **Co-authorship & editorial coherence:** Multi-institutional set curated by GE team (Gdańsk Tech/NTUA/KTH) with external reviewers and IJMR EIC oversight.
- **Public availability:** OA SI per Inderscience policy (articles open to the public upon publication).
- **Evidence package (annex):** SI proposal form, CfP PDF, Guest Editor Pack extracts, list of submissions/decisions, and accepted-manuscript proofs (as available).

3. Publication B — Neptun Ebook 2025

- **Title:** *Neptun Ebook 2025 — The Book of Trends and Good Manufacturing Practices* (PDF, public).
- **Content:** AM routes (incl. lattice, W-LMD/PBF), post-processing & inspection (brushing/AFM, metrology), monitoring & optimisation, HRC for disassembly, and digital-transformation patterns for SMEs; method-to-practice orientation (SOPs/checklists).
- **Role in D5.9:** Co-authored monograph that complements the SI with tutorials and good-practice guidance, ensuring wide uptake by industry and students.
- **Evidence (annex):** full PDF; bibliographic record; licensing note and acknowledgements (HE funding).

4. Conclusions

D5.9 is achieved via a **two-pillar publication strategy**: (A) a **peer-reviewed, OA edited volume** (IJMR Special Issue) consolidating research outputs and (B) a **public e-book** translating project knowledge into **usable good practices**. This pairing maximises scientific credibility and industrial uptake, ensuring durable post-project impact.

5. Annexes

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- **IJMR Special Issue**: Special-issue pro-forma; OA CfP; Guest-Editor guidelines; list of submissions/decisions;
- **E-book:** *Neptun Ebook 2025 — The Book of Trends and Good Manufacturing Practices* (full PDF).

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INDERSCIENCE PUBLISHERS
Linking academia, business and industry through research

International Journal of Manufacturing Research

OA Special Issue on "New Approaches to Innovative Technologies in Manufacturing"

Guest Editors:
Dr. Marek Chodnicki and Prof. Mariusz Deja, Gdansk University of Technology, Poland
Prof. George-Christopher Vosniakos, National Technical University of Athens, Greece
Assoc Prof. Xi Vincent Wang, KTH Institute of Technology, Sweden

This special issue aims to showcase the latest research in advanced manufacturing techniques, smart production systems, and sustainable industrial practices. The focus is on bridging the gap between academic research and industrial applications, ensuring that manufacturing remains efficient, sustainable, and digitally integrated.

Subject Coverage
Suitable topics include, but are not limited, to the following:

- Process planning and scheduling
- Innovative manufacturing processes
- Advanced metrology
- Digital twins
- Human robot collaboration
- Humar robot interaction
- Manufacturing innovation
- Manufacturing automation
- Additive manufacturing and advanced materials
- AI and machine learning in manufacturing
- Virtual reality in manufacturing
- Sustainable and green manufacturing
- Industry 4.0 / 5.0 applications

Notes for Prospective Authors

Submitted papers should not have been previously published nor be currently under consideration for publication elsewhere. (N.B. Conference papers may only be submitted if the paper has been completely re-written and if appropriate written permissions have been obtained from any copyright holders of the original paper).

All papers are refereed through a peer review process.

All papers must be submitted online. To submit a paper, please read our Submitting articles page.

This is an Open Access Special Issue. There is an article processing charge of EUR€2000 per paper to publish in this Special Issue for authors. You can find more information on Open Access here.

Important Dates

Manuscripts due by: *31 July, 2025*

Notification to authors: *31 August, 2025*

Final versions due by: *30 September, 2025*

INDERSCIENCE PUBLISHERS

SPECIAL ISSUE proposal for
International Journal of Manufacturing Research (IJMR)

(1) Will the special issue be based on selected extended conference papers?	***No*** *(please delete as applicable)*
Please provide the **name**, **acronym, dates** and **url** of the conference below.	
name, **acronym, dates** and **url**:	
***Note 1:** Conference papers are not accepted. Authors can submit an article that is based on a conference paper, so long as it has been substantially revised, expanded and rewritten so that it is significantly different from the conference paper or presentation on which it is based. The article must be sufficiently different to make it a new, original work. The rewritten article can have a similarity index with the original conference paper of no more than 5%.* ***Note 2:** The title of the special issue must NOT include the name of the conference. Please use a topic title [details of the conference the accepted articles are based on can be included in your Editorial].*	
(2) All other special issues should be made up of papers invited directly from experts by the Guest Editors. ***Do you require a headed call for papers PDF to be provided for you and your Co-Guest Editors to use when sending invitations for submissions?***	***No*** *(please delete as applicable)*
Inderscience prefers special issues based on invited papers only. To invite papers, you would normally expect to initially identify 30-50 authors. In this way, you should not only be able to attain sufficient high-quality papers, but also good publicity for the special issue, the journal and yourself by being introduced to experts in the field.	
(3) Do you acknowledge that this will be an open access issue with an OA fee to be paid per accepted paper?	***Yes*** *(please delete as applicable)* *2000 euros*
[Please complete Special Issue details]	
Special Issue on: "New Approaches to Innovative Technologies in Manufacturing"	

Important dates	
Manuscripts **due by**:	*20 September, 2025*
Notification to authors:	*06 October, 2025*
Final versions due by:	*20 October, 2025*

We recommend that you allow 3-4 months for authors to submit the first drafts of their papers; 2 months for the refereeing process and for informing authors of the outcome of the refereeing process and any changes requested by the referees; and 2 months for authors to resubmit their revised manuscripts.

Description [aims/objectives/content/readership/etc]

This special issue aims to showcase the latest research in advanced manufacturing techniques, smart production systems, and sustainable industrial practices. The focus is on bridging the gap between academic research and industrial applications, ensuring that manufacturing remains efficient, sustainable, and digitally integrated.

Subject Coverage

Topics include, but are not limited to, the following:

• Process planning and scheduling • Innovative manufacturing processes • Advanced metrology • Digital twins • Human robot collaboration • Humar robot interaction • Manufacturing innovation • Manufacturing automation	• Additive manufacturing and advanced materials • AI and machine learning in manufacturing • Virtual reality in manufacturing • Sustainable and green manufacturing • Industry 4.0 / 5.0 applications

Please continue to the next page

Guest Editor(s) details (maximum of four)
(*to be completed in full for each Guest Editor)
(N.B. We suggest that Guest Editors invite Co-Guest Editors from top relevant Centres of Excellence in Western Europe and the USA (at least one Guest Editor from each, respectively) to be involved in their special issue. Such guest editorship will encourage the submission of strong relevant papers from authors in the USA and Western Europe to the special issue and help to ensure that submitted papers are not just regional submissions.)

*Title [Dr/Prof/etc]:	Dr.
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Notes for Prospective Authors

Submitted papers should not have been previously published nor be currently under consideration for publication elsewhere. (N.B. Conference papers may only be submitted if the paper has been completely re-written and if appropriate written permissions have been obtained from any copyright holders of the original paper).

All papers are refereed through a peer review process. All papers must be submitted online. Please read our information on submitting articles.

This is an open access special issue. There is an article processing charge of USD $0 to publish in this special issue. You can find more information on OA here.

Guest Editor Guidelines for Special Issues

Online submission

- All papers must be submitted and reviewed via the Inderscience online system. Guest Editors will be asked to supply their full contact details along with the title of their proposed special issue in order for them to be registered with the online submission system. Guest Editors are expected to organise and manage the review process, and will be provided with login details and instructions to guide them through the system. Authors must submit their papers online by registering at http://www.inderscience.com/info/inauthors/author_submit.php , and following the onscreen instructions

1. Quality

- Online submissions will be screened by the system to filter viruses, malicious, erroneous and unsuitable data. Those which pass this initial screening stage must be double-blind refereed according to our strict standards. Guest Editors are responsible for appointing (or approving the appointment of) referees. Papers should be allocated to a minimum of two referees (but preferably three) and must be amended according to their comments. If one referee accepts the paper and one rejects it, the decision of the third referee is final. The system will retain the referees' reports. The publisher reserves the right to re-referee and/or reject an accepted paper if it does not meet the criteria outlined in the review form or if the paper is otherwise deemed possibly unsuitable.

- Guest Editors are responsible for the breadth and balance of papers to be published. There must be a balance of papers internationally and topically, and account must be taken of the status and credibility of the research centres from where the submitted papers are accepted and published.

- Papers should also be international in origin. Where a special issue is based on conference papers presented from only one country, please ensure the selected articles to be rewritten are from different institutions in that country. Journal issues should not be dominated by authors from the same institute or research group as the Editor, or dominated by any single group, whether ethnic, political or academic. Issues should ideally contain no more than one paper from the same author/co-author.

- It is essential to ensure that papers submitted from the Guest Editors' institutes or research groups or from the Guest Editors themselves, as authors, are refereed and accepted independently and that the referees are not appointed by the Guest Editors. Therefore, such papers should be referred to Inderscience's Editor-in-Chief so that independent refereeing can be arranged.

- While the use of Artificial Intelligence (AI) to develop and edit text is allowable, we do not accept papers that have been generated mostly or entirely by an AI tool. Inderscience is increasingly finding cases of unethical conduct in papers written with the assistance of AI, where it is obvious that the author is not writing about their own legitimate research. Such papers are not acceptable and should be desk-rejected. You can find more detailed information about identifying such papers in the Editor Guidelines PDF that you will see when you log into the submissions system.

