Review of state-of-the-art in Fabrication of Connections found in Reticulated Structures developed by Topology Optimisation and Additive Manufacturing Processes

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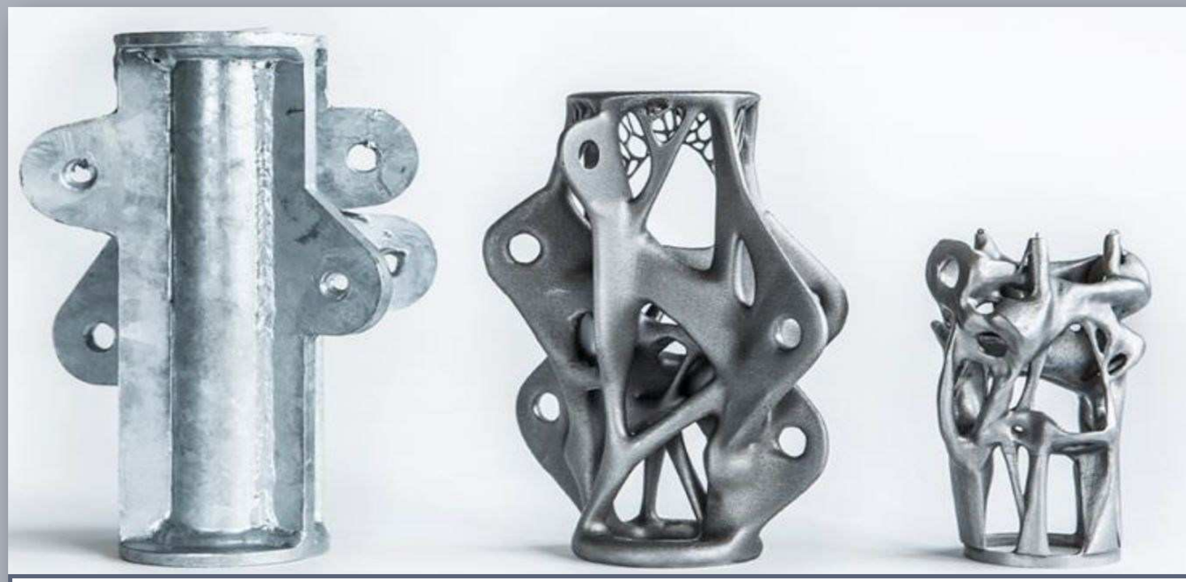

Figure 1 [1]

[A] Introduction

- Reticulated structures are some of the most efficient structures in the civil engineering field. They are used to construct long-span roofs with few internal column supports while maintaining high stiffness-to-weight ratio. They have a wide range of applications ranging from warehouses to airports and stadiums.
- The fabrication of these connections has not seen much development over the years, with either welding or casting fabrication usually adopted. This results in typical, symmetrical, repetitive nodes which could be considered relatively expensive and time-consuming to produce.

[B] Study Objective

- Advancements in Additive Manufacturing and Structural Topology Optimisation technologies present an opportunity to design and fabricate these connections to be more efficient, cost-effective, and provide improved structural performance and geometrical complexity. Thus, it was considered of significant importance to conduct a literature review to critically analyse the applicability of designing and fabricating these connections using the State-of-the-art in these technologies.
- The main scope of the study is to understand the potential benefits which could be gained, a simple understanding of the economics involved in the manufacturing process, and the critical limitations which can be considered of importance to address in the near future.

[C] Overview of the Engineering Fields Involved

Reticulated Structures [RS]: are truss-like, light-weight structures with regular and usually repetitive geometric forms, constructed from interlocking struts and connected to each other using connections [2].

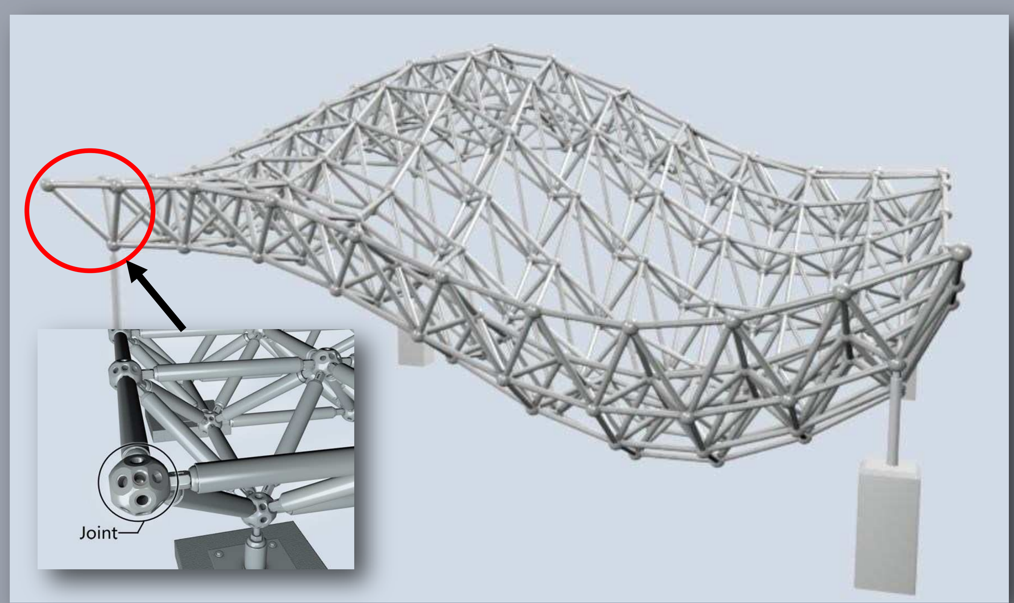

Figure 2 [3]

