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A framework for strategic alignment of development activities in accordance with agile principles for direct manufacturing applications

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Abstract

Advances in process and production engineering, growing material diversity and new design for additive manufacturing (DfAM) methods are driving the adoption of additive manufacturing (AM) for series production of complex products. The economic efficiency of such direct manufacturing applications depends on the extent to which the design potential offered by these technologies can be realised in the final product to meet the product requirements. To support in this endeavour, research has so far focused on the proposal of DfAM methods. As a result, much of the design potential has been tied to designers implementing these methods, while higher-level development processes have rarely been adapted to the technological characteristics of these technologies. In this article, we propose a development framework for direct manufacturing that allows companies to align their development activities strategically in line with principles of agile development, enabling them to benefit from synergies between the methodological aspects of iterative, incremental development and the technological characteristics of AM. The framework comprises three core elements: product and potential identification, prioritisation of product features according to DfAM potential and incremental design. These elements are derived from the synthesis of the results of a recent qualitative study of 11 German companies on the challenges of industrialising AM, and of five quantitative studies on the state of agile hardware development in the German-speaking economic area between 2019 and 2023. The framework illustrates how applications for direct manufacturing can be identified by analysing technological contradictions within product requirements. The extended design space of DfAM is used to resolve these contradictions, with a TRIZ-based method presented for this purpose. To maximise DfAM potential in the final product, a prioritisation logic is introduced to guide the incremental design in iterations.

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1. Introduction

Since the industrialisation of additive manufacturing (AM), there has been growing interest in using these technologies beyond prototyping to produce end-use parts, known as direct manufacturing (DM) [1]. Today, nearly one in three components produced on an industrial AM system is intended for series production, making DM the largest share of this technology's use in industrial practice [2]. The introduction of AM for direct manufacturing created additional requirements for product development compared to prototyping [3]. This

gave rise to the research field of 'design for AM (DfAM)', which focuses primarily on design methods (e.g. [4]) and development methodologies (e.g. [5,6]) to integrate the potentials offered by DfAM into products. The importance of this research field was further validated by the unprecedented standardisation efforts of ISO and ASTM, which unified key aspects of DfAM methodology for industrial use in the standard 52910 [7]. However, knowledge in the field of DfAM has mainly been formalised as methods to support designers in product design, while higher-level development processes have rarely been adapted to the technological characteristics of these

technologies [8]. Development frameworks for DM still integrate the proposed DfAM methods primarily into traditional, plan-driven approaches [9]. Research on DfAM methods recognised early on the importance of the initial development phases [10]. Subsequent industry studies identified confirmed the need for methodological DfAM support in the early stages of development [11]. Consequently, particular emphasis was placed on the development of design priming methods, which aim to make DfAM expertise available in the geometrically indistinct early phases to support the generation of AM-compatible concepts [12]. However, recent findings from industrial practice suggest that the DfAM knowledge developed thus far is challenging to implement in actual development processes [13]. Since DfAM expertise is largely tied to methods and individual users, this knowledge is not fully available in every phase of the development process for DM. Early development phases are particularly affected, as the engineers with the most DfAM expertise are typically also involved in operating the AM systems and are therefore frequently only consulted in late stages of the development process. This problem is exacerbated by plan-based development methodologies, as the stage-gate approach further promotes the fragmentation of DfAM expertise throughout the development process. In plan-based development, most of the DfAM potential of products is determined during the concept phase and can hardly be influenced in the subsequent phases up to production, which contradicts the inherent iterative capability of AM (see Fig. 1).

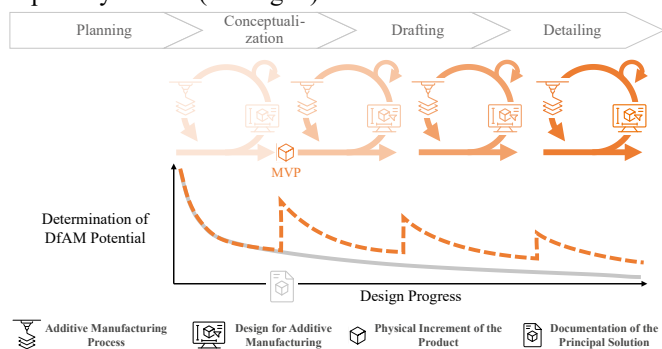


Fig. 1. Schematic comparison of the determination of DfAM potential during the development of a component for AM: plan-driven (grey) versus agile (orange).