- Although Guest Editors should encourage the citation of papers from the journal; please be aware that Clarivate Analytics (formerly Thomson Reuters) monitors self-citation. It is acceptable for research to have up to 20% of "self-published" citations. This means that, in an issue, as long as no more than 20% of citations overall are references to articles from the journal, the practice is allowable. If, however, editors are overzealous and self-citation is utilised too heavily, Clarivate may blacklist the title.

2. Conference papers

It is not unusual for papers to be submitted that are based on conference papers, which may have been published elsewhere. They require special care. It is important to observe the following in considering submissions based on them:

- Conference papers are not accepted. Authors can submit an article that is *based* on a conference paper, so long as it has been substantially revised, expanded and rewritten so that it is significantly different from the conference paper or presentation on which it is based. The article must be sufficiently different to make it a new, original work. The rewritten article can have a similarity index with the original conference paper of no more than 5%.

- All such papers must be submitted online. These articles will be treated like any other article submitted to Inderscience, and will go through our plagiarism checker and also undergo a double-blind peer-review process, all using Inderscience's online submissions system.

- Please include the statement 'This article is a revised and expanded version of a paper entitled [title] presented at [name, location and date of conference]' in the online system when you submit your paper, using the "Notes for the Editor" field.

- Because of past problems, it is a further requirement that if the original conference paper on which the extended paper is based has been published elsewhere, or its copyright has been assigned to the conference organisers or another party, Editors should ensure that the authors have cleared any necessary permissions with the copyright owner. Articles cannot be accepted, post-review, for publication unless such written permissions have been provided along with Author Copyright Agreement forms.

- Also, selected papers may only appear on the web as part of any freely-available proceedings or the like if they are the author's original (prior to peer review) or accepted (but not corrected, i.e. not the proof) manuscript.

3. Editorials

Guest Editors may include an Editorial or Preface giving a brief outline of the topic of the special issue and a summary of the contents: this should not generally exceed three pages and should be emailed to the appropriate Journal Manager and the Editor of the journal.

4. General remarks

- As is the case with many other publishers, Inderscience is moving towards open access for all of its journals. All Inderscience special issues are therefore open access to help in contributing to publication costs. Open access papers are published online-only and are available to readers free of charge. A special issue's papers are published together at the same time when ready.

- To ensure high-quality special issues, Guest Editors should solicit papers by issuing direct invitations to authors in the field. By sending such invitations both the Journal and the Guest Editor(s) come to the attention of experts, and citations should increase when papers are published by authors with high citation activity.

- Guest Editors should complete the Inderscience call for papers pro forma which will enable the special issue to be registered for online submission. A headed pdf version of the CFP can be provided for Guest Editors to use when sending invitations for submissions to the special issue. We recommend inviting an initial 30-50 authors.

- Guest Editors should appoint a panel of referees to help them in their task who must be added to the reviewer database on the online system, bearing in mind the comment above concerning papers authored by Guest Editors or by members of Guest Editors' research groups.

- Guest Editors can invite other Co-Guest Editors to help them in their task, if they wish.

- Both general and special issues should not have more than one paper submitted by an author, unless there is a very strong reason for that.

- The average size of a special issue is about 100-112 typeset journal printed pages (approx.165 A4 pre-typeset pages) for a single issue or about 200 typeset printed journal pages (approx 300 A4 pre-typeset pages) for a double issue. As a rough rule of thumb, one of our regular size journal pages has 600 words [3500 characters], and an A4 size page has 800 words [5600 characters]. At this stage there are no restrictions on the size and number of high quality papers accepted for publication in the special issue. However, if Guest Editors would like to publish 12-15 papers, for example, they need to invite at least 30 experts to write papers for the special issue. It is preferable to have special issues published as single, since subscribers and the citation services prefer single issue sizes to a double issue size. However, if Guest Editors have a large number of high quality papers refereed and accepted for publication, they must contact the Editor and/or Inderscience to discuss publishing a large single issue, a double issue or more than one special issue if necessary.

- If Guest Editors receive more high-quality refereed and accepted papers than would fill a double issue, please let the Editor-in-Chief know to discuss the possibility of another special issue in the journal or a further special issue in a different, relevant Inderscience journal. If a different journal is proposed, the Guest Editor must contact each author to advise him/her of the reasons, and to seek his/her explicit consent. Under no circumstances should a paper be published in a different journal without the prior written consent of the author.

- Guidelines for authors and sample papers, as well as information about the refereeing process and other relevant journals, are available on our website: www.inderscience.com/guidelines.

- Guest Editors can choose referees to help them, as they wish, from experts in the subject of the special issue. Since the refereeing process is a blind one, Guest Editors can also use some of the other authors as referees if they have problems in appointing enough referees.

- An example of a timetable for editing a special issue is as follows. Allow:
  - 3-4 months for invited authors to upload the first draft of their papers;
  - 2 months for the refereeing process and to inform the authors of the outcome of the refereeing process and of any changes requested by the referees
  - 2 months for authors to upload the final manuscript of their papers after incorporating any changes requested by the referees

- Upon publication, Guest Editors have the option of purchasing physical copies of their special issue at a discounted rate.

5. Review, typesetting and publication processes

a) Review Process

Only good and relevant papers should be processed and sent to referees (we do not want to waste the time of the referees by sending poor or marginal papers to them).

Send every paper which is suitable to be refereed to three experts not from the same institution or research group as the author and preferably from more than one country.

Since the refereeing process is a blind one, Guest Editors can use some of the authors as referees if they have problems in appointing enough referees.

In general, after the author has uploaded the revised article implementing the reviewers' recommendations from the first-round review, the decision of the Guest Editor to end the review process or request a further round of reviews would be based on the following six scenarios:

1. The article should be REJECTED if at least two of the reviewers have rejected the article. There is no need for further reviews. Inderscience's Editorial Office carries out a quality assurance process and will question submissions that were accepted by the editor in spite of the fact that they were rejected by more than one reviewer.

2. The article should be ACCEPTED if at least two of reviewers have accepted the article and have given marks of Honours or Good in some of the ratings.

3. If one or more reviewers accept the article with MINOR REVISIONS, the article should be sent to the author for changes and, once they are made, the Guest Editor can review the uploaded revised version and recommend to accept the submission if he is happy with the changes made. There is no need to send the revised version to the reviewers for further rounds of review.

4. If one or more reviewers accept the article with MAJOR REVISIONS, the article has to be sent to the author for revision and the revised version has to be sent to the reviewers again for their final decision to accept or reject the article. The article cannot be accepted until the reviewers who have requested major revisions have agreed with the changes and recommended acceptance of the article.

5. If one reviewer accepts with major revisions, one with minor revisions and the third reviewer does not reply, the article should be sent to the author to revise and the revised version should be sent to the reviewer who requested major revisions for a final decision to accept or reject. The article cannot be accepted until the reviewer who requested major revisions has agreed with the changes and recommended acceptance. Sending the revised article to the reviewer that suggested minor revisions is optional, as the Guest Editor is allowed to use his own judgment to decide whether the author has implemented the minor revisions requested by the reviewer.

6. If one reviewer accepts the article, one rejects it and the third one does not reply, then the Guest Editor must replace the third reviewer with a new reviewer to supply a final decision to accept or reject.

The resolution of other scenarios is left to the discretion of the journal's Editor in Chief.

NOTE: Each time an author is asked to implement reviewer recommendations and upload a revised version, the system instructs the author to append his reply to each of the comments made by the reviewers to the beginning or in the first pages of the revised version. The author is also always instructed not to include any identification in his revised versions. However, the Guest Editor is expected to check each revised version uploaded in case author replies were not included and/or identification (e.g. author names, addresses, etc) has been added. If the Guest Editor finds any of these problems, he should ask the author to re-upload a revised version before asking reviewers to carry out further reviews.

If/when their paper is accepted for publication authors will be required to sign and upload an Author Copyright Agreement form, assigning copyright of their paper to the Publisher. http://www.inderscience.com/www/authoragree.pdf. If the paper has more than one author each author can sign the same Author Copyright Agreement form. However, it is also acceptable for individual authors to sign a separate agreement form. Author Copyright Agreement forms are available on the website as a part of guidelines for authors. Papers cannot be published unless a signed Author Copyright Agreement form from each author, assigning the copyright of papers to the publisher, has been received.

The final decision to accept or reject papers is taken by the Editor in Chief in a final review process, forming part of the publisher's quality assurance process before publication. The publisher reserves the right to have the final say for submissions at any stage of the refereeing, publication and post-publication process. If papers are published in good faith and are found to have breached the review process guidelines, ethical publishing code of practice or the policy of the publisher, such papers will be retracted.

The final manuscript of each selected paper should include:

- Title of the paper, names of authors, their affiliations, complete addresses and e mail addresses.
- The name, address, email address and fax number of the corresponding author to whom the proofs of the typeset paper should go to for checking.
- A brief abstract.
- Keywords.
- Brief biographical notes about authors.
- High quality and high resolution figures capable of printing high quality figures in black and white.

