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ROUGHNESS MODELLING, AND PREDICTING MECHANICAL PERFORMANCE OF LATTICE STRUCTURES

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ABSTRACT

Evolutionary algorithms are still evolving, resulting in different topology optimised runs (Meisel et al., 2017). Especially when iterative design study processes are computationally burdensome (Hertlein et al., 2021). This leads to multiple optimisation techniques following different criteria to be created for each analysis. Therefore, the development of an accurate lattice prediction methodology is needed, after texturing a series of operations on the primary surface. Consequently, predicting the mechanical performance provides a more accurate prediction, improving on topological modelling for spatial material distribution within a defined domain.

INTRODUCTION

Lattice structures through Additive Manufacturing (AM) processes allow the production of conformal cooling channels attractive for aeronautical applications (Tan et al., 2020). Besides, they also lead in biological implant development for surgical implants, to identify optimal surgical orientation (Saini et al., 2015). An appropriate surface roughness estimation for manufactured surface prediction affects performance, and wear thus important to quantify (Chandler, 2022).

Specifically, AlSi10Mg and Ti–6Al–4V lightweight metal alloys can successfully fabricate extreme fine microstructures, and hence higher hardness when compared to fabricated samples by conventional approaches (Aboulkhair et al., 2019). However, surface quality and dimensional accuracy of lattice structures remain a challenge and thus dimensional error must also be taken into account.

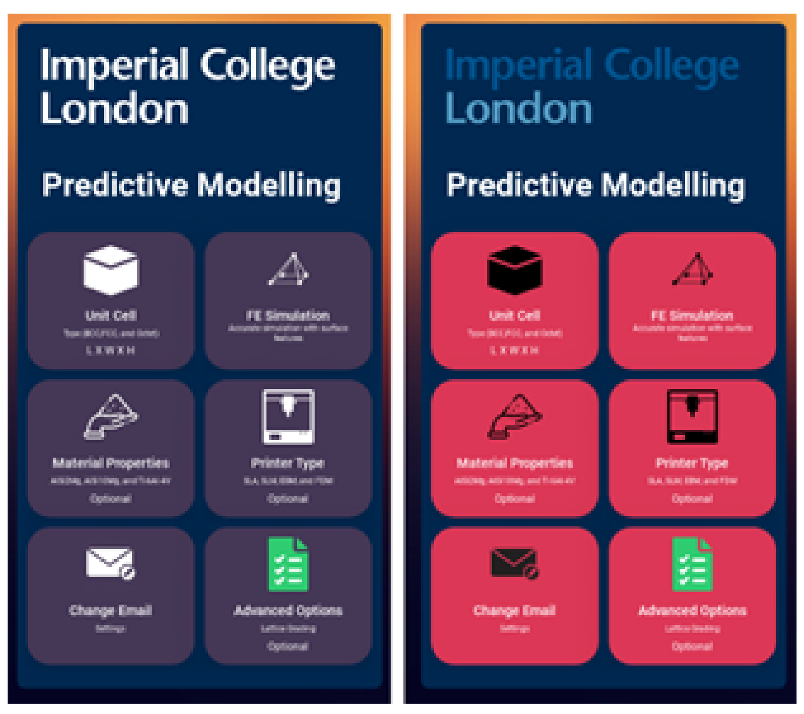
Limitations of Selective Laser Melting (SLM) processes can lead to substantial differences between the intended and as-fabricated geometries (Kelly et al., 2019). These discrepancies result due to shrinkage after melting, waviness and roughness, which is detrimental to the critical buckling load, strength, and stiffness of lattice structures.

ROUGHNESS PREDICTIVE MODELLING

Surface roughness is fundamentally a result of a geometric manufacturing error, affecting structural integrity and geometric tolerance (Benardos and Vosniakos, 2003). Overhang surface roughness not only impacts lattice structures but also internal geometries in aeronautical channels i.e. fluid flow and heat transfer (Zhang et al., 2020). Consequently, there is a clear need for a CAD surface recreation without consecutive physical characterisations of surface geometries through microscopical scans which would be time and cost consuming.