The shift from conventional thinking towards an AM mindset in product design, which is often discussed in DfAM research (e.g. [14]), is therefore not only a problem that needs to be solved at the individual level, but also at the process and organisational levels.

For these reasons, we propose that product development for direct manufacturing should be guided by the principles of agile hardware development to benefit from synergies between the methodological aspects of iterative, incremental development and the technological characteristics of AM. The main advantage of the agile approach is that the undetermined design space can be regained between iterations, while physical increments of the final product are already produced, thereby reducing the risk of a fixed principal solution (concept) without involving all DfAM knowledge resources (Fig. 1). This paper presents an agile framework comprising three elements:

product and potential identification; prioritisation of product features according to DfAM potential; and incremental design. This framework addresses the persistent challenge of DfAM knowledge fragmentation in industrial practice and establishes the basis for applying agile principles to product development for DM.

AM	additive manufacturing
DfAM	design for additive manufacturing
DM	direct manufacturing

2. Literature background

2.1. Agile development for additive manufacturing

Literature largely agrees that the technological properties of additive manufacturing processes exhibit synergies with the methodological perspective of agile hardware development. These synergies are primarily based on the increased flexibility compared to conventional methods [15], enabling physical increments to be produced directly from CAD data without tools [8]. This reduction in lead time [16] promotes the frequent realization of physical increments, which are of high importance for agile hardware development [17]. Almeida et al. highlight that the flexibility of AM can be leveraged to support product development by quickly producing and testing physical artefacts, thereby generally reinforcing the concept of agility [15]. The authors thus propose an agile framework that involves the customer in each iteration to use their feedback for adapting the product backlog for subsequent iterations. Enkler & Sporleder describe AM technology as virtually predisposed to agile workflows, as it offers the potential to support early stages of product development by providing physical products [18]. Fontana et al. defined seven value-adding clusters for the industrial use of AM, with prototyping, incremental product launch, and customisation linked to agile development principles [19]. Montero et al. demonstrate that incorporating agile principles, even in projects not strictly following overarching agile methodologies, enhances resilience to volatility and improves the quality of additively manufactured spare parts [20–22]. Omidvarkarjan et al. [17] show how additively manufactured physical increments in agile hardware development contribute to the mitigation of issues associated with the Constraints of Physicality as defined by [23]. Both Reichwein et al. [8] and Schmitt et al. [9] propose Scrum frameworks adapted for AM. The framework by [8] addresses the increased efficiency in realizing a functional prototype with AM, as the hardware equivalent of a Minimum Viable Product.

Apart from these synergies, the literature offers only superficial discussions on how agile development can be applied to DM and how this could improve the implementation of existing DfAM knowledge within organisational structures. Comprehensive agile frameworks integrating DfAM methods are rare; where proposed, their application and implications remain vague. DfAM-knowledge fragmentation as well as product and potential identification for DM, which we consider the main barriers to industrial adoption, remain unaddressed in this context.

2.2. DfAM with TRIZ

TRIZ (Teoriya Resheniya Izobretatelskikh Zadach), known in English as the theory of inventive problem solving, is a qualitative theory for supporting the solution of technical problems [24]. Developed by Genrich Altshuller (1926–1998), TRIZ provides diverse aids for solving technical problems, grounded in extensive experiential knowledge from patent analyses. It is axiomatically assumed that inventing is characterised by resolving contradictions. A general procedure according to Wenzke can be described in four steps [25]:

- The specific problem is first abstracted, e.g., via function analysis, to reduce complexity.
- At the abstract level, the problem is formulated to identify contradictions; these resemble the core of the problem and resolving them enables a holistic solution.
- From a set of 40 inventive principles, the contradiction matrix [26] is used to identify those suited to resolving the formulated technical contradictions.
- Finally, the abstract solutions are translated into specific solutions; this step relies heavily on the user's domain expertise.

