Developing Trabecular Structure

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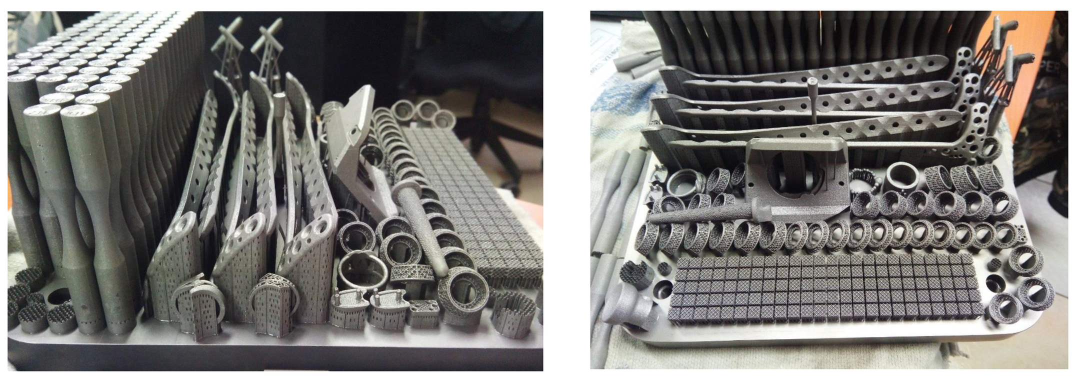
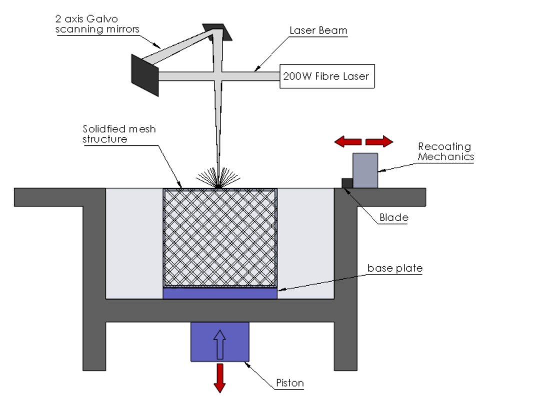
Abstract

Trabecular or porous structures are widely used in the biomedical industry in order to achieve ideal bone integration. The current porous structures are stochastic in principle and used as a surface coating that is based on their manufacturing using plasma spray. Additive manufacturing (AM) is capable to deliver bulk porous structure with controlled geometry. The porous structure consists of elements at the limit of AM accuracy that has not been studied extensively so far. Mechanical properties of trabecular metal structure created by using additive manufacturing technique for orthopaedic application have been evaluated. It has been experimentally shown that mechanical properties have been influenced by open-cell architecture, strut thickness, relative density. Post-treatment methods have been evaluated for porous structure. In this research, hierarchical experimental and theoretical approaches reflecting the porous material structure were developed.