N.B. If papers have been refereed and accepted and sent for typesetting, the authors have to abide by what they have written; no further changes are acceptable in

- author details (e.g. adding more names or deleting names) or in their sequence
- the content of the paper (except for typesetting corrections)

If authors wish to make changes to content, then the paper has to be withdrawn and must go back to be refereed as a new paper. If there is any dispute about authorship or intellectual property, the paper must be withdrawn completely from publication until the authors settle their legal claims. It is not the publisher's responsibility to solve or interfere in any intellectual property dispute.

b) Typesetting

When the papers for the special issue are accepted by the final review process, the papers are processed for typesetting and all the succeeding publication processes will be conducted by the publisher.

The corresponding author of each paper will receive by email the proofs of his/her paper to check. He/she must return the corrected proofs within fourteen days in order to avoid any delays in publishing the special issue. If we have not received a response by then, we will contact Guest Editors to help chase the author for a reply.

After having their corrections incorporated by the typesetter, the proofs will again be sent to authors to check and to ensure that all their corrections are included. It is the responsibility of authors to check and correct the proofs of their papers. Papers cannot be published until they are checked and approved by authors. And papers cannot be amended once they are published, except in very exceptional circumstances, so authors should take great care in approving the final version for publication.

Papers accepted for the special issue will be published together at the same time when all papers for the issue are ready.

The Book of Trends
and Good Manufacturing Practices

GDAŃSK UNIVERSITY OF TECHNOLOGY

NEPTUN

Editors: Alina Guzik, Aleksandra Wiśniewska, Marek Chodnicki

Place of publication: Gdańsk, 2025

ISBN: [to be assigned]

New Approach to Innovative Technologies in Manufacturing (NEPTUN) is a project under the Horizon Europe program, of which Gdańsk University of Technology has become a leader. Scientists from the Faculty of Mechanical Engineering and Ship Technology, in cooperation with foreign universities, will work to raise the level of excellence of Gdańsk University of Technology in the area of broadly understood manufacturing.

GDAŃSK UNIVERSITY OF TECHNOLOGY

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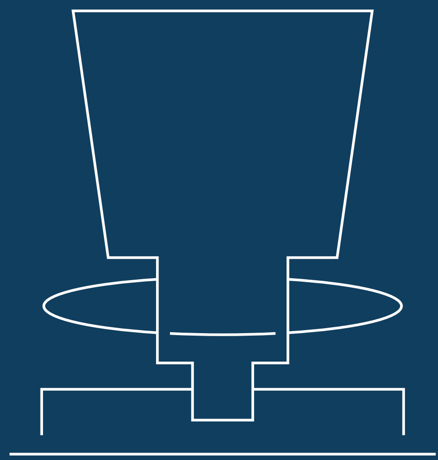
Chapter 01

PROCESSES



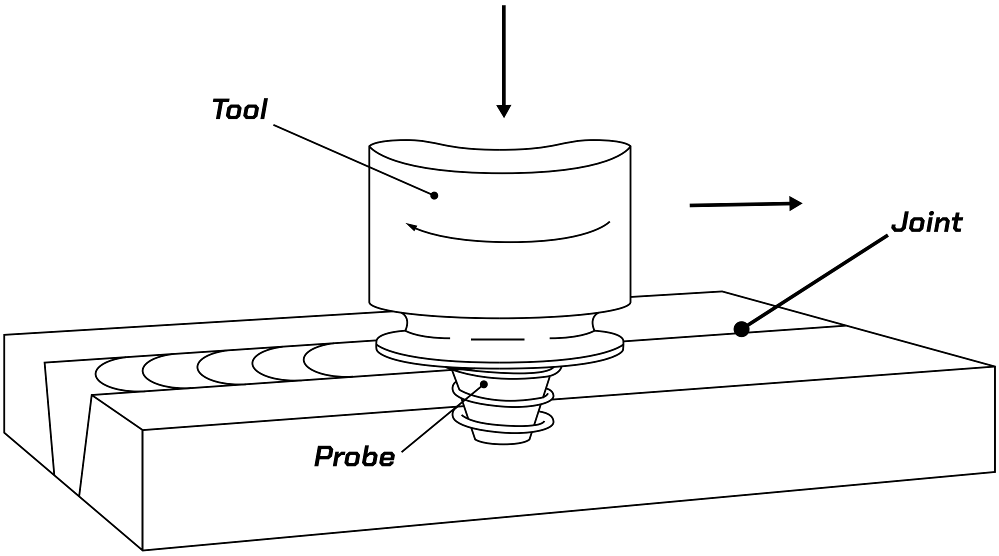
Friction Stir Welding (FSW)

#FSW #WeldingInnovation #SolidStateJoining
#LightweightStructures #AerospaceTech #GreenManufacturing

TRL9 Proven in real industrial environments

About the method

Friction Stir Welding is a solid-state joining technique where a rotating tool "stirs" two materials together without melting them. It produces strong, defect-free welds, especially in lightweight alloys (aluminum, magnesium) and is widely used in aerospace, automotive, shipbuilding, and rail industries.



Friction Stir Welding (FSW) is often described as one of the most significant breakthroughs in metal joining since the invention of arc welding. Unlike traditional methods, it does not involve melting the material. Instead, it uses mechanical friction and pressure to "stir" two pieces of metal together in their solid state.

The process begins with a rotating cylindrical tool fitted with a specially designed pin. This tool is plunged into the joint line between two pieces of metal. As it rotates, the intense friction generates heat—softening, but not melting, the surrounding material. The softened metal is then stirred and forged by the tool as it moves along the joint, creating a seamless, high-strength bond once it cools.

Because the metal never fully melts, the weld avoids common defects such as porosity, cracking, or weak spots that can occur in conventional fusion welding. The result is a weld that is often stronger and more fatigue-resistant than the base material itself.

FSW has proven especially valuable for aluminum alloys, which are notoriously difficult to weld using traditional processes due to their high thermal conductivity and tendency to form defects when melted. For this reason, FSW has been rapidly adopted in industries where lightweight, fatigue-resistant structures are essential.

Another key advantage is energy efficiency and environmental friendliness. FSW consumes less energy than fusion welding, produces no harmful fumes or spatter, and requires minimal filler material. This makes it not only a technical innovation but also a step toward more sustainable manufacturing.

Finally, the technique is highly dependent on operator expertise and precise process control. Parameters such as tool rotation speed, downward pressure, and welding travel speed must be carefully optimized. Even small deviations can affect weld quality, which is why training and advanced monitoring systems are crucial in industrial practice.

In short, friction stir welding represents a quiet revolution in materials engineering—a process that reshapes how we design and build airplanes, trains, ships, and spacecraft, pushing the boundaries of what lightweight aluminum structures can achieve.

How does Friction Stir Welding work?
Stirweld | Friction Stir Welding

Use cases

Aerospace – fuselage panels, wings

Friction Stir Welding is a standard in aerospace manufacturing, where large aluminum panels are joined with exceptional precision. The method ensures strong, lightweight seams that withstand fatigue, making it ideal for fuselage skins and wing structures.

- **Airbus** uses FSW for assembling large fuselage panels and wing structures in the A340 and A380 programs.
- **Boeing** applies FSW for Delta II rockets and space launch systems.

Shipbuilding: aluminum decks and panels

Shipyards apply FSW for joining long aluminum panels in cruise ships and ferries. The technique reduces defects compared to fusion welding and guarantees durable, watertight joints for decks and hull structures.

- **Meyer Werft** integrates FSW for cruise ship panels.
- **Aker Yards** applies FSW in aluminum superstructures of large vessels.

Railways: high-speed train carriages

Rail manufacturers rely on FSW for lightweight train car bodies. The method produces smooth, uniform seams that improve aerodynamics, reduce maintenance, and enhance passenger safety in high-speed applications.

- **Hitachi Rail** uses FSW for aluminum body shells of high-speed trains.
- **Bombardier** applies the process in lightweight train carriage panels.

Energy – heat exchangers, wind turbine components

In the energy sector, FSW enables precise joining of complex aluminum components such as heat exchangers and wind turbine parts. The resulting welds increase efficiency, durability, and resistance to harsh operating conditions.

- **Siemens Gamesa** implements FSW in wind turbine components.
- **GE Energy** and **Alstom** use FSW in heat exchangers and power systems.

Expert recommendations

Specialists working with modern transport and aerospace systems highlight several key guidelines when it comes to aluminum structures and welding technologies such as friction stir welding:

1. Choose aluminum where fatigue resistance matters most.
Aircraft fuselages, high-speed trains, and even spacecraft fuel tanks are subjected to countless load cycles. Aluminum alloys, when properly joined, can deliver the combination of low weight and long-term durability that these industries demand.

2. Apply the technology to long, linear welds.
Large panels in aircraft wings, ship hulls, railway carriage walls, or propellant tanks benefit the most from this process. The technique is especially efficient where consistent, extended seams are required.

3. Invest in skilled operators and precise training.
Welding quality depends heavily on the correct setting of parameters such as tool rotation speed, welding pressure, and travel rate. Small deviations can make a big difference in strength and safety. Properly trained operators ensure the full potential of the technology is realized.

Alternatives

Alternatives: MIG, TIG, laser welding.

Advantages of FSW:

- No filler material needed.
- No shielding gas.
- No melting, less distortion, fewer defects.
- Very energy-efficient.

Why it works?

It works because the material remains in the solid state throughout the process, eliminating the risk of cracks, porosity, and other defects typical of conventional fusion welding.