TRIZ has also influenced DfAM method development. Studies examining the overlaps between TRIZ inventive principles and established DfAM methods are particularly relevant for this work. Independent studies by Kretschmar & Chekurov [27], Lang et al. [28], and Mazlan et al. [29] consistently identified a set of eight TRIZ principles that are particularly well supported by DfAM methods: *local property*, *asymmetry*, *merging*, *multi-purpose use*, *nesting*, *curvature*, *higher dimension* and *porous materials*.

3. Empirical data and information from previous studies

3.1. Study on industrial challenges in DfAM

The following presents five key challenges in current industrial product development for AM. They derive from a thematic analysis of interviews conducted in 2024 across 11 German-speaking companies [13].

Decision-making: Decisions for or against the use of AM are often opportunistic and uninformed rather than methodical. Early leaps in thinking by individual designers tend to set the course in component design without involving DfAM experts. It is often unclear when in the development process decisions for AM are made or revised. Multiple, poorly defined gates encourage ad-hoc decisions. **Lack of an additive mindset:** Decision-makers and designers rarely recognise when 3D printing can solve a real problem. DfAM potential often remains unnoticed in early phases. **Illusory expectations:** Overestimating technological capabilities of AM leads to unsuitable designs. When manufacturing limits become evident, these flawed designs are used as arguments against AM. **Late involvement of AM expertise:** DfAM experts are frequently consulted too late in the design process. Time pressure leads teams to rush into design processes causing potential to be lost early. **Reluctance towards metal AM:** Metal-based additive manufacturing is primarily relevant for end-use components. Integrating metal AM often exposes

methodological weaknesses, such as the inability to identify suitable components.

3.2. Studies on agile hardware development

From 2019 to 2023, industrial practice in the DACH region (Germany, Austria and Switzerland) shows a consistent picture: Agile development is used across sectors and company sizes. Perceived benefits manifest themselves mainly in soft factors: better intra-team communication, faster response, and greater transparency, while hard KPI improvements in time and cost are less often affirmed [30]. Iterative work is widespread, but producing MVPs or demonstrable hardware increments remains a key challenge. Companies use various physical and virtual demonstrators and do not view prototypes as the dominant cost driver [31,32]. Most companies use AM to manufacture physical increments [30]. These applications represent rapid prototyping, as series products are not additively manufactured. Implementation is shifting from pilots to scaled setups. The main challenges are synchronisation, coordination, and dependency management, especially at interfaces between agile and non-agile development units [33]. Methodologies are typically adapted; “by-the-book” application of agile frameworks is rare [30].

4. Research approach

The study underpinning this article employs a mixed-methods approach. The fundamental hypothesis is based on empirical observations from the study presented in Chapter 3.1.: We contend that DfAM knowledge from research is difficult to integrate into industrial product development. Predominant stage-gate models in plan-based development promote the fragmentation of DfAM expertise and hinder its continuous application. Therefore, the development methodology for direct manufacturing should be aligned with principles of agile development. To address this issue, concrete elements of an agile development framework for direct manufacturing are derived, based on the iterative and incremental principles of agile development [34]. To ensure the practical relevance of such a framework, it is important to understand how these agile principles have so far been interpreted and applied in the hardware industry. For this reason, the results of five quantitative studies on the status of agile hardware development in the German-speaking economic region from 2019 to 2023 are also incorporated into the analysis (Chapter 3.2). The final synthesis of the findings identifies the three essential elements of the framework presented in this article. For each element, the respective necessity is explained and discussed. Insights into completed, ongoing or future work on the individual elements are provided.

