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Geometric Characterisation of 3D Printed Steel Structural Elements

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INTRODUCTION

3D printing, or additive manufacturing, is gaining in popularity across multiple industries with its ability to manufacture complex geometric forms, in a wide range of materials. Metallic structural elements can be printed, although the existing experimental dataset is very limited. Stainless steel flat plates and square hollow sections (SHS) were built using wire and arc manufacturing (WAAM), laser scanned and their measured geometry analysed. The specimens were subsequently destructively tested in pure compression. Computational methods have been used to characterise the geometric properties and seek their relationship to the buckled shapes of specimens.

METHODOLOGY

The geometric properties of the printed specimens were investigated by laser scanning, stereolithographic modelling and MATLAB computation, as shown in Figure 1.

FARO

The specimens were scanned into a computer using a FARO Design ScanArm, and millions of spatial coordinates points were captured.

The scanned specimen data points were grouped and processed into stereolithographic models using Geomagic Wrap.

Rhinoceros

Stereolithographic models were exported into Rhinoceros to extract data in a computationally efficient resolution from a re-defined coordinate system.

Extracted data sets were exported into MATLAB to compute all geometric properties, followed by an imperfection analysis.

Figure 1: Geometric characterisation procedures.

MODEL VERIFCAITON

To ensure the stereolithographic model captures all surface features of structural elements and model analysis is computationally efficient, a series of verification steps are performed using the following flow chart:

