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Fracture toughness and tensile strength of 316L stainless steel cellular lattice structures manufactured using the selective laser melting technique

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Main Points of The Presentation:

- Project Background
- Aims and Objective of The Project
- Experimental work
- Results
- Future Work

❖ BACKGROUND

Additive Manufacturing

- Additive manufacture (AM), is a name describes the technology that built 3D object by adding layer-upon-layer of material whether is metal, concrete or plastic.
- AM has the capability to manufacture complex geometries completely without need of tooling, which will result in reducing the manufacture time and costs for such items, as well as economic, low volume production and design freedom.

Fig 1. AM Freeform Fabrication Capabilities



1. AM parts for Automotive



2. AM parts for aerospace

3. AM medical model implant



❖ BACKGROUND

Selective Laser Melting (SLM)

- SLM process commercialized by MTT technology Ltd group of stone in 2003, it is similar to SLS process technique, but in SLM process the laser dose not sinter but melting the powder.

- In SLM process, metallic parts built produced layer upon layer until the part completely form.

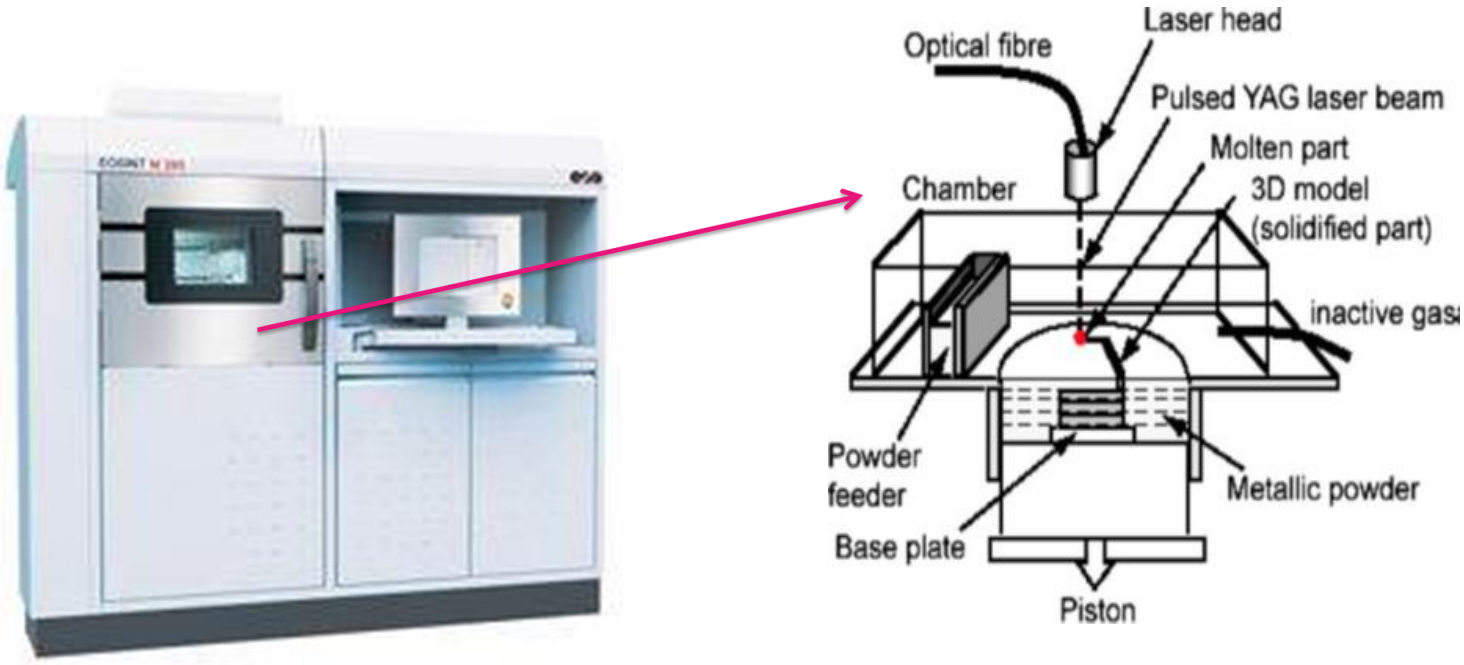


Fig 2. Selective laser melting machine

❖ RESEARCH AIMS AND OBJECTIVES:

Today, most of the research in aerospace applications tends to be focused on increasing energy efficiency and reducing fuel consumption and exhaust emissions.