4.1. Product and potential identification

The ability to identify suitable products within an existing portfolio, as well as the ability to identify potential opportunities for new developments, addresses a key challenge in industrial practice and represents a core element of the agile development framework for DM presented here. The proposed

identification logic is based on elements of TRIZ. It hypothesizes that AM is particularly suited for resolving technical and physical contradictions by applying the innovation principles of TRIZ within the expanded design space of DfAM. The method presented here is based on a logical inversion of the TRIZ problem-solving approach described in Chapter 2.2. Methodologically, this represents a TRIZ reverse approach, adapted for the first time to identify potentials and products for AM. Starting from the DfAM methods that exhibit inherent synergies with TRIZ inventive principles, the associated conflicting parameters are identified. Such conflicts may arise directly from product requirements and can therefore be used in the early, shape-agnostic development phases to assess the suitability of DfAM. This logic can also be applied to existing product portfolios. For physical products, a product portfolio reflects a company's material- and form-related competencies. To support a company in identifying suitable products for DM in its portfolio, we therefore propose to analyse which contradictions have already had to be resolved in its product design. By identifying the parameters associated with these technical contradictions, it is possible to suggest further products in the portfolio for which these parameters are also relevant in their design. Figure 2 shows an exemplary application of this method. Based on a portfolio of military personal protective equipment, products were identified that are generally suitable for DM and can be improved through DfAM. The identified application must satisfy technical contradictions. The central contradiction is achieving high kinetic energy absorption at low weight. At the parameter level, the specific technical contradiction arises between 'stability' and 'weight of a moving object'. Resolving this contradiction through design requires deviating from geometric primitives and adjusting the local mechanical properties of the energy-absorbing structure between the outer shell and the liner inside the helmet. DfAM provides abstract solution approaches to the design problem through innovation principles such as 'local property', 'asymmetry', 'nesting', 'curvature', and 'higher dimension'.

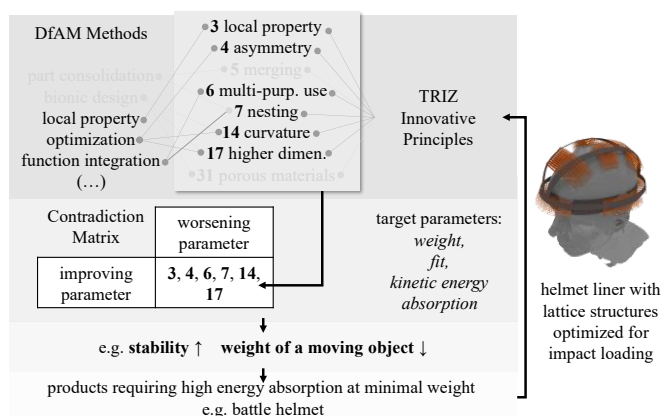


Fig. 2. Application example of the TRIZ-based identification method: A portfolio of military protective equipment shows technical contradictions between requirements for high strength and low weight. Suitable TRIZ principles overlap with the highlighted DfAM methods.

The concrete solution was to develop and employ additively manufactured lattice structures with optimised kinetic energy

absorption and high adaptability [35]. These are iteratively incorporated into the helmet liner design, integrating TRIZ innovation principles and the corresponding DfAM methods (see Fig. 2)

4.2. Iterative and incremental DfAM

An iterative, incremental approach is technologically suited for DM, as issues related to tooling and long lead times for producing physical increments are less pronounced compared to conventional manufacturing processes [16]. Moreover, an iterative approach to designing components for AM has been shown to enhance end-product quality through cyclical expansion of the design [21]. We therefore regard the DfAM process as inherently iterative and incremental. In practice, however, it must be considered that products can be complex systems also comprising physical components that are not suitable for AM. The cited synergies do not necessarily provide a solution for creating physical increments and MVPs in short iterations when there are functional dependencies between AM and non-AM components, especially for long-lead items. Therefore, the methodological scope introduced by the iterative–incremental element of the agile framework is limited to the additive parts of the final product to avoid disillusionment. For this, DfAM offers a broad design space to be utilized for defining increments. Given the proximity of digital models to their additively manufactured physical representations, we also suggest treating both as valid increments (provided they meet a clear definition of done). In this context, we recommend companies to evaluate how they can profitably use the possibilities of scaling and changing materials and processes when creating physical increments (see [20–22]). From a methodological perspective, we also recommend considering the approach from [17] of keeping product features deliberately simple initially and only elaborating on them after customer validation. A distinctive feature of the framework presented here is that, once a DM application has been identified using the method in Chapter 4.1, information on potentially applicable DfAM methods for design is already available. This applies particularly to DfAM methods that overlap with the TRIZ innovation principles, e.g. principle 5 *merging* and the corresponding DfAM method *part consolidation*. Access to information on these DfAM methods is not limited to academic literature or tacit knowledge, since extensive knowledge of these methods is already embedded in industry standards ([36] provides an overview). Iterative, incremental DfAM also addresses the problem of knowledge fragmentation in companies. The composition of cross-functional teams systematically promotes the integration of designers with extensive DfAM expertise from the outset.