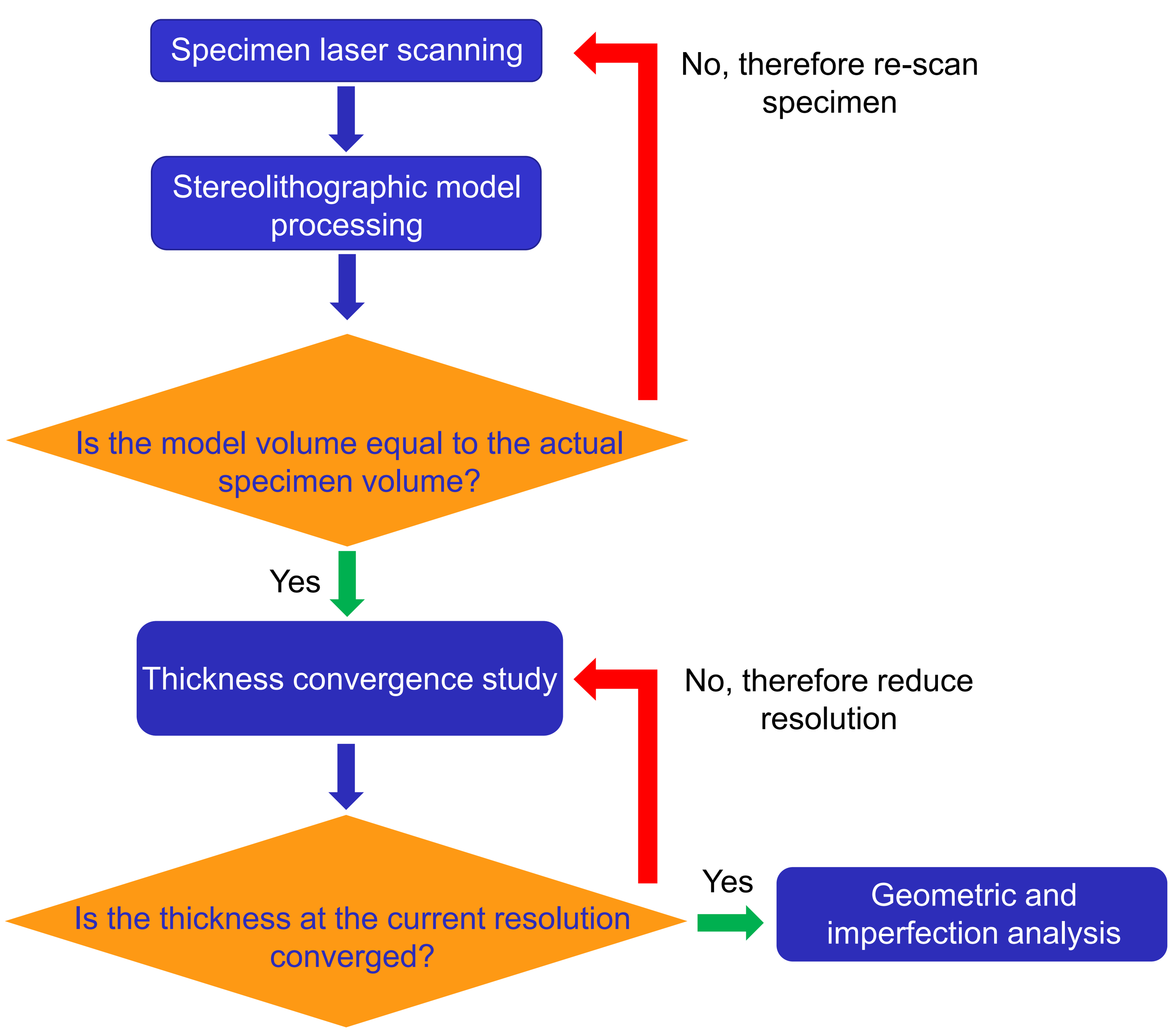

Figure 2: Flow chart of model verification process

ACKNOWLEDGEMENTS

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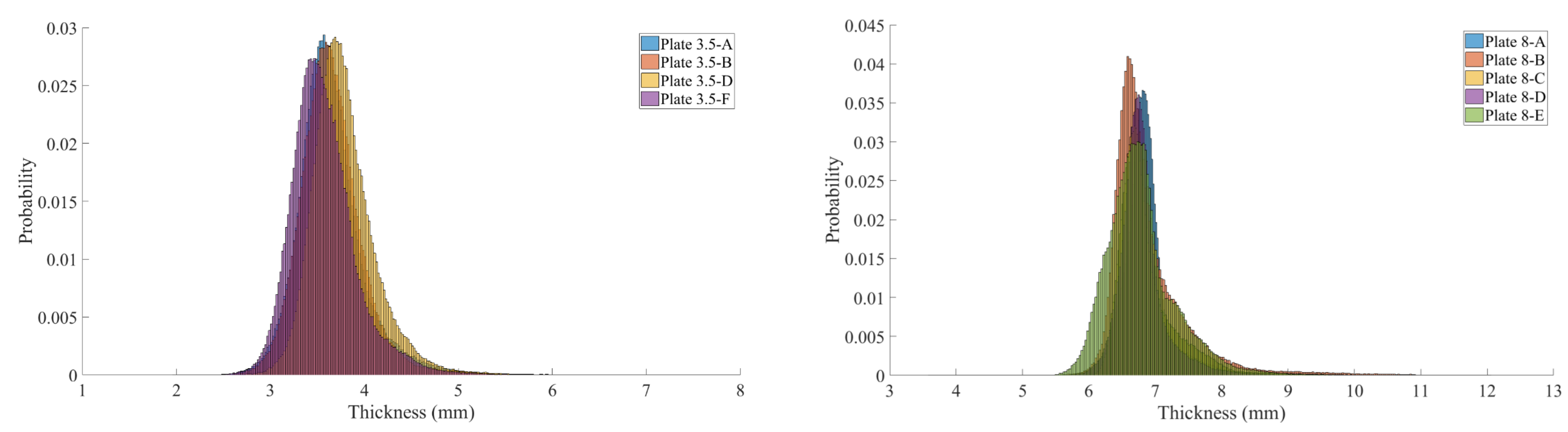
RESULTS

The thickness, cross-sectional area, area centroid, and radius of the stub columns were computed for each specimen and their distributions were investigated. Figure 3 shows that the thinner walled specimens were observed to have a more consistent thickness than the thicker walled specimens, due to the multiple passes of material deposition from the WAAM printer in order to achieve the desired thickness.