What resources do you need

Hardware — FSW machine/robot, specialized rotating tools.
Software — CNC programming for precision paths.
Infrastructure — rigid clamping system, cooling system.
Staff — skilled operator/engineer for process parameter optimization.

Limitations

- Not suitable for ferrous metals (steel, titanium) without special tools.
- Limited to linear or circular welds.
- High initial cost of equipment.
- Requires rigid clamping of workpieces.

Challenges

Tool wear when welding harder alloys.	→	Use polycrystalline cubic boron nitride (PCBN) tools. High investment cost.
High investment cost.	→	Focus on high-volume applications to achieve ROI.
Limited geometries.	→	Hybrid methods (FSW + mechanical fastening).

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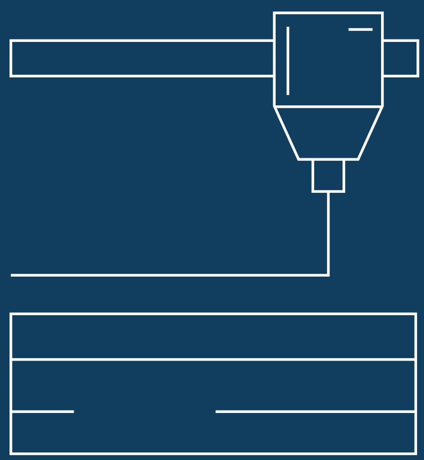


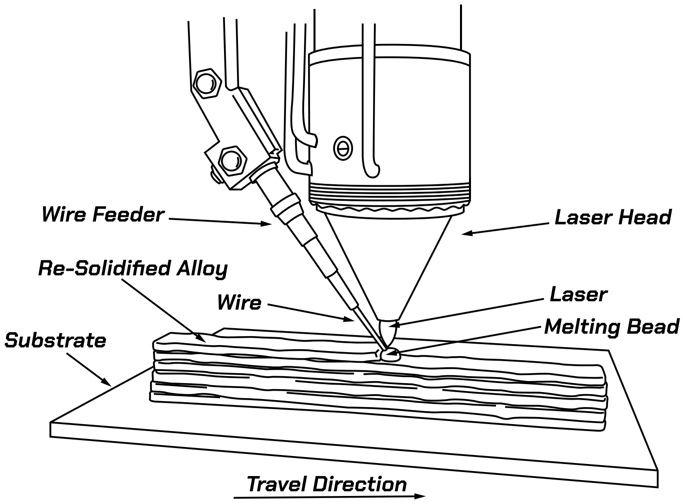
Wire Laser Metal 3D Printing

#WireLaser3DPrinting #AdditiveManufacturing #MetalAM
#LightweightDesign #NextGenManufacturing

TRL7 Demonstrated in operational environments

About the method

Wire Laser Metal 3D Printing is an additive manufacturing process that uses a laser beam to melt a continuously fed metal wire, building fully dense parts layer by layer. Unlike powder-bed methods, it avoids handling hazards, delivers high deposition rates, and minimizes waste. This makes it ideal for aerospace, energy, and automotive industries seeking scalable, sustainable manufacturing solutions.



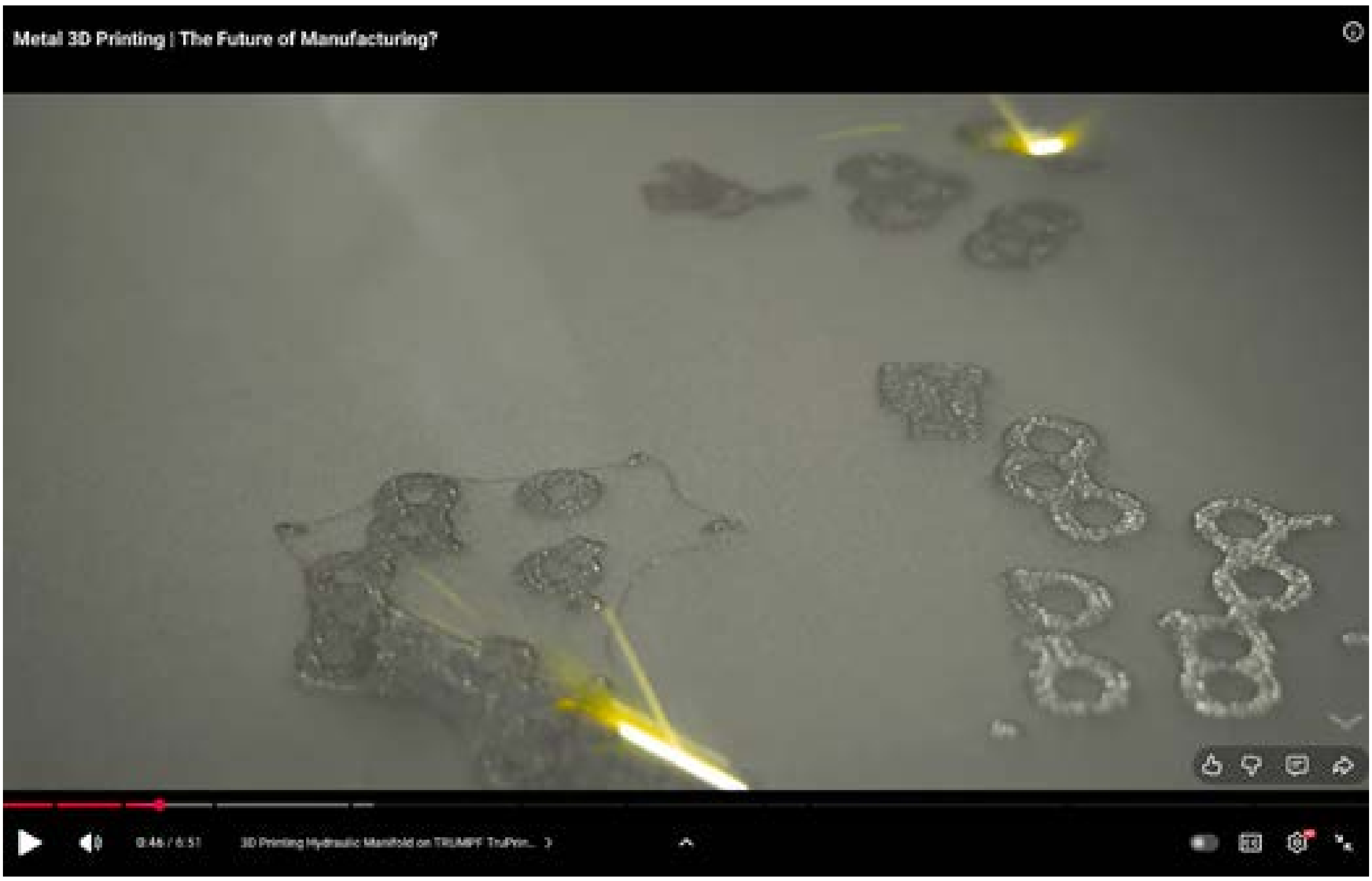
Wire Laser Metal 3D Printing is a technique that merges a high-power laser with a continuously fed wire to create near-net-shape metallic parts. Unlike powder-bed fusion, which relies on fine powders, this method uses wire as feedstock, ensuring a safer and cleaner process. The wire is melted by the focused laser and deposited layer by layer along a programmed path, producing dense, structurally sound components.

One of the primary advantages of wire-based laser AM is scalability. It supports the production of large aerospace and energy components, which are often too big or expensive to fabricate with powder-bed systems. With deposition rates significantly higher than powder methods, it shortens lead times and reduces production costs while maintaining strong metallurgical bonds. Furthermore, wire feedstock minimizes waste compared to machining, making the process both cost-efficient and resource-conscious.

Another key strength lies in sustainability. The absence of powder-handling hazards reduces health and environmental risks, while efficient energy use lowers the carbon footprint. Aerospace companies employ wire-laser AM to manufacture titanium brackets, turbine casings, and structural components. In the energy sector, it is applied for offshore parts, wind turbine components, and heat exchangers.

Automotive firms use it for tooling, rapid prototyping, and lightweight chassis elements.

However, precision and surface finish typically require post-processing, and resolution is lower than in powder-bed methods. Success depends on advanced path planning, process monitoring, and skilled operator expertise. Still, wire-laser 3D printing represents a bridge between traditional welding and modern additive manufacturing, expanding design freedom while supporting industrial-scale, sustainable production.



Metal 3D Printing | The Future of Manufacturing?
TITANS of CNC MACHINING

Use cases

Aerospace – turbine casings, space structures

Wire Laser Metal 3D Printing is widely used in aerospace and space applications, where titanium and nickel alloys must deliver high strength and reliability. The method enables both new part production and repair of large, costly components.

- **Airbus** applies wire-laser AM for structural elements in engines and fuselage assemblies.
- **SpaceX** uses the process for rocket nozzles and satellite components.

Automotive – tooling, EV battery housings

In the automotive sector, wire-based AM supports rapid tooling, prototyping, and structural parts for electric vehicles. It reduces waste and speeds up development cycles for lightweight designs.

- **Tesla** explores the technology for battery housings and crash-safe frames.
- **BMW** employs wire-laser AM for tooling inserts and prototype components.

Construction – modular steel and bridge nodes

The construction industry applies wire-laser AM to manufacture heavy-duty joints and customized nodes for bridges and modular buildings. The process provides cost savings for complex geometries.