4.3. Prioritization of product features

In agile product development, specific features of the final product are implemented iteratively. This iterative extension of physical increments reflects a prioritised realization of requirements for the final product, with interim results being continuously made available to the customer. In Scrum, such prioritisation is implemented, for example, by moving items

between the Product Backlog and Sprint Backlog [37]. With the agile development approach for DM presented here, we place particular emphasis on the importance of prioritising backlog items for DfAM. An adapted prioritisation logic is essential to ensure that the extended design space offered by DfAM is not restricted in the first iteration. This is illustrated in Fig. 3. using a simplified component: The product is a compressor wheel that must meet only two requirements (presented here as backlog items) and is developed in two iterations. The first requirement (1) concerns a high air flow rate, the second (2) high pressure build-up. Figure 3 demonstrates how the order in which these backlog items are implemented can affect the geometry of the physical increment after the first iteration.

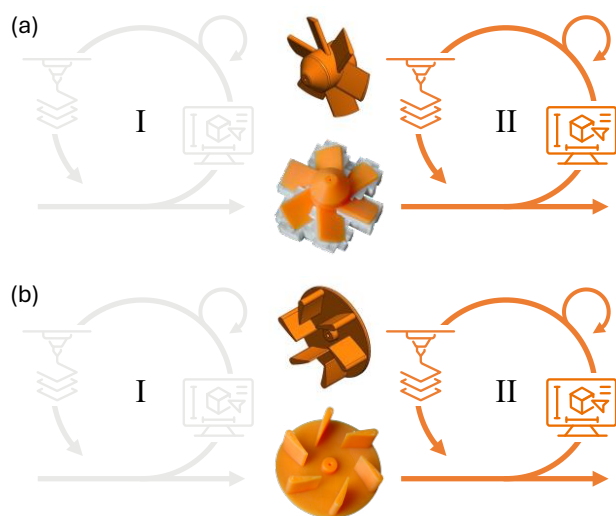


Fig. 3. Effect of backlog prioritization on the design of a compressor after the initial iteration (I). (a) I: (1) high air flow rate over (2) high pressure build-up. (b) I: (2) high pressure build-up over (1) high air flow rate.

If (1) is prioritised over (2), the first physical increment has an axial geometry (Fig. 3. a). With the reverse prioritisation, a radial compressor design results (Fig. 3. b). Since the remaining requirement must be fulfilled for the final product in both cases, it becomes clear that, depending on the first increment, different design parameters are available for this purpose if the initial design is retained. One reason to retain the initial design could be that the first physical increment meets the definition of the minimum viable product and has been validated by the customer. In this case, the customer may expect the product to maintain this validated design, and any adjustments in the product backlog would be made accordingly. In this example, the fan was to be printed using FDM. For the axial design, this is only possible with support structures, demonstrating that prioritising item (1) already has implications for manufacturability. Extending the length of the blades to meet the remaining requirement would furthermore result in the increment from iteration II having a larger diameter in the axial design, while the radial design would have a greater overall height. When scaling the significance of this simple example to the development of more complex products for AM, it becomes clear that the prioritisation of backlog items has a significant impact on realising the overall DfAM potential of the final product. Extrapolating to complex AM products,

backlog prioritization shapes the achievable DfAM potential. Correct prioritization establishes the most essential baseline features early, simultaneously meeting requirements and preserving maximum design freedom. Instruments such as the Kano model [38] can be used to guide this.