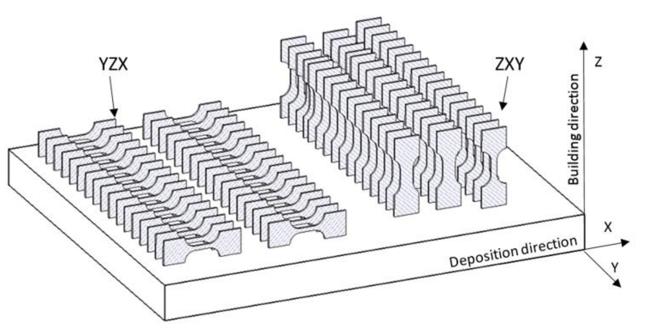
Additive Manufacturing



SLM chamber of cubical and small samples manufacturing

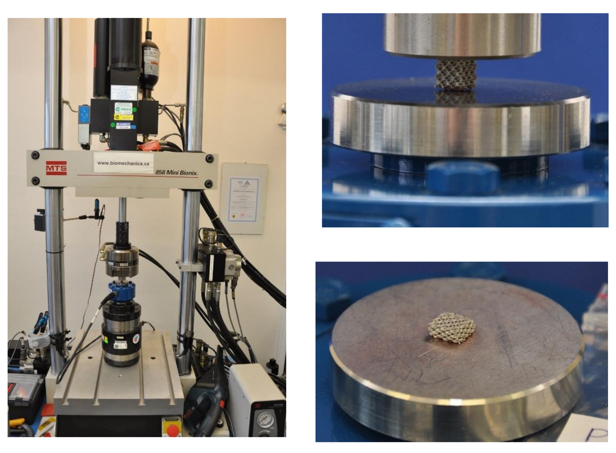


Schematic overview of the SLM process

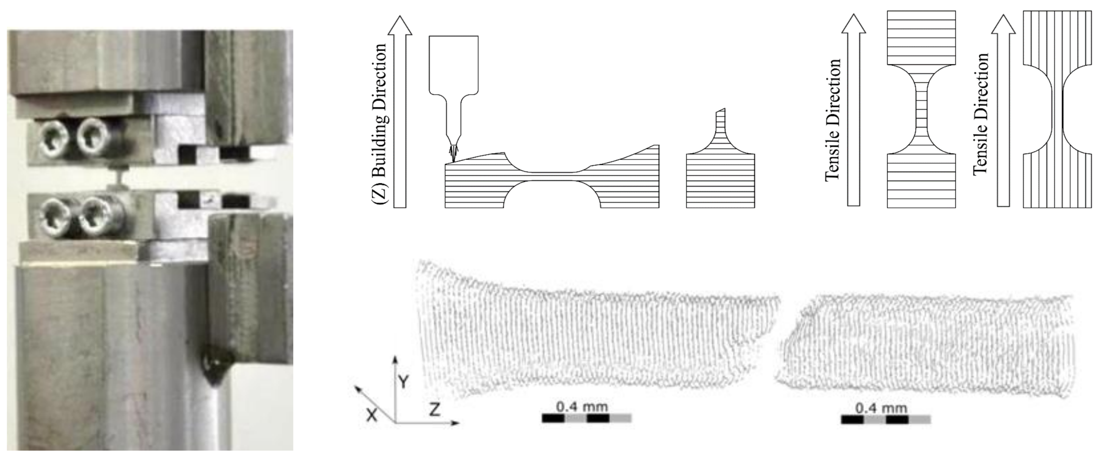


Small sample orientation

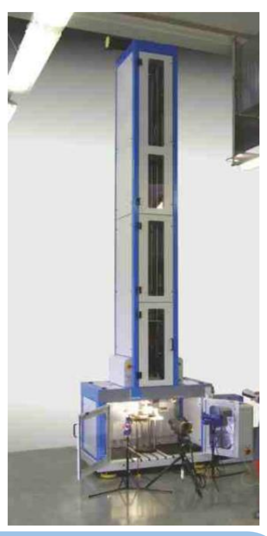
Mechanical Testing

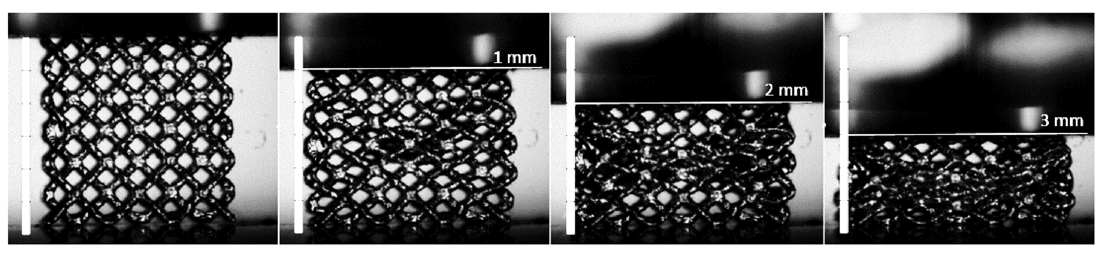


Titanium cubical porous sample static test