- **MX3D (Netherlands)** built a 3D-printed steel bridge in Amsterdam.
- **Arup** has tested wire AM for structural connectors in high-rise buildings.

Medical – custom implants and surgical tools

Healthcare manufacturers adopt wire-based AM for large titanium implants and custom surgical instruments. The ability to produce patient-specific parts improves outcomes and reduces lead times.

- **Stryker** investigates wire AM for orthopedic implants.
- **Oxford University Hospitals** tested the method for surgical tool production.

Expert recommendations

Specialists working with modern aerospace and energy systems highlight several key guidelines when it comes to large-scale additive manufacturing technologies such as wire laser metal 3D printing:

1. Select wire-based AM where scalability and cost efficiency matter most.

Aerospace engines, offshore energy systems, and large automotive prototypes often require oversized components that are expensive or impractical with powder-based methods. Wire feedstock reduces waste and enables the fabrication of parts that combine high strength with economic production.

2. Apply the technology to large, near-net-shape builds.

Engine casings, ship panels, turbine hubs, and train body shells benefit the most from this approach. The process achieves high deposition rates, making it ideal where extended build volumes and consistent, dense structures are essential.

3. Invest in advanced monitoring and operator training.

Build quality depends on the precise control of parameters such as laser power, wire feed rate, and travel path. Even minor deviations can affect surface quality and structural integrity. Skilled engineers, supported by closed-loop monitoring systems, are crucial to realize the full potential of wire laser metal 3D printing.

Alternatives

Alternatives: Powder Bed Fusion (SLM, SLS), Electron Beam Additive Manufacturing (EBAM), Directed Energy Deposition with powder feed.

Advantages of FSW:

- Wire feedstock is clean, safe, and easy to handle.
- High deposition rates and scalability.
- Minimal material waste compared to machining.
- Lower health and environmental risks than powder processes.

Why it works?

It works because the wire is melted and deposited in a controlled manner, producing dense, defect-free structures without the challenges of powder handling or the porosity issues typical of other fusion-based additive manufacturing methods.

What do you need?

- **Hardware** — laser system with wire feeder, robotic arm or gantry for precise deposition.
- **Software** — path planning, process monitoring, and adaptive control algorithms.
- **Infrastructure** — inert gas shielding, cooling and clamping systems.

Staff — skilled AM engineers and operators for process optimization and quality control.

Limitations

- Lower resolution and surface finish compared to powder-bed methods.
- Post-processing often required for precision components.
- Limited alloy selection to those available as wire feedstock.
- High initial cost of equipment and integration.

Challenges

Surface roughness and accuracy limitations.	→	Apply machining or hybrid AM-subtractive finishing.
High heat input in large builds	→	Use adaptive cooling and thermal management systems.
Restricted feedstock range.	→	Collaborate with suppliers to expand available wire alloys.

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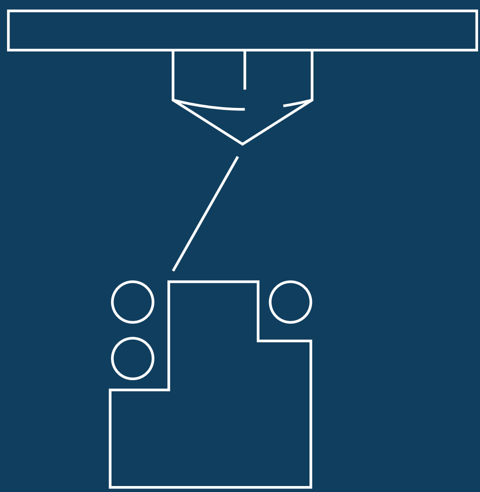


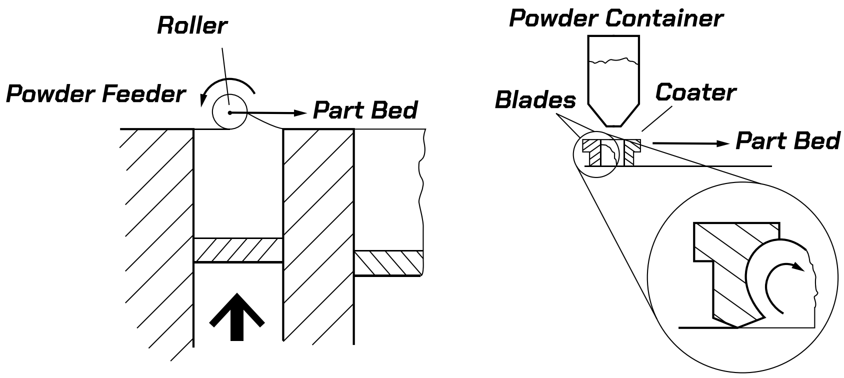
SLS/SLM with Non-Standard Powders

#SLS #SLM #PowderBedFusion #AdditiveManufacturing #NovelMaterials #ProcessOptimization

TRL 4 Technology validated in laboratory

About the method

Selective Laser Sintering (SLS) and Selective Laser Melting (SLM) with Non-Standard Powders refers to powder-bed additive manufacturing where recycled, irregular, or novel alloy powders are used instead of standardized feedstock. These unconventional powders require precise process parameter optimization—laser power, scan speed, and layer thickness—to achieve reliable results. Despite the challenges, they enable sustainable recycling, cost reduction, and development of advanced materials for aerospace, medical, and industrial applications.

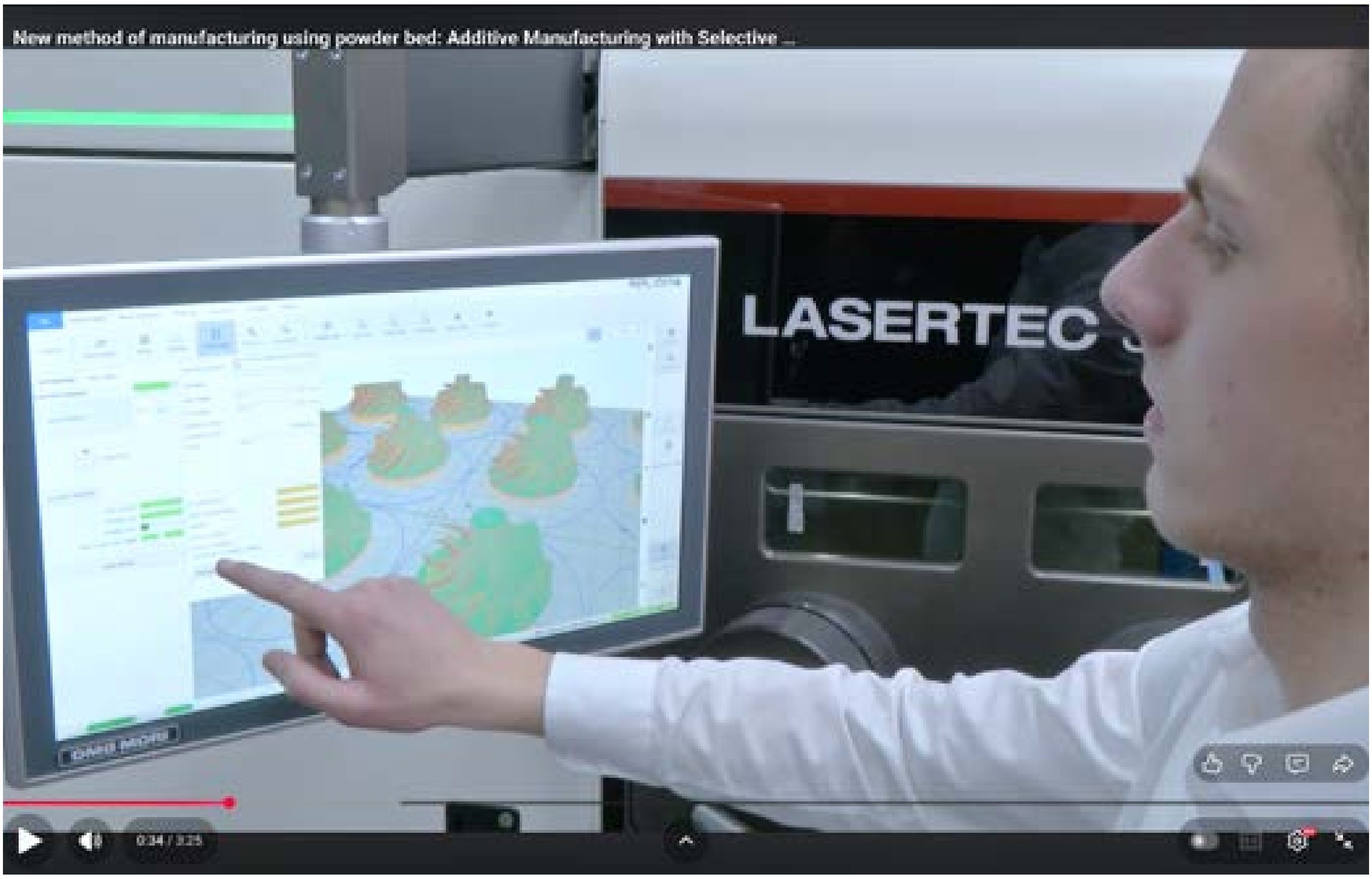


SLS and **SLM** are widely used powder-bed additive manufacturing techniques that build complex parts by selectively fusing or melting layers of powdered material with a laser beam. Traditionally, the process relies on highly standardized powders with uniform particle size, shape, and flowability to ensure predictable quality. However, growing interest in **recycled feedstock, irregular powders, and novel alloy blends** has shifted attention to the challenge of optimizing parameters for non-standard powders.