5. Conclusion and further work

This contribution presents an agile product development framework for direct manufacturing. Based on empirical data from a study on the current challenges in AM product development, we conclude that agile principles are suitable for addressing the prevailing fragmentation of DfAM knowledge within industrial development processes. In addition, the framework supports the identification of suitable products and opportunities for direct manufacturing, another fundamental challenge in industry. The three core elements of the framework are introduced and discussed in the context of the state of the art in academic literature on combining AM with agile hardware development. We thus broaden the literature's focus by examining how agile principles can be utilized to advance the industrialisation of AM through a development methodology for end-use parts synergistic with the characteristics of these technologies. We acknowledge the significant progress that has been made in the development of DfAM methods. At the same time, however, our framework addresses the practical constraints that still hinder the implementation of this knowledge. Several studies are currently underway to extend the framework elements presented here and to validate them in practice. An international survey investigates to what extent industry is prepared to adopt agile working methods for direct manufacturing. In addition, the presented TRIZ-based product identification method is currently being tested in more than ten university projects on additive manufacturing. Due to the limited scope of this contribution, we refrain from including preliminary results from these studies and instead focus on the theoretical basis of the three core elements. Soon, we will publish work demonstrating the framework's practical applicability. In view of the above, we conclude that the framework presented here should be understood as a theoretical foundation for an agile development methodology tailored to direct manufacturing contexts. The constituent methods require further refinement for practical applications, which should explicitly reference the framework elements adapted to the defining characteristics of AM technologies. The authors are confident that systematically addressing and elaborating on the framework's key elements: product and potential identification, iterative and incremental DfAM, and feature prioritisation adapted to DM, constitutes a set of pivotal success factors for fully exploiting the potential of AM from a development methodology perspective.