(a) (b)

Figure 3: Thickness probability distributions of (a) 3.5 mm and (b) 8 mm plates

GEOMTRIC IMPERFECTION

During the manufacturing process, sometimes the 3D printer deposits material out of position due to the high travelling speed of printing tip and this affects the quality of the printed object (Williams et al., 2016). This issue causes geometry variation as shown in the Figure 3 (a) and (b) above, and also affect the position of the area centroid along the specimen length, as shown in Figure 4.

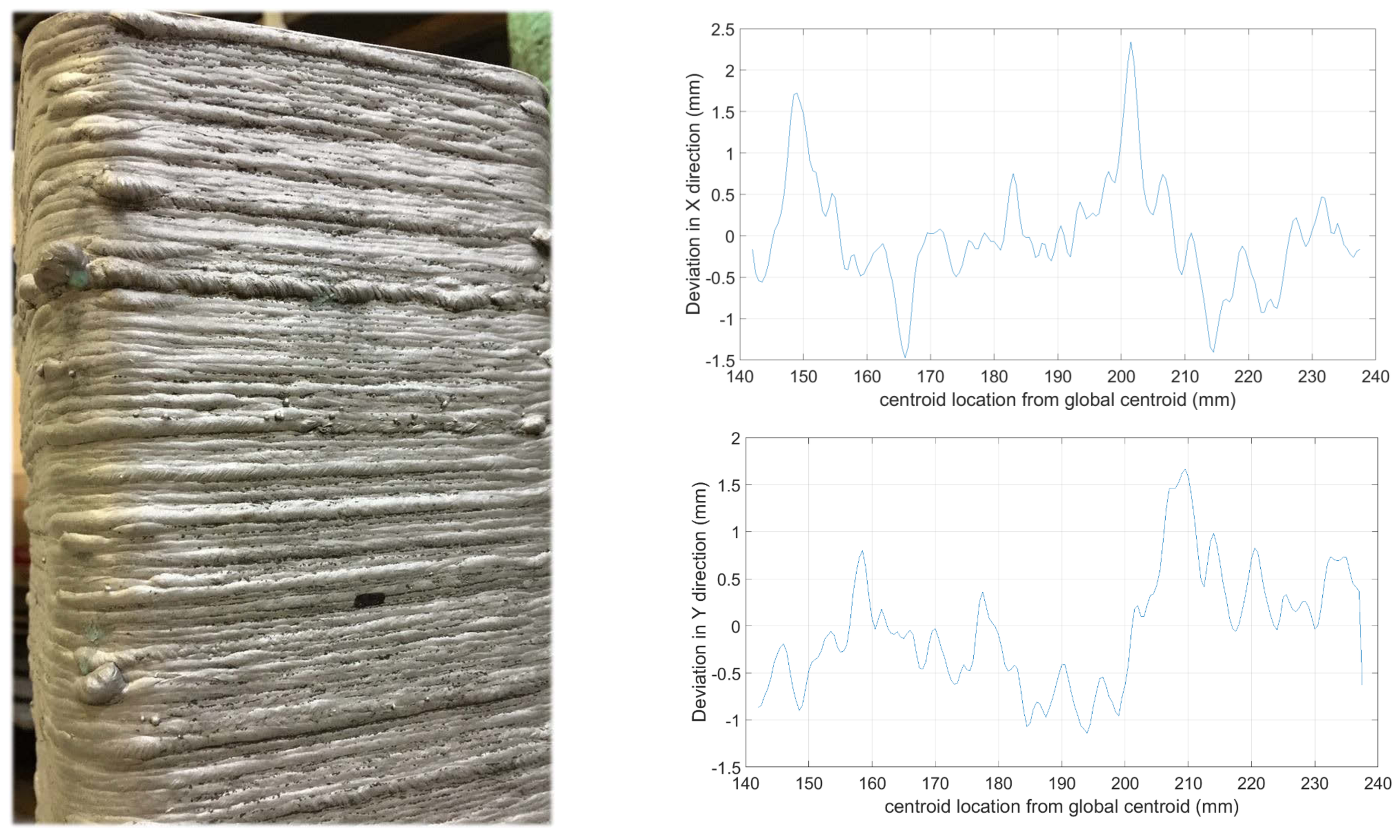


Figure 4: (left) Surface profile of specimen and (right) variation of centroid in x- and y-direction along the specimen length due to printing speed issue.

SPECTRAL ANALYSIS

The surface imperfection profile causes the specimen to buckle in a shape different to a perfect structural element. A Fourier transform was used to investigate the