When using unconventional powders, **laser power, scan speed, hatch spacing, and layer thickness** must be carefully adjusted to account for differences in reflectivity, thermal conductivity, and packing density. Irregular particle shapes or varying size distributions can cause uneven energy absorption, leading to **porosity, incomplete melting, or warping.** This makes parameter optimization essential for producing parts with the desired density, strength, and surface finish.

To overcome these difficulties, engineers increasingly apply **design of experiments (DoE), in-situ monitoring systems, and machine learning algorithms** to identify stable processing windows. By integrating **real-time feedback** into laser control, manufacturers can adaptively compensate for powder inconsistencies and stabilize part quality.

The benefits are significant. Using non-standard powders enables **sustainable recycling of costly materials,** expands the potential for **custom alloy development,** and reduces dependence on highly refined, expensive feedstock. Aerospace, medical, and energy industries are exploring this approach to unlock new material properties while lowering costs and environmental impact. Though challenges remain, parameter selection for non-standard powders is becoming a frontier of innovation in laser powder-bed fusion.



New method of manufacturing using powder bed: Additive Manufacturing with Selective Laser Melting
DMG MORI

Use cases

Aerospace – lightweight lattice structures and novel alloys

The aerospace sector experiments with non-standard powders to achieve lighter, stronger designs and reduce costs. Recycled titanium and custom alloy blends are tested for structural brackets and lattice components.

- **NASA** has investigated alternative titanium powders for lightweight spacecraft parts.

- **Airbus** applies recycled alloy powders in prototyping for next-generation aircraft.

Medical – custom implants and biocompatible materials
In medical applications, patient-specific implants are often produced with experimental powders, including titanium blends and bioresorbable alloys. Optimized parameters ensure both strength and biocompatibility.

- **Stryker** has explored recycled titanium powders for orthopedic implants.
- **Zimmer Biomet** develops new powder blends for surgical devices.

Sustainable manufacturing – recycling and circular economy
Using recycled or reclaimed powders reduces waste and cost, enabling more sustainable production cycles. Automotive and energy industries are especially interested in powder reuse for prototyping and tooling.

- **BMW** has trialed SLM with recycled aluminum powders.
- **Siemens** has tested parameter optimization for reclaimed nickel-based powders in turbine parts.

Research and development – high-entropy alloys
Universities and labs use SLS/SLM to explore novel powder blends such as high-entropy alloys, which cannot be processed with traditional feedstocks.

- **MIT** and **ETH Zurich** have published studies on optimizing laser parameters for experimental alloy powders.

Expert recommendations

Specialists working with additive manufacturing of advanced alloys highlight several key guidelines when it comes to using non-standard powders in SLS/SLM processes:

1. Carefully characterize powders before printing.
Recycled, irregular, or experimental powders vary widely in flowability, particle size, and reflectivity. Full characterization of these properties is essential to define stable processing windows and avoid unpredictable results.

2. Use systematic parameter optimization.
Laser power, scan speed, hatch distance, and layer thickness must be tuned precisely. Applying **design of experiments (DoE)** and simulation-based modeling can help identify robust parameter sets for uncon-

ventional powders.

3. Integrate real-time monitoring and adaptive control.
Defects such as porosity or incomplete fusion can occur suddenly when using non-standard powders. Closed-loop monitoring systems with optical or thermal sensors allow in-situ corrections and significantly improve part reliability.

Alternatives

Alternatives: Electron Beam Melting (EBM), Binder Jetting with sintering, Directed Energy Deposition (powder-fed).

Advantages of SLS/SLM with Non-Standard Powders:
Enables recycling and reuse of costly alloys.
Supports development of novel and experimental materials.
Reduces dependence on expensive, highly standardized powders.
Opens pathways to more sustainable AM.

Why it works?

It works because controlled adjustment of laser parameters can compensate for powder irregularities, stabilizing the melt pool and producing dense, reliable parts even with unconventional feedstock.

What do you need?

Hardware — SLS/SLM machine with advanced sensors.
Software — parameter optimization, machine learning models, real-time monitoring.
Infrastructure — powder recycling and handling systems.
Staff — materials scientists, AM engineers, and process specialists.

Limitations

- High sensitivity to powder quality and variability.
- Parameter optimization is time-consuming and costly.
- Surface finish and density may be inconsistent.
- Limited industrial adoption beyond research stage

Challenges

Powder degradation after multiple reuse cycles.	→ Establish standardized protocols for powder recycling and qualification.
High trial-and-error cost in parameter development.	→ Leverage AI-driven predictive models to reduce experimentations
Data scarcity for new alloy systems.	→ Foster collaborations between research institutions and industry for knowledge sharing.

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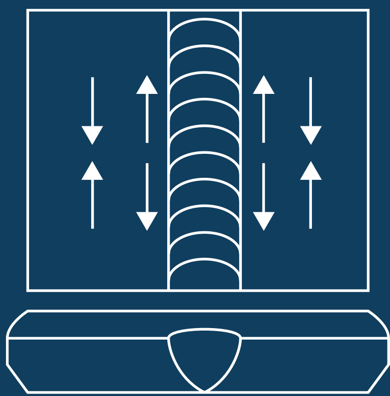


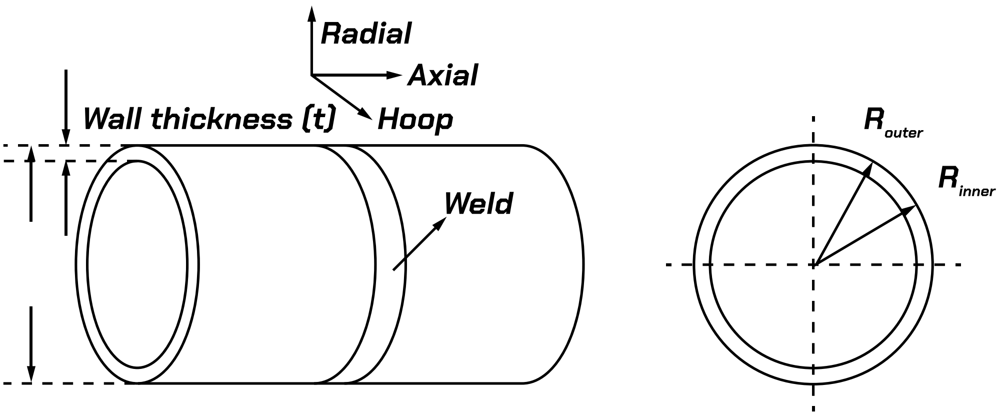
Smart prediction of residual stresses in welding

#FSW #WeldingInnovation #SolidStateJoining #LightweightStructures #AerospaceTech #GreenManufacturing

TRL 4 Technology validated in laboratory

About the method

Smart prediction of residual stresses in welding combines computational modeling, sensor-based monitoring, and AI algorithms to forecast stress distributions during and after welding. By anticipating where distortions or weaknesses will form, manufacturers can adjust parameters or sequences proactively. This approach improves fatigue life, reduces defects, and enhances reliability across aerospace, energy, and automotive applications.