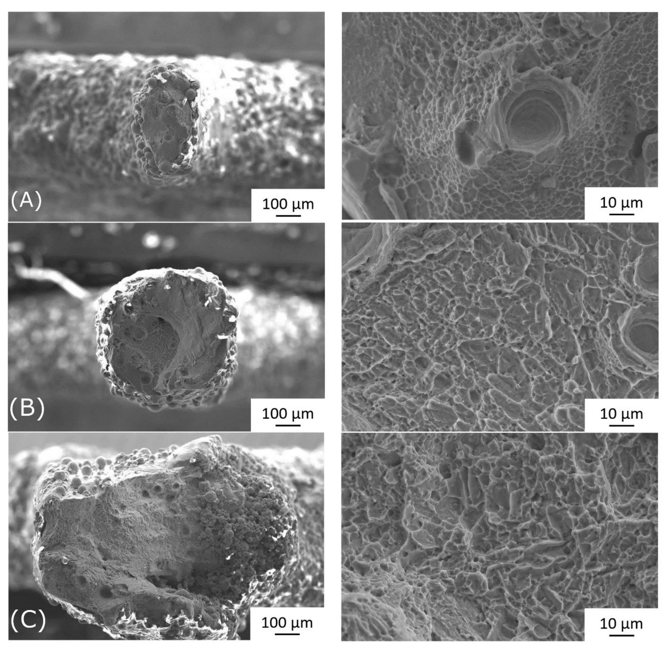
Titanium small connector static test



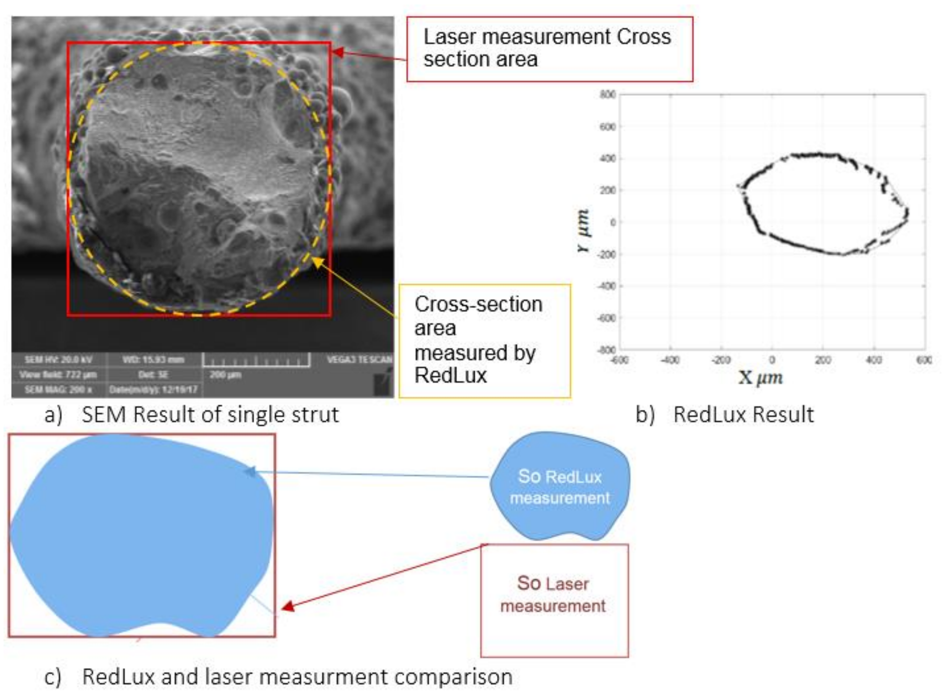


Titanium cubical porous sample dynamic test

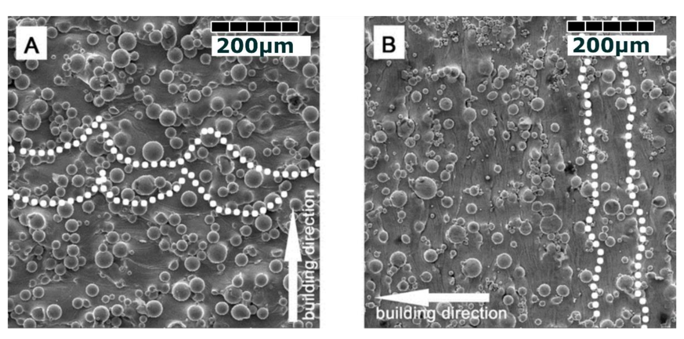
Microstructure



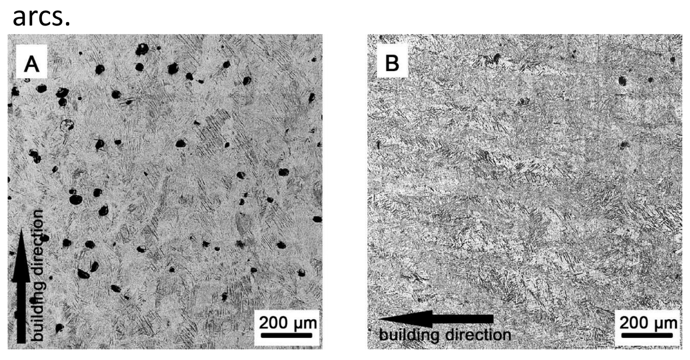
Fracture surfaces from samples with different cross-section area: (A) Sample 1, build direction ZXY, cross-section