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References

- [1] M. K. Thompson et al., "Design for Additive Manufacturing: Trends, opportunities, considerations, and constraints," *CIRP Annals*, vol. 65, no. 2, pp. 737–760, 2016, doi: 10.1016/j.cirp.2016.05.004.
- [2] Wholers Associates and ASTM International, "WOHLERS REPORT 2024: 3D PRINTING AND ADDITIVE MANUFACTURING GLOBAL STATE OF THE INDUSTRY," Washington, DC, 2024. [Online]. Available: wholersassociates.com
- [3] I. Gibson, D. Rosen, B. Stucker, and M. Khorasani, Eds. *Additive Manufacturing Technologies*. Cham: Springer International Publishing, 2021.
- [4] F. LAVERNE, F. Segonds, N. Anwer, and M. Le Coq, "Assembly Based Methods to Support Product Innovation in Design for Additive Manufacturing: An Exploratory Case Study," *Journal of Mechanical Design*, vol. 137, no. 12, 2015, Art. no. 121701, doi: 10.1115/1.4031589.
- [5] R. Lachmayer, T. Ehlers, and R. B. Lippert, Eds. *Entwicklungsmethodik für die Additive Fertigung*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2022.
- [6] M. Kumke, "Methodisches Konstruieren von additiv gefertigten Bauteilen," Dissertation, Technische Universität Braunschweig, Wiesbaden, 2018.
- [7] DIN EN ISO/ASTM 52910, *Additive Fertigung – Konstruktion – Anforderungen, Richtlinien und Empfehlungen (ISO/ASTM DIS 52910:2022)*, DIN e. V.
- [8] J. Reichwein, S. Vogel, S. Schork, and E. Kirchner, "On the Applicability of Agile Development Methods to Design for Additive Manufacturing," *Procedia CIRP*, vol. 91, pp. 653–658, 2020, doi: 10.1016/j.procir.2020.03.112.
- [9] P. Schmitt, L. Siewert, and K. Gericke, "A proposal for guiding the selection of suitable DfAM support based on experiential knowledge," *Proc. Des. Soc.*, vol. 4, pp. 1829–1838, 2024, doi: 10.1017/pds.2024.185.
- [10] F. Laverne, F. Segonds, N. Anwer, and M. Le Coq, "DFAM IN THE DESIGN PROCESS: A PROPOSAL OF CLASSIFICATION TO FOSTER EARLY DESIGN STAGES," 2014.
- [11] P. Pradel, Z. Zhu, R. Bibb, and J. Moultrie, "Investigation of design for additive manufacturing in professional design practice," *Journal of Engineering Design*, vol. 29, 4-5, pp. 165–200, 2018, doi: 10.1080/09544828.2018.1454589.
- [12] S. Pearl and N. A. Meisel, "Assessing the Manufacturability of Students' Early-Stage Designs Based on Previous Experience With Traditional Manufacturing and Additive Manufacturing," *Journal of Mechanical Design*, vol. 146, no. 1, 2024, Art. no. 012301, doi: 10.1115/1.4063564.
- [13] F. Günther, G.-J. Tüzün, M. Kreimeyer, and A. Koch, "Current challenges in the development of products for additive manufacturing - an interview study," *Proc. Des. Soc.*, publication in progress, 2025.
- [14] R. Prabhu, T. W. Simpson, S. R. Miller, S. L. Cutler, and N. A. Meisel, "Teaching Designing for Additive Manufacturing: Formulating Educational Interventions That Encourage Design Creativity," *3D printing and additive manufacturing*, early access. doi: 10.1089/3dp.2021.0087.
- [15] J. F. de Almeida, D. C. Amaral, and R. T. Coelho, "Innovative Framework to manage New Product Development (NPD) Integrating Additive Manufacturing (AM) and Agile Management," *Procedia CIRP*, vol. 103, pp. 128–133, 2021, doi: 10.1016/j.procir.2021.10.020.
- [16] K. von Petersdorff-Campen et al., "3D Printing of Functional Assemblies with Integrated Polymer-Bonded Magnets Demonstrated with a Prototype of a Rotary Blood Pump," *Applied Sciences*, vol. 8, no. 8, p. 1275, 2018, doi: 10.3390/app8081275.
- [17] D. Omidvarkarjan et al., "Prototyping Strategies for the Agile Development of Additive Manufactured Products: A Case Study from the COVID-19 Pandemic," in *Proceedings of the 31st Symposium Design for X (DFX2020)*, Dec. 2020, pp. 161–168, doi: 10.35199/dfx2020.17.
- [18] H.-G. Enkler and L. Sporleder, "Agile Product Development—coupling explorative and established CAX methods in Early Stages of Virtual Product Development," *Procedia CIRP*, vol. 84, pp. 848–853, 2019, doi: 10.1016/j.procir.2019.04.221.
- [19] F. Fontana, C. Klahn, and M. Meboldt, "Value-driven clustering of industrial additive manufacturing applications," *JMTM*, vol. 30, no. 2, pp. 366–390, 2019, doi: 10.1108/JMTM-06-2018-0167.