Structural Topology Optimisation [STO]: a Finite Element Analysis [FEA] based technique which aims at changing a certain feature/s of a design while maintaining certain constant conditions [ex: reducing weight while keeping the maximum capacity load].

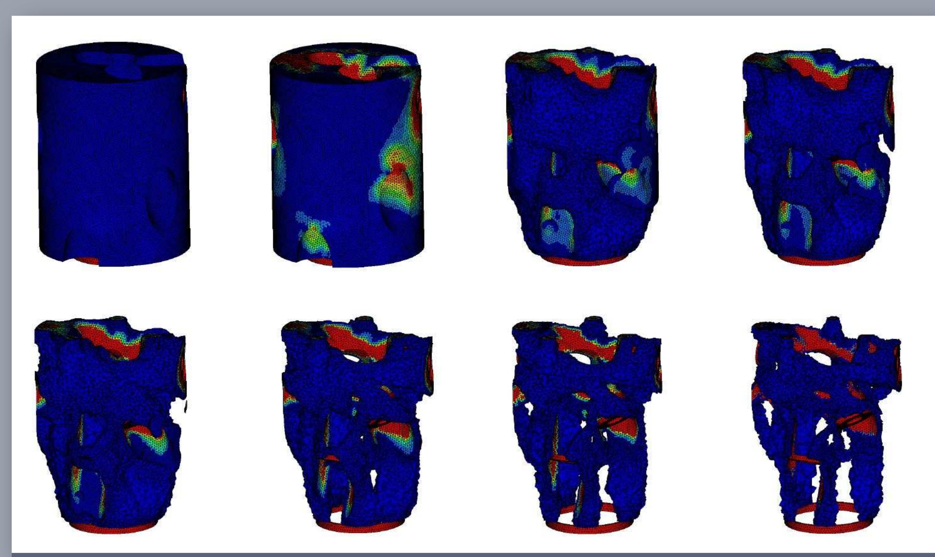

Figure 3 [4]

Additive Manufacturing [AM]: a process of joining thin layers of a material together, layer upon layer, to make an object based on a 3D computer model.

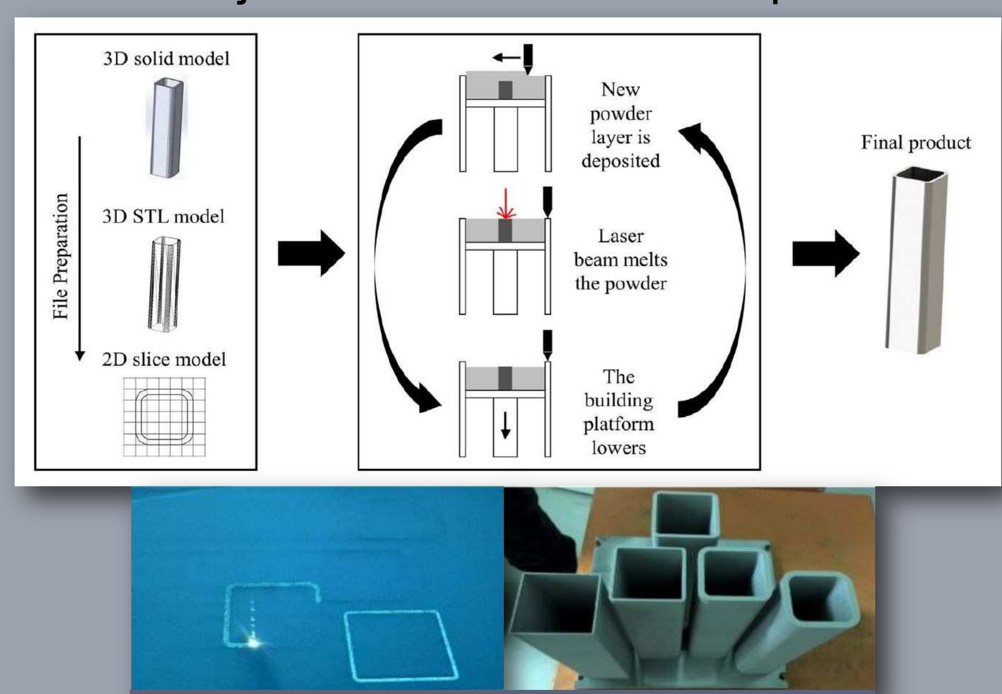

Figure 4, 5, 6 [5, 6]

[D] Research Findings

Predicted Benefits

Design Complexity

The integrated use of both STO and AM technologies would allow for more specialised and efficient designs with improved structural performance. As shown in figure 7, an optimised connection has been developed which is 50% shorter and 75% lighter compared to the original part.