area is 0.12 mm^2; (B) Sample 30, build direction ZXY, cross-section area is 0.3 mm^2; (C) Sample 13, build direction YZX, cross-section area is 0.75 mm^2.



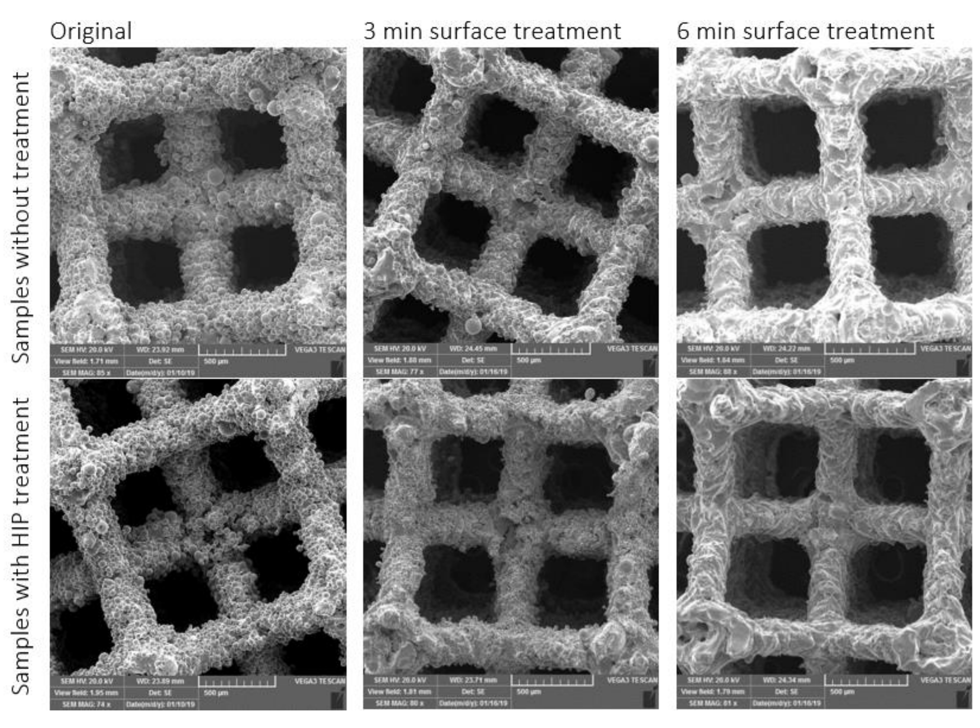
Cross-section area measurement comparison



Comparison of external surfaces of sample built (A) with ZXY and (B) YZX orientation. Dotted lines in each image represent remnants of the melt pool arcs.