underlying wave functions of the surface profile and to predict the buckled shape, by identifying the dominant imperfection frequencies, as illustrated in Figure 5.

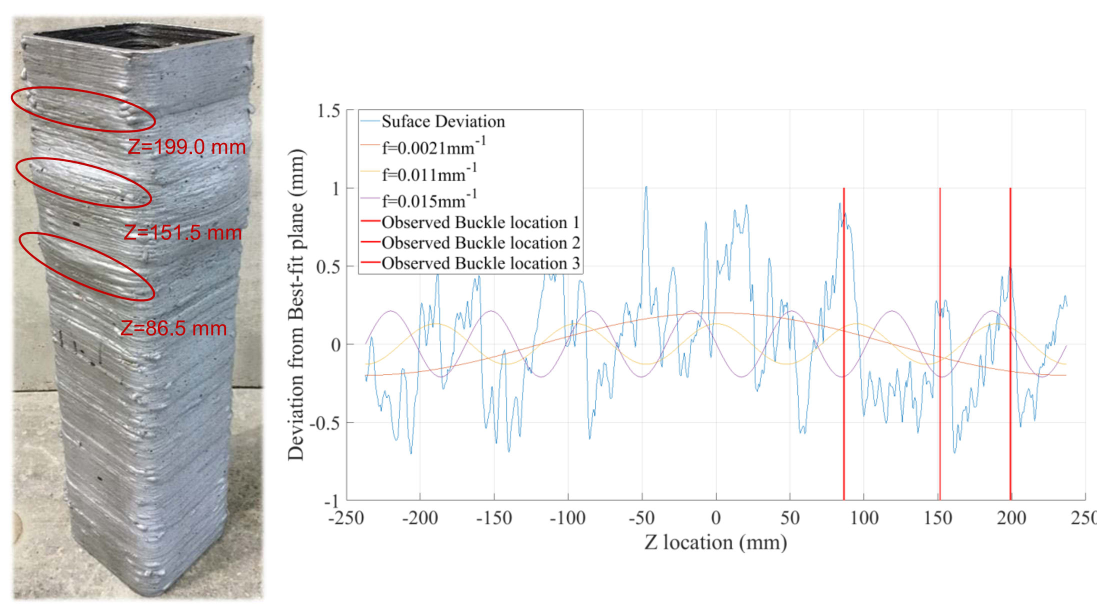


Figure 5: Experimental column buckling peaks (left in red circle) approximately share the same location as the peaks of one of the dominant wave functions (right, purple wave).

CONCLUSION

Wire and arc additive manufacturing (WAAM) provides an unprecedented degree of design freedom, however the geometry variations and imperfections arising from the manufacturing process needs to be considered when using 3D printed products as structural elements.

REFERENCES

Williams, S. W., Martina, F., Addison, A. C., Ding, J., Pardal, G. & Colegrove, P. (2016) *Wire + Arc Additive Manufacturing*. Materials Science and Technology. 32 (7), 641-647. Available from: doi: 10.1179/1743284715Y.0000000073.