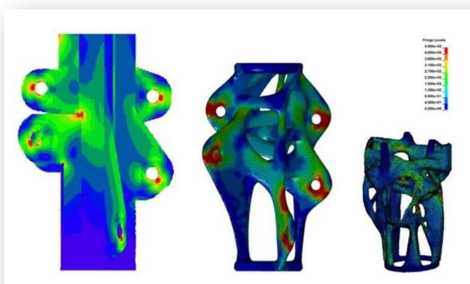

Figure 7 [1]

Economics

Non-identical low to medium production volumes could allow for AM to be a cost-effective solution.

Figure 8 compares the costs associated with additively and traditionally fabricating aluminium alloy aircraft landing gears. The AM cost per part remains fixed irrespective of the production volume.

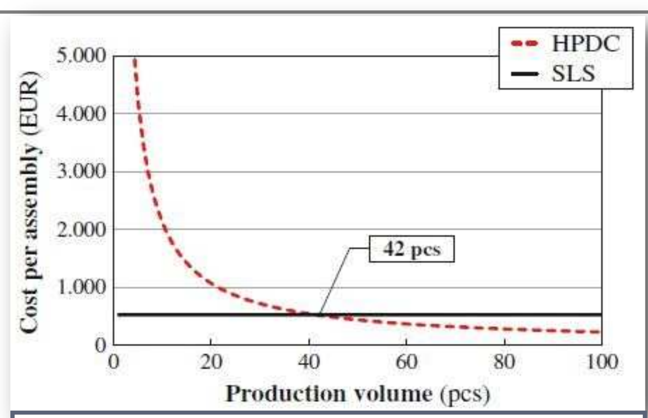

Figure 8 [7]

Material Efficiency

Overall, AM requires fewer raw materials than traditional fabrication. In metallic AM, the only raw material required is the metallic powder as shown in figure 9, and up to 95% of that used powder can be recycled and reused.

Figure 9 [4]

Critical Limitations

The Need for Sacrificial Structural Supports [SSS]

The SSS shown in figure 10 are used to prevent the development of internal stresses due to the structure self-weight and reduce the heat dissipation during laser scanning. SSS increase the fabrication costs and can be time-consuming to design, process, and remove.

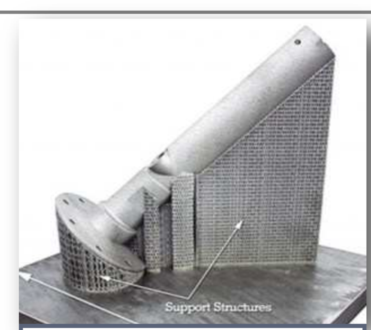

Figure 10 [8]

Lack of Integration between STO and AM

Research into integrating the STO and AM processes is a key factor in properly advancing their integrated use. The common method of considering the AM process characteristics in the design and STO stages is through human intervention. This intervention can lead to lack of creativity, time consumption, and a higher risk of errors.

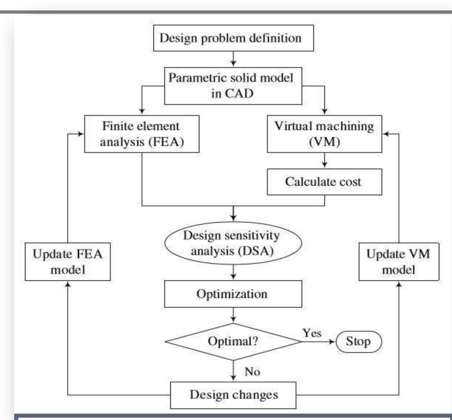

Figure 11 [9]

Lack of Market-Targeted Research

Research into the effects of switching production lines to AM and the adaptability of a business to that should be conducted to better understand the risks involved and the likely sources of costs and profits.

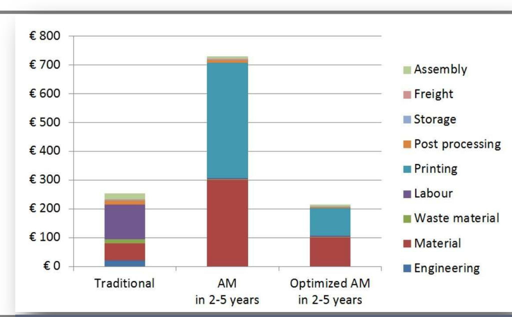

Figure 12 [10]

Other limitations include: Shortage of experienced labour and long fabrication time.

[E] Conclusion and Future Implications

- A basic foundation for the technologies has been established which shows a promising future in large-scale non-repetitive rapid manufacturing applications.
- The technologies could provide an applicable engineering solution in the future for the design and fabrication of RS connections upon further advancements and addressing the limitations thought of in the literature review.
- A live case study of designing and 3D printing these connections has to be attempted to assess in practice the applicability of using these design and fabrication technologies on the connection of reticulated structures.

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