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Critical Review On Applications Of Reverse Engineering In The Field Of Additive Manufacturing

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Abstract:
Reverse Engineering Is A Crucial Tool In The Field Of Additive Manufacturing. It Allows For The Production Of Existing Parts And The Creation Of New Designs. The Process Of Reverse Engineering Is Particularly Useful In Cases Where The Original Design Is Not Accessible. This Paper Provides A Comprehensive Review Of The Application Of Reverse Engineering In Additive Manufacturing. The Challenges Of Using Reverse Engineering In This Field Are Highlighted, And The Current State-Of-The-Art Techniques Used For Reverse Engineering Are Discussed. These Techniques Include Laser Scanning, Computed Tomography, And Photogrammetry. The Paper Also Covers The Software Used For Processing The Data And Generating The Design For Additive Manufacturing. The Challenges Of Integrating Reverse Engineering Into The Design Process Of Additive Manufacturing Are Also Discussed, Along With The Need To Ensure Accuracy And The Complexity Of The Software Used. Finally, The Paper Discusses Future Research Directions For Improving The Application Of Reverse Engineering In Additive Manufacturing. This Includes The Need For Improved Data Acquisition And More Sophisticated Software. The Paper Concludes By Emphasizing The Importance Of Reverse Engineering In The Design Process Of Additive Manufacturing And The Need For Continued Research In This Area To Improvethe Accuracy And Efficiency Of The Process.

***Key Word**: Additive Manufacturing, Reverse Engineering, Rapid Prototyping.*

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I. Introduction

Additive manufacturing has revolutionized the production of complex geometries and customized parts that were previously impossible to create with traditional manufacturing methods. However, designing for additive manufacturing can be a daunting task, especially when the original design is not available. In such cases, reverse engineering can be used to replicate an existing part. This article provides a critical review of the use of reverse engineering in additive manufacturing. Using reverse engineering for additive manufacturing poses several challenges. One of the significant challenges is obtaining high-quality data, as the data acquired through scanning or Other methods may be incomplete, which can compromise the accuracy of the resulting design. The complexity of the software used for reverse engineering is another challenge as it needs to be capable of handling large amounts of data and generating a usable design for additive manufacturing. Various additive manufacturing techniques are currently used for reverse engineering, including laser scanning, computed tomography, and photogrammetry. Laser scanning involves using a laser to scan an object's surface and create a point cloud that can be used to generate a 3D model. Computed tomography involves using X-rays to create a 3D model, while photogrammetry uses photographs to create a 3D model. Future research should focus on improving the accuracy of reverse engineering in additive manufacturing by improving the quality of data acquisition. [1]–[3]

Reverse engineering is a technique that plays a significant role in additive manufacturing. It allows for the reproduction of existing parts or the creation of new designs. A literature review was conducted to provide a critical overview of this technique's use in additive manufacturing. The review covers various data acquisition techniques such as laser scanning, computed tomography, and photogrammetry. The software used for processing the data an generating the design for AM is also discussed, including the challenges of integrating RE into the design process of AM. The review highlights the need for continued research in this area to improve the accuracy and efficiency of the process. It concludes that although RE is a valuable tool for AM, more research is necessary to optimize the use of RE in the design process.

II. Literature Review

Reverse engineering has been explored as a viable option for additive manufacturing for quite some time now. [4]–[13]

In 1997, Edmonds et al. published a paper on the use of reverse engineering in additive manufacturing. Their study showed that by using a coordinate measuring machine, they were able to replicate existing parts in additive manufacturing with great success.

In 2014, Shi et al. used laser scanning and CAD software to create a 3D model of a patient-specific implant for use in selective laser melting. Their study showed that reverse engineering was an effective way to produce customized implants with precise accuracy.

Kaushik Yanamandra1 et al. performed Reverse engineering of additive manufactured composite part by toolpath reconstruction using imaging and machine learning where work is focused on using imaging methods to reverse engineer a composite material part, where not only the geometry is captured but also the tool path of 3D printing is reconstructed using machine learning of microstructure. A dimensional accuracy with only a 0.33% difference is achieved for the reverse-engineered model.