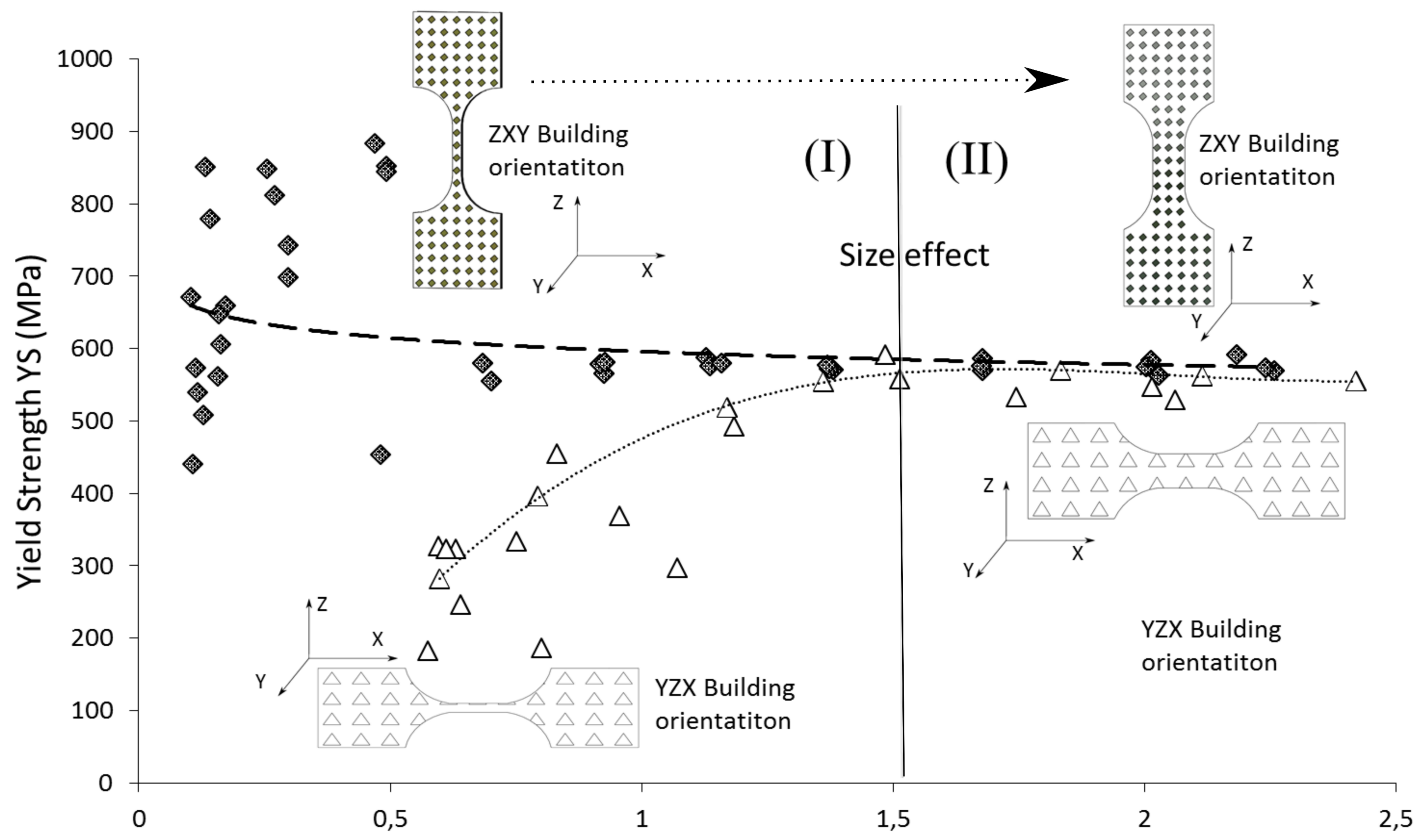


Microstructure of samples built in (A) ZXY and (B) YZX building orientation

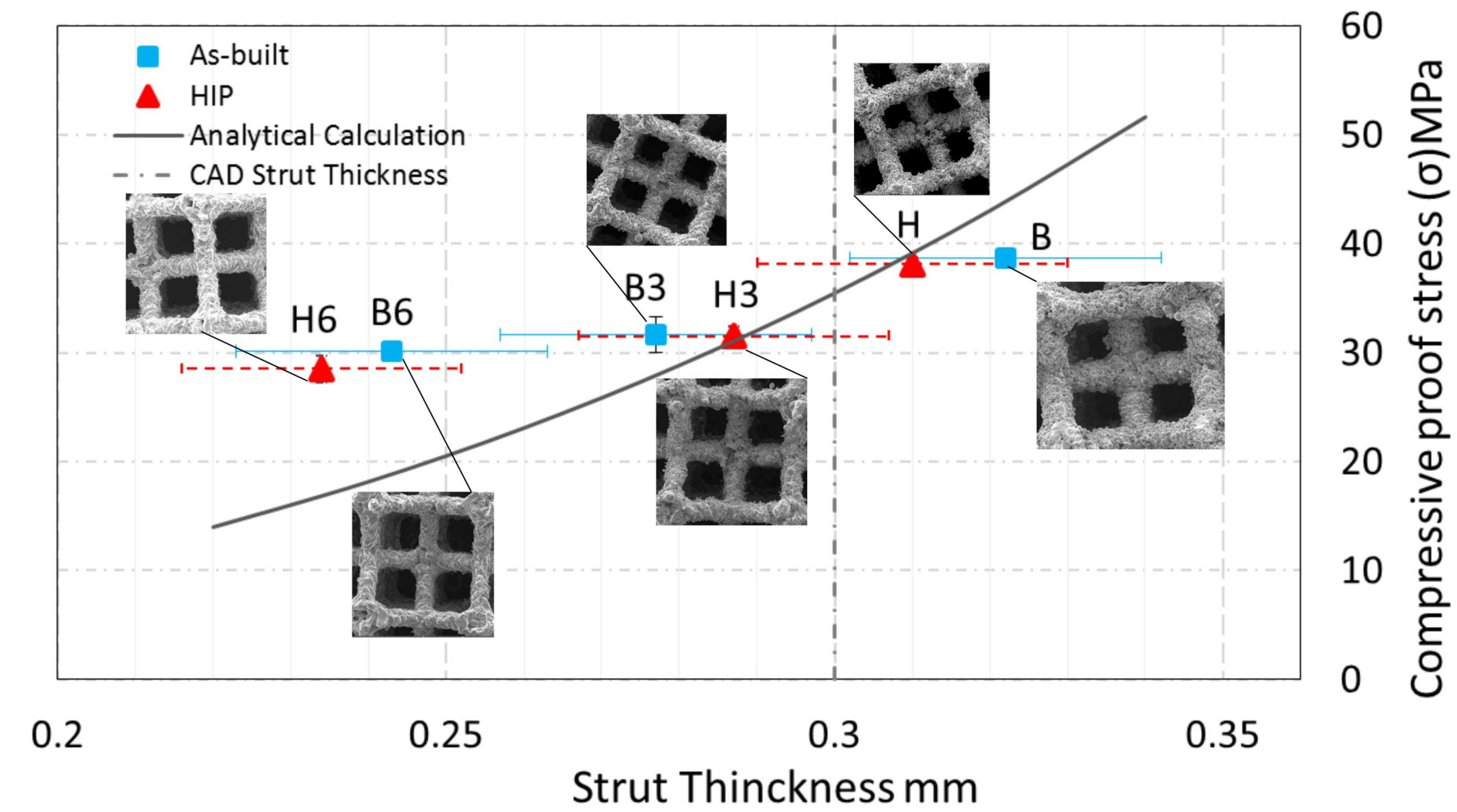


SEM result of post-treatment effect on surface

Result



Effects of build orientation and sample geometry on the mechanical response



Post-treatment effect on titanium alloy porous structure mechanical performance

Conclusion

- Single strut properties were affected by the size and building orientation. The building orientation direction effect is much less pronounced in larger samples
- Single strut mechanical properties have been used for analytic and numerical calculation. Material properties definition plays a vital role in analytical and numerical calculation approach.
- The surface etching is appropriate method for post-processing of the porous structure for biomedical implants.
- The dynamic test result of porous structure in the air was very similar to water and blood like material environment. It shows that future mechanical tests of porous structure can be carried out in air condition for biomedical applications.

References

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