- [20] J. Montero, S. Weber, M. Bleckmann, and K. Paetzold, "A methodology for the decentralised design and production of additive manufactured spare parts," *Production & Manufacturing Research*, vol. 8, no. 1, pp. 313–334, 2020, doi: 10.1080/21693277.2020.1790437.
- [21] J. Montero, S. Weber, M. Bleckmann, A. Atzberger, L. Wirths, and K. Paetzold, "Spare part production in remote locations through Additive Manufacturing enhanced by agile development principles," in *2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)*, Valbonne Sophia-Antipolis, France, 2019, pp. 1–8, doi: 10.1109/ICE.2019.8792631.
- [22] J. Montero, A. Atzberger, M. Bleckmann, J. Holtmannspotter, and K. Paetzold, "Enhancing the Additive Manufacturing process for spare parts by applying Agile Hardware Development principles," in *2019 IEEE 10th International Conference on Mechanical and Intelligent Manufacturing Technologies (ICMIMT)*, Cape Town, South Africa, 2019, pp. 109–116, doi: 10.1109/ICMIMT.2019.8712045.
- [23] N. Ovesen, "The Challenges of Becoming Agile," Aalborg University, Aalborg, 2012.
- [24] M. A. Orloff, *Grundlagen der klassischen TRIZ: Ein praktisches Lehrbuch des erfinderischen Denkens für Ingenieure ; mit 374 Beispielen*, 3rd ed. (VDI-Buch). Berlin, Heidelberg: Springer, 2006.
- [25] S. Wenzke, "Flexible Gestaltung des Analyseprozesses technischer Probleme mit TRIZ-Werkzeugen," Dissertation, Technische Universität Cottbus, Cottbus, 2003.
- [26] D. Mann, S. Dewulf, B. Zlotin, and A. Zusman. "Matrix 2003." Accessed: Aug. 26, 2025. [Online]. Available: https://www.triz-consulting.de/wp-content/uploads/2021/09/matrix2003-eng_v4.pdf
- [27] N. Kretschmar and S. Chekurov, "The Applicability of the 40 TRIZ Principles in Design for Additive Manufacturing," in *Proceedings of the 29th International DAAAM Symposium 2018 (DAAAM Proceedings)*, B. Katalinic, Ed., DAAAM International Vienna, 2018, pp. 888–893.
- [28] A. Lang, C. Gazo, F. Segonds, F. Mantelet, C. Jean, J. Guegan, S. Buisine, "A Proposal for a Methodology of Technical Creativity Mixing TRIZ and Additive Manufacturing," in *New Opportunities for Innovation Breakthroughs for Developing Countries and Emerging Economies*, R. Benmoussa, R. de Guio, S. Dubois, and S. Koziolok, Eds., Cham: Springer International Publishing, 2019, pp. 106–116.
- [29] S. N. H. Mazlan, A. Z. Abdul Kadir, M. Deja, D. Zieliński, and M. R. Alkahari, "Development of Technical Creativity Featuring Modified TRIZ-AM Inventive Principle to Support Additive Manufacturing," *Journal of Mechanical Design*, vol. 144, no. 5, 2022, Art. no. 052001, doi: 10.1115/1.4052758.
- [30] A. Atzberger, S. J. Nicklas, J. Schrof, S. Weiss, and K. Paetzold, "Agile Entwicklung physischer Produkte 2020," 2020, doi: 10.18726/2020_5.
- [31] S. Weiss, K. Paetzold-Byhain, M. Michalides, M. Pendzik, F. Scharold, and L. Stoiber, "Agile Entwicklung physischer Produkte 2023," 2023, doi: 10.25368/2023.213.
- [32] T. Schmidt, A. Atzberger, C. Gerling, J. Schrof, S. Weiss, and K. Paetzold, "Agile Entwicklung physischer Produkte 2019,"
- [33] M. Michalides, S. J. Nicklas, S. Weiss, and K. Paetzold-Byhain, "Agile Entwicklung physischer Produkte 2022," 2022, doi: 10.18726/2022_3.
- [34] K. Beck et al. "Manifesto for Agile Software Development."
- [35] J. Cronau and F. Engstler, "Energy absorption of 3D printed stochastic lattice structures under impact loading – design parameters, manufacturing, and testing," *Prog Addit Manuf*, vol. 10, no. 5, pp. 3145–3156, 2025, doi: 10.1007/s40964-025-01094-5.
- [36] F. Günther and A. Koch, "Design for Additive Manufacturing – Application System based on Design Methodology in Industrial Standards," in *Entwerfen Entwickeln Erleben 2024 : Menschen, Technik und Methoden in Produktentwicklung und Design*, 2024, pp. 134–146, doi: 10.25368/2024.EEE.012.
- [37] K. Schwaber and J. Sutherland, "The Scrum Guide," 2020
- [38] N. Kano, N. Seraku, F. Takahashi, and S. Tsuji, "Attractive Quality and Must-Be Quality," *The Journal of the Japanese Society for Quality Control*, vol. 14, pp. 39–44, 1984.