Dorota Palka[2] et al. studied the Use of Reverse Engineering and Additive Printing in the Reconstruction of Gears and presented the basic assumptions of the methods used and the methodology for conducting reconstruction work. FDM (Fused Deposition Modeling) technology was used for the research. The results obtained are a real example of the practical application of the presented methods. At the same time, they create great opportunities for their wider use.

J López[3] et al. worked on an approach to Reverse Engineering Methodology for Part Reconstruction with Additive Manufacturing and concluded that an absence of a general method to use embedded knowledge and information through classical reverse engineering approaches, digitization technologies, and advanced software to develop accurate 3D models adequate for Additive Manufacturing technologies. His work has introduced a new framework for the analysis and evaluation of mechanical components, aiming to assess the implementation of additive manufacturing as the primary manufacturing technology and the recreation or re-design of the component's design depending on several factors, such as acquired knowledge through component analysis, part manufacturing feasibility, and customer requirements.

Mehmet Aladag[4] et al. worked on reverse engineering of parts with asymmetrical properties using replacement materials and presented a case study that explains how such an approach can be implemented in the case of products with asymmetric mechanical properties and using replacement materials. In this case study, a reverse engineering application was conducted on a textile machine spare part. To this end, the nearest material was selected to the actual material selection, and some mechanical tests were made to validate it. Next, a replacement part was designed by following the asymmetric push-in pull-out characteristic. Finally, the finite element analysis with Additive Manufacturing was combined and validated experimentally.

Fabrizio Clemente[5] et al. studied Reverse engineering and 3D additive manufacturing from research to clinical assistance and concluded that collaboration between a researcher from CNR and clinical practitioners inside a health facility produces real innovations and represents a great opportunity to promote new collaborations and research projects among stakeholders. Indeed the introduction of image processing, reverse engineering, and 3D printing techniques is rapidly spreading to exploit the advantages given by the design flexibility and low-cost production of prostheses, medical devices, and anatomical models.

Özgür Verim[6] et al. studied the applications of the reverse engineering approach on a damaged mechanical part and concluded that the damaged motor cam gear was scanned with a three-dimensional (3D) scanner and a mesh model was formed. Then, a solid model of the part was created and the genuine prototype was produced with a 3D printer. The deviations of geometric dimensions between the mesh model and the solid model were analyzed and the levels of convergence were determined. The three-dimensional prototyping method provides great convenience for the designer because it gives quick feedback in product development. At the end of the study, geometric values between the solid model and the prototype model were compared and deviations from actual value were determined.

Pavel Stoklasek[7] et al. performed a case study on Optical digitization, reverse engineering, and rapid prototyping as a solution in the pedal car development process and the application of optical digitization, reverse engineering, and rapid prototyping in the manufacturing process of accessories for handmade pedal car, which imitates a unique historic Czech car, a Škoda 1000 MB, type 990 Roadster. Two well-known design elements, the rear light, and front indicator, were digitized by the non-contact 3D scanner. The digitized 3D models were used as input for reverse engineering. Their shapes were modified due to technological limits of vacuum forming, scaled, and used to design the 3D printed vacuum forming molds. The final parts were made of transparent foil, trimmed around the perimeter, and airbrushed from the inside. The described process served to verify the manufacturability of these accessories before commencing works on mass-produced pedal cars intended for sale to customers.

Salah Amroune[8] et.al studied the manufacturing of rapid prototypes of mechanical parts using reverse engineering and 3d printing and focused on the design and manufacture of mechanical parts that have complicated shapes using the technique of reverse design using a scanner or an MMT for data acquisition in the form of a point cloud, using CAD software (CATIA).

An A Kaleev[9] et. al studied applications of reverse engineering in the medical industry in which a studio program was used to remove defects and inaccuracies of the obtained parametric model and a prototype of the finished model was made on the installation of laser stereo lithography Projet 6000. The total time of the creation was 16 hours from the reverse engineering procedure to the 3D printing of the prototype.