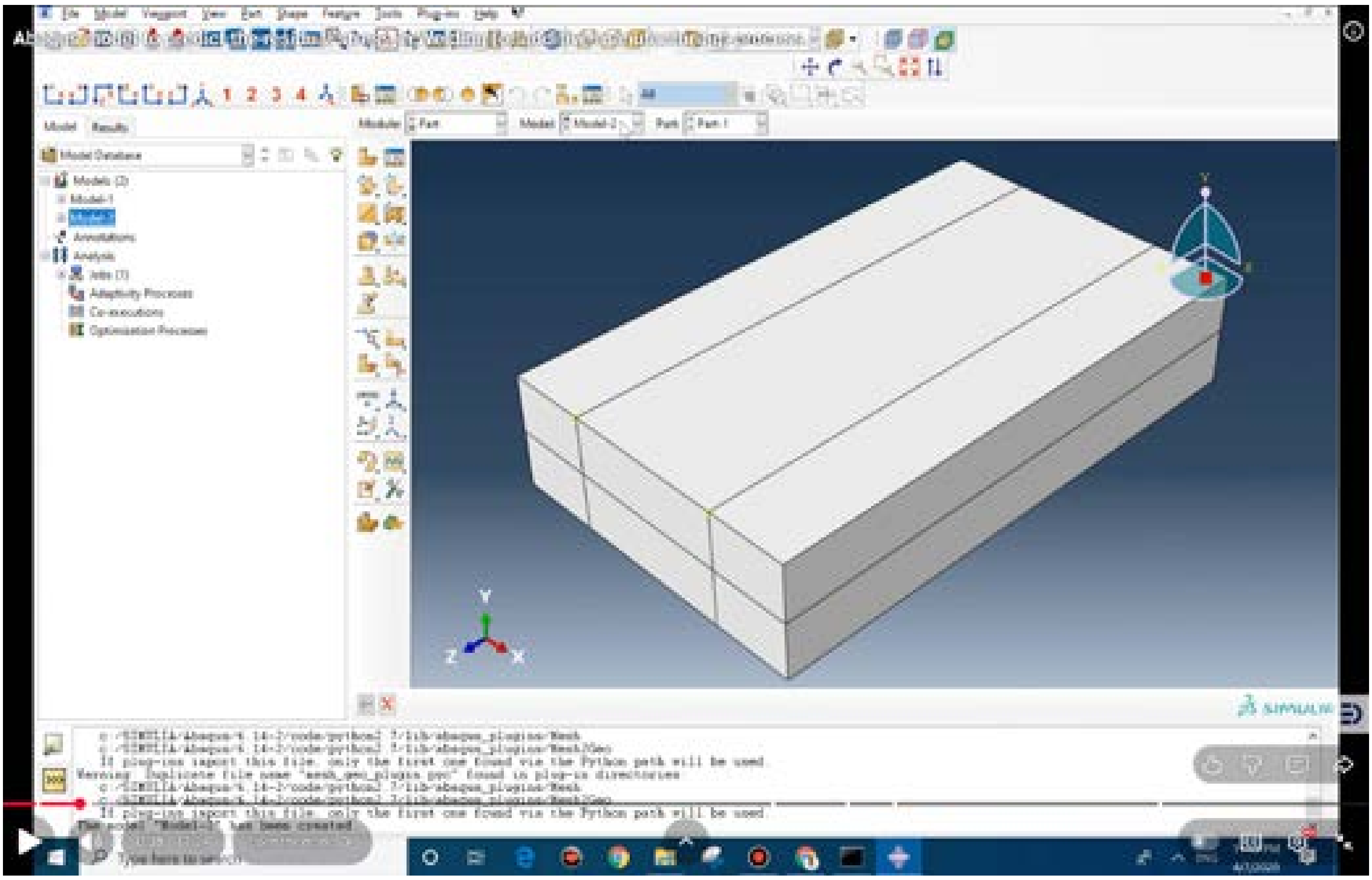
Residual stresses are an unavoidable byproduct of welding, created when rapid heating and cooling cycles cause uneven expansion and contraction of the material. These hidden stresses can distort parts, shorten fatigue life, or even trigger premature failure in safety-critical structures. **Smart prediction of residual stresses** seeks to address this challenge by integrating **computational models, sensor systems, and artificial intelligence** into the welding process.

At the core of the approach are **finite element simulations** that replicate thermal cycles, material flow, and stress evolution. Coupled with **real-time input from sensors**—such as thermocouples, strain gauges, or infrared cameras—these models generate digital twins of the welding operation. **Machine learning algorithms** further refine predictions by analyzing historical data and identifying stress patterns under varying process conditions.

This predictive capability allows engineers to apply **preventive strategies** such as preheating, adaptive cooling, optimized weld sequencing, or stress-relief treatments before defects occur. The result is greater confidence in weld integrity, lower rework costs, and extended component lifetimes.

Industries such as **aerospace,** where thin aluminum fuselage panels must resist fatigue, or **energy,** where pipelines and pressure vessels face extreme environments, benefit directly from this technology. Automotive manufacturers also use predictive models to minimize distortion in lightweight EV frames and improve assembly precision.

Although implementation requires significant computational resources and expert knowledge, smart prediction is becoming increasingly feasible with advances in high-performance computing and AI. It represents a shift from reactive inspection to proactive control, moving welding closer to a **digitally optimized, defect-free future.**



Abaqus model to predict the residual stress in Welding (or additive manufacturing) process.
Engineering Downloads

Use cases

Nuclear energy – reactor vessels and safety-critical welds
In nuclear power plants, predicting residual stresses is essential for reactor pressure vessels and containment structures, where failure is not acceptable. Advanced models allow lifetime extension and safer operation.

- **EDF Energy** applies predictive stress modeling for reactor vessel welds.
- **Westinghouse** uses simulation-based prediction for critical nuclear components.

Oil & Gas – offshore pipelines and risers
Smart stress prediction secures the integrity of long subsea pipelines, which face severe pressure and temperature fluctuations. By forecasting stress accumulation, engineers can minimize risks of cracking.
- **Shell** integrates predictive welding models for deepwater projects.
- **Petrobras** applies stress monitoring in riser and flowline construction

Construction – bridges and high-rise nodes
Large welded joints in steel bridges and skyscrapers benefit from predictive modeling, which reduces distortion and extends service life. This ensures safer and more cost-effective infrastructure.

- **Arup** has trialed predictive welding simulations for bridge nodes.
- **Skanska** employs stress analysis in high-rise structural welding.

Defense – armored vehicles and naval systems
Defense manufacturers use stress prediction to secure welds in armored vehicles, ships, and missile launch systems. Predictive models increase durability and safety under battlefield conditions.

- **BAE Systems** applies digital stress simulations for naval ship structures.
- **General Dynamics** uses predictive welding models in armored vehicle assembly.

Expert recommendations

Specialists working with advanced welding and structural engineering highlight several key guidelines when it comes to applying smart residual stress prediction technologies:

1. Integrate prediction early in the design process.
Residual stress modeling is most effective when incorporated before fabrication begins. By simulating weld sequences and heat inputs during the design stage, manufacturers can prevent costly redesigns or post-weld corrections.

2. Combine physics-based models with data-driven AI.
Finite element simulations capture thermal and mechanical behavior,

while machine learning recognizes hidden patterns in large datasets. Using both approaches together improves prediction accuracy and reduces uncertainty.

3. Invest in sensor systems and operator training.
Accurate predictions depend on real-time feedback from thermal cameras, strain gauges, and acoustic sensors. Skilled engineers and technicians are essential to interpret results and adjust welding strategies based on predictive outputs.

Alternatives

Alternatives: destructive testing, X-ray diffraction, hole-drilling, and neutron diffraction for residual stress measurement.

Advantages of smart prediction:

- Non-destructive and cost-efficient.
- Provides real-time feedback during welding.
- Improves fatigue life and reduces rework.
- Integrates directly into digital twin frameworks.

Why it works?

It works because predictive models capture the relationship between heat input, material properties, and cooling rates, allowing manufacturers to anticipate where stresses will accumulate and apply countermeasures before damage occurs.

What do you need?

Hardware — thermal cameras, strain gauges, high-resolution sensors.
Software — finite element analysis (FEA), machine learning models, digital twin platforms.
Infrastructure — high-performance computing and secure data pipelines.
Staff — welding engineers, computational modelers, data scientists.

Limitations

- High computational costs for complex assemblies.
- Accuracy depends on availability of reliable material data.
- Integration into legacy welding processes can be challenging.
- Specialist expertise required to interpret results.

Challenges

Large data requirements for training AI models.	→	Develop shared databases and industry consortia.
Sensor durability in harsh environments.	→	Design robust, heat-resistant sensor systems.
Slow adoption in small and medium enterprises.	→	Encourage hybrid approaches with simplified models for SMEs.

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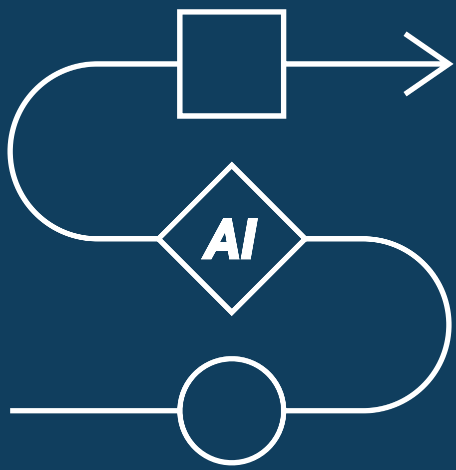
Chapter 02

OPTIMIZATION



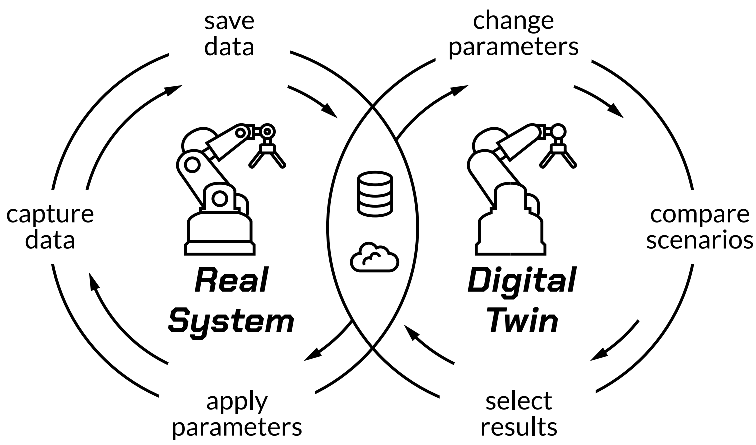
Smart process parameters optimization

#SmartManufacturing #AIinWelding #ProcessOptimization #DigitalT-wins #AdvancedManufacturing #GreenTech

TRL 5 Technology validated in relevant environment

About the method

Smart process parameters optimization uses advanced simulations, real-time sensor data, and AI algorithms to fine-tune welding and manufacturing processes. Instead of relying solely on trial-and-error, engineers apply digital twins and machine learning to identify the best combination of parameters such as heat input, speed, or pressure. The result is higher-quality joints, reduced defects, improved efficiency, and more sustainable production.