At low strut angles layer thickening (stair stepping effect) plays a major role in applying high surface topographical effects, and on a vertical strut, strut direction fused particles account for roughness instead (Murchio et al., 2021). Combining both observations, roughness can be modelled as a function of the strut's diameter, angle of inclination, printer process parameters, and powder flowability to identify the criticalness of surface roughness on simulated mechanical properties.

FIGURE 1

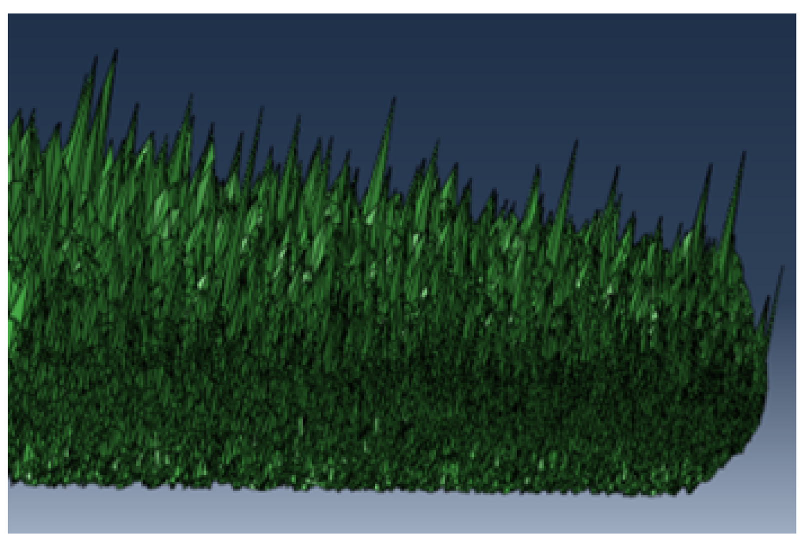


Through Kivy (python library) for multi-platform application the following interface has been developed for usage on Windows, macOS, Linux, IOS, and Android.

It is developed to automatically designs a particular unit cell type (BCC, FCC, Tetrahedron), with inputted user dimensions, and optionally material and printer type to mechanically simulate with surface features giving a close case scenario to a true mechanical test.

The user is provided with advanced tools in grading the unit cell structure. (Plocher and Panesar, 2019)

FIGURE 2



Generated surface features through a tetrahedron first order mesh by displacing surface nodes off in the normal direction off the surface to generate a CADwDS.

Note: Meshing sequence is order dependent. Thus, a second order mesh majorly increases the file size.

IN THIS RESEARCH

Previous experimental studies have confirmed that the area of downward facing surfaces is inversely proportional to inclination angle, thus at lower inclined angles have a greater downward-facing surface area leading to circumferential roughness heterogeneity, further complicating roughness modelling (Charles et al., 2021), (Alghamdi et al., 2019).

The research's objective is to estimate a quantitative value of deviations between an ideal CAD and process optimised SLM layered model. Creating a virtual "CAD with Designed Surface" (CADwDS), and attempting statistical and ANOVA testings to develop roughness mathematical models. Finally, the work involves building initial roughness models and training obtained predictions through neural network activation functions, and compare to experimental mechanical measurements.

The user is asked to input his designing criteria as shown in figure 1, and within five mins of job submission, an attached result of the requested ABAQUS .cae design, readily simulated with surface features sent via email.

As a result of a change in foam's relative density due to over/undersized printing, sandwich construction optimisation based on previously researched analytical and finite element techniques would not be accurate as well. Therefore, an account for the load versus deflection response of experimental simply supported and clamped beam designs was studied (Peng et al., 2020), (Tagarielli, Fleck, and Deshpande, 2004). A digitalised mapped response has been developed of the collapse mechanism maps with contours being applied to determine an optimal required composite laminate thickness. Optimised to approach Indentation, core shear, and micro-bucking under the same critical loading conditions based on the updated relative density (Steeves, 2012).

CONCLUSION

Designers often push the capabilities of 3D printers to build lattice structures as small as possible. However, the mismatch between AM parts and desired lattice structures provides inaccurate estimations. inherent defects are often missed in FE analysis and are idealised as perfectly smooth geometries. In this project a review of surface roughness through an SLM printing technology leads to the accurate roughness modelling of lattice designs allowing for realistic predictions as shown in Figure 2.

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