Antonio Marzola[10] et.al studied Additive Manufacturing and Reverse Engineering in Cranioplasty where A Personalized Approach to Minimize Skin Flap Complications is evaluated and concluded that described approach highlights RE and AM potentialities in allowing the surgeons, through synergistic work with engineers, to tailor the device and the surgery to the patient's specific needs. Future developments of the proposed approach could concern the automation of the in silico measurements and the standardization of the materials and methods of fabrication of the physical models to carry out the simulation.

Leu et al. conducted a study in 2018 on the use of reverse engineering for creating parts with lattice structures using the Fused Filament Fabrication (FFF) process. Their research showed that reverse engineering was an effective way to create complex lattice structures in additive manufacturing. In a review paper by Buijs et al. in 2019, the authors provided an extensive overview of the different techniques used for reverse engineering in additive manufacturing. They concluded that reverse engineering was a valuable tool for additive manufacturing, and further research was needed to improve the accuracy and efficiency of the process.

III. Latest development in the field of reverse engineering

There have been some recent advancements in reverse engineering, particularly in the field of additive manufacturing. Below are some of the latest trends and developments:

1. Artificial intelligence (AI) and machine learning (ML) are being used to enhance the accuracy and efficiency of the reverse engineering process. For example, AI algorithms can be trained to automatically recognize and extract features from scanned data, reducing the time and effort required for manual processing.
2. Hybrid approaches are becoming more common, where multiple data acquisition techniques are used together to create more accurate and complete 3D models. For example, combining photogrammetry with structured light scanning can help compensate for the limitations of each technique and improve the overall accuracy of the model.
3. High-resolution 3D scanning technology is becoming more affordable and accessible, allowing for more widespread use of reverse engineering in small and medium-sized businesses. Portable handheld scanners, in particular, are becoming more popular as they offer a flexible and cost-effective way to capture data.
4. In addition to improving the accuracy of the reverse engineering process, there is also a focus on improving the efficiency and automation of the process. For example, researchers are looking into automating the creation of CAD models from scanned data, reducing the need for manual intervention.

IV. Advantages, Disadvantages, and Applications

Reverse engineering offers several advantages. It allows for the reproduction of existing parts, which is particularly useful when replacement parts are no longer available or when customization is required. Reverse engineering can also optimize the design of existing parts or products, making them more efficient and effective. It can help reduce costs by eliminating the need to start from scratch in the design process and by providing an alternative to expensive original equipment manufacturer (OEM) replacement parts. Additionally, it can save time by allowing for faster prototyping and production of parts, especially when existing designs need to be modified. However, reverse engineering also has its disadvantages. It can raise legal and ethical concerns if it involves copying proprietary designs or violating patents. It can lead to lower-quality parts or products if the reverse engineering process is not carried out accurately or if substandard materials are used. It can also be challenging if the original part or product is not available, or if limited information is available about the original design. Reverse engineering has several applications in various industries. It is commonly used in the automotive industry to reproduce parts that are no longer available or to modify existing designs to meet specific needs. The aerospace industry uses reverse engineering to create replacement parts for aging aircraft and to improve the design of existing components.

V. Conclusion

1. Reverse engineering is becoming increasingly popular in additive manufacturing.
2. It allows for the creation of exact replicas of existing parts, product design improvement, and cost and time reduction. The use of AI and machine learning, hybrid approaches, and improved 3D scanning technology are making the process more efficient and accurate. However, there are also potential drawbacks to using reverse engineering, such as intellectual property concerns, quality issues, and limited information. It's

important to consider these issues and take steps to mitigate them when using reverse engineering.

3. The development and optimization of the reverse engineering process will be critical to unlocking its full potential in additive manufacturing. Ongoing research into automating the creation of CAD models from scanned data, improving the accuracy of the process, and integrating reverse engineering with other manufacturing processes will be key to achieving this goal.
4. Reverse engineering is a valuable tool that can help drive innovation and improve efficiency in various industries. By carefully considering its benefits and challenges and leveraging the latest technological advances, companies can unlock the full potential of this powerful technique.

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