Smart process parameters optimization represents a new approach to welding and manufacturing control, where traditional trial-and-error methods are replaced by digital modeling, sensor integration, and artificial intelligence. In welding, additive manufacturing, or machining, quality and performance depend heavily on parameters such as heat input, travel speed, current, gas flow, or tool pressure. Small deviations can significantly affect strength, microstructure, and durability. Optimizing these parameters has always been critical, but until recently it required extensive testing and operator expertise.

With smart optimization, engineers create **digital twins** of the process using finite element models and historical datasets. These are continuously updated with **real-time sensor data** such as temperature, vibration, or acoustic emissions allowing predictive algorithms to simulate outcomes under different parameter settings. **Machine learning models** can then identify optimal configurations that minimize defects such as porosity, cracks, or residual stresses, while maximizing efficiency and repeatability.

The approach is especially valuable for **advanced manufacturing sectors,** where high precision and reliability are essential. Aerospace companies apply smart optimization to control welding of thin aluminum alloys, while automotive firms use it to stabilize lightweight structures in electric vehicles. In additive manufacturing, the method enables consistent builds even with challenging powders or novel alloys. Energy and construction industries benefit from improved reliability of pipelines, pressure vessels, and structural welds.

Beyond quality, smart parameter optimization also contributes to **sustainability,** reducing material waste, energy consumption, and rework. By moving from reactive inspection to proactive process control, it transforms manufacturing into a **data-driven, adaptive system,** accelerating innovation and reducing costs.

Digital Twins are Revolutionizing Manufacturing
MHM

Use cases

Aerospace – thin-walled panels and engine welds

In aerospace, parameter optimization ensures defect-free welds in thin aluminum panels and high-performance engine alloys. Adjusting heat input and travel speed prevents warping and maintains fatigue resistance.

- **Airbus** applies optimization models in fuselage panel assembly.
- **GE Aviation** uses AI-driven parameter tuning in turbine component welding.

Automotive – EV battery housings and lightweight frames
Automotive manufacturers rely on smart parameter optimization to stabilize welding in aluminum battery trays and lightweight chassis. Precision control reduces distortion and improves crash safety.

- **Tesla** employs data-driven optimization for battery housing assembly.
- **BMW** applies smart tuning for lightweight aluminum body structures.

Construction – steel bridges and modular structures
Large structural welds in bridges and modular buildings benefit from optimized heat input and sequencing. This minimizes distortion, improves durability, and reduces rework.

- **Arup** integrates optimization tools for complex bridge welds.
- **Skanska** applies adaptive welding parameters in high-rise construction.

Medical – implants and surgical instruments
Smart optimization enables consistent additive manufacturing of implants and surgical tools where precision is critical. Parameter tuning ensures biocompatibility and surface quality.

- **Stryker** uses optimized laser parameters for orthopedic implants.
- **Zimmer Biomet** applies adaptive settings in custom surgical device production.

Expert recommendations

Specialists working with advanced manufacturing highlight several key guidelines when applying smart parameter optimization technologies:

1. Define critical quality metrics before optimization.
Identifying whether the priority is fatigue resistance, surface finish, or dimensional accuracy ensures optimization focuses on the right outcomes.

2. Leverage both simulation and machine learning.
Finite element modeling predicts physical behavior, while machine learning accelerates discovery of stable parameter sets across different alloys

Alternatives

Alternatives: manual parameter selection, trial-and-error experiments, lookup tables from standards.

Advantages of smart prediction:

- Reduces time and cost compared to trial-and-error.
- Improves weld consistency and repeatability.
- Adapts dynamically to new materials.
- Enhances sustainability by lowering waste and energy use.

Why it works?

It works because algorithms capture the interactions between process parameters and material response, enabling predictive control and adaptive adjustment for stable, defect-free results.

What do you need?

Hardware — welding machines or AM systems with integrated sensors.
Software — simulation models, AI optimization engines, digital twin platforms.
Infrastructure — data acquisition, cloud or HPC computing, process monitoring.
Staff — welding engineers, data scientists, process control specialists

Limitations

- High upfront investment in sensors and computing systems.
- Relies on large datasets for accurate predictions.
- Integration into legacy manufacturing lines can be difficult.
- Requires specialized expertise to interpret optimization outputs.

Challenges

Data scarcity for novel alloys and processes.	→	Develop open databases and collaborative test programs.
Complexity of multiparameter interactions.	→	Use hybrid approaches combining physics and AI models.
Slow adoption by SMEs due to cost barriers.	→	Develop simplified, modular optimization solutions.

References

DebRoy, T., Wei, H.L., Zuback, J.S., Mukherjee, T. (2018). Additive manufacturing of metallic components – Process, structure and properties. Progress in Materials Science, 92, 112–224.

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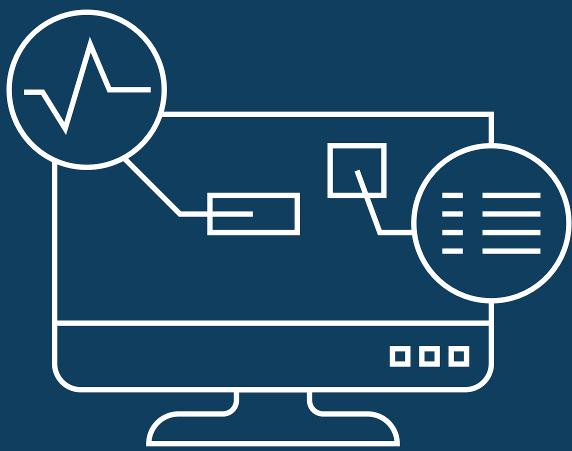

Smart real time process monitoring

#RealTimeMonitoring #AdvancedManufacturing #GreenTech

TRL 5 Technology validated
in relevant environment

About the method

Smart Real-Time Process Monitoring integrates advanced sensors, data analytics, and digital twins to continuously track manufacturing processes as they occur. It detects deviations, predicts potential failures, and enables instant corrective responses. By ensuring full transparency and adaptive control, the method improves product quality, reduces downtime, and enhances sustainability.

Imagine a production line that can “feel” what’s happening, spot problems before they appear, and even fix them automatically. That’s the idea behind Smart Real-Time Process Monitoring, a new way of making factories more intelligent, efficient, and sustainable. In the past, engineers had to stop machines to check if everything was working correctly. Today, thanks to networks of sensors and digital twins factories can monitor themselves. Every second, sensors measure things like temperature, vibration, and energy use. This data is analyzed instantly by algorithms that can recognize even the smallest irregularities. If something starts to go wrong, the system reacts immediately, adjusting parameters or alerting operators before a failure occurs.

Because the digital twin mirrors what’s happening in real life, engineers can test solutions virtually, without disrupting production. It’s like having a simulator that predicts how each change will affect quality and efficiency. This constant feedback loop helps companies make better products faster, while wasting less energy and material.

Industries such as additive manufacturing, precision welding, and energy production already use this technology to keep operations stable and sustainable. Smart monitoring also makes predictive maintenance possible machines signal when they need servicing, preventing costly breakdowns.

DELMIAworks Product Demo: RealTime Process Monitoring
DELMIAWorks

Use cases

Automotive. EV production and smart assembly lines

Automotive factories use real-time process monitoring to maintain precision in robotic welding, painting, and battery module assembly. AI analyzes streaming data to instantly correct deviations that could affect vehicle safety or efficiency.

- **Tesla** monitors temperature and current flow during battery pack welding to prevent overheating.
- **Volkswagen** applies smart sensors across its modular assembly lines to reduce downtime and ensure consistent quality.

Energy. Wind turbine and pipeline fabrication

In energy infrastructure, smart monitoring ensures the integrity of welds and joints in wind towers and pipelines. Continuous data from strain and ultrasonic sensors helps predict failures before they happen.

- **Siemens Gamesa** uses live stress monitoring to detect fatigue in wind turbine towers.
- **Shell** applies digital twin–driven monitoring to track pressure and thermal stability in offshore pipeline construction.

Construction. Bridges and industrial installations
On large construction sites, real-time monitoring systems track temperature, humidity, and stress during welding or curing processes. The data helps prevent cracks, ensure alignment, and reduce costly rework

- **Skanska** employs live process monitoring in modular building fabrication.
- **Arup** integrates digital twin dashboards to visualize stress evolution in bridge structures.

Medical. Additive manufacturing of implants
In medical device production, smart monitoring provides continuous control over 3D printing and laser processes used to manufacture implants and surgical tools. This guarantees precision and biocompatibility.

- **Stryker** monitors temperature and layer consistency in titanium implant printing.
- **Zimmer Biomet** uses AI-based monitoring to validate each production step for patient safety.

Expert recommendations

Specialists working with advanced manufacturing highlight several key guidelines when applying smart parameter optimization technologies:

1. Define critical quality metrics before optimization.
Identifying whether the priority is fatigue resistance, surface finish, or dimensional accuracy ensures optimization focuses on the right outcomes.

2. Leverage both simulation and machine learning.
Finite element modeling predicts physical behavior, while machine learning accelerates discovery of stable parameter sets across different alloys and geometries.

3. Ensure operator training and monitoring.
Even with automation, skilled engineers are needed to validate data-driven decisions, maintain calibration, and interpret optimization results in real-world conditions.

Alternatives

Alternatives: manual parameter selection, trial-and-error experiments, lookup tables from standards.

Advantages of smart optimization:

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