There are still certain evaluation criteria such as fracture toughness and tensility of cellular structure made by SLM which were not reported such as:

1. Investigate the local failure mechanism of a 316L stainless steel cellular structure manufactured by SLM under uniaxial tension loading and three point bending load.

2. The effect of different build directions of the 316L lattice structure on the fracture toughness properties and compared to the Ashby and Gibson models.

- This need was the main driver for this project.

❖ Experimental work

1. Materials and cellular lattice structure design

- All of the samples were made from a 316L stainless steel at 15% volume fraction and unit cell size 3mm
- The CAD software provided by simple-ware Ltd

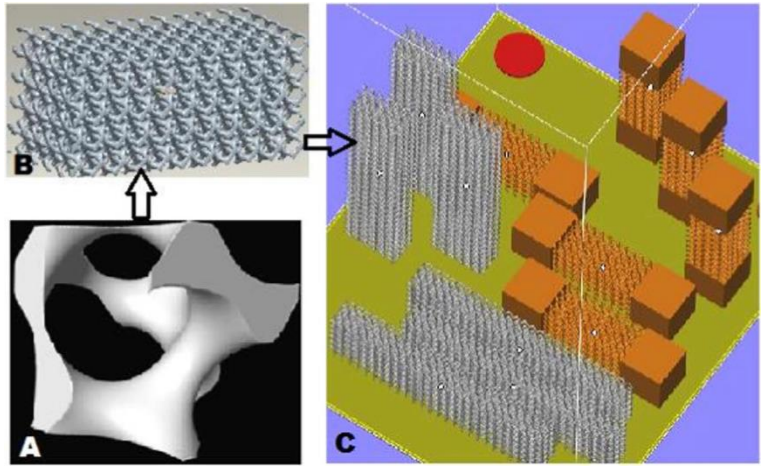


Fig 3. (a) CAD model of gyroid unit cell (b)periodic cellular lattice structures (c) samples at different building direction.

2.The selective laser melting process

- The SLM process was carried out on a concept laser (M1)

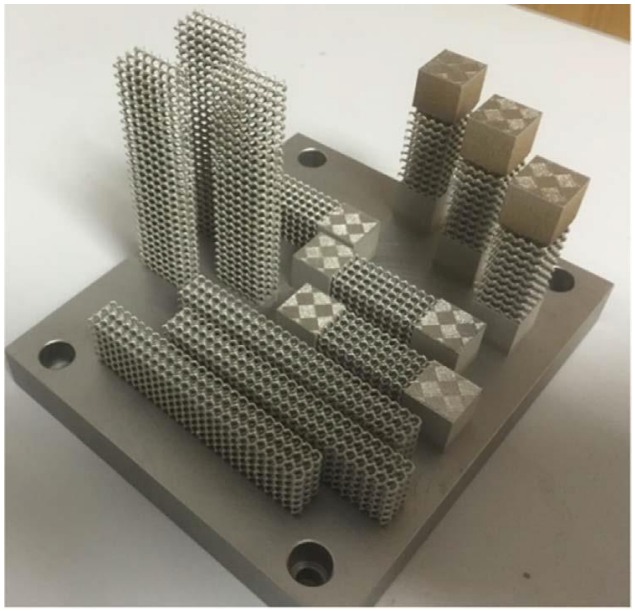


Fig 4. Periodic cellular lattice structures of 316L stainless steel samples in the platform.

3. Measurements and mechanical tests

- A micro-CT scanner, to scan the samples before and after the mechanical testing
- A scanning electron microscope SEM to characterise the failure behaviour
- EZ20 universal material testing machine (Lloyd instruments Ltd., UK) was used for tensile and fracture toughness test

❖ Results:

1.Effect of different building direction on density of lattice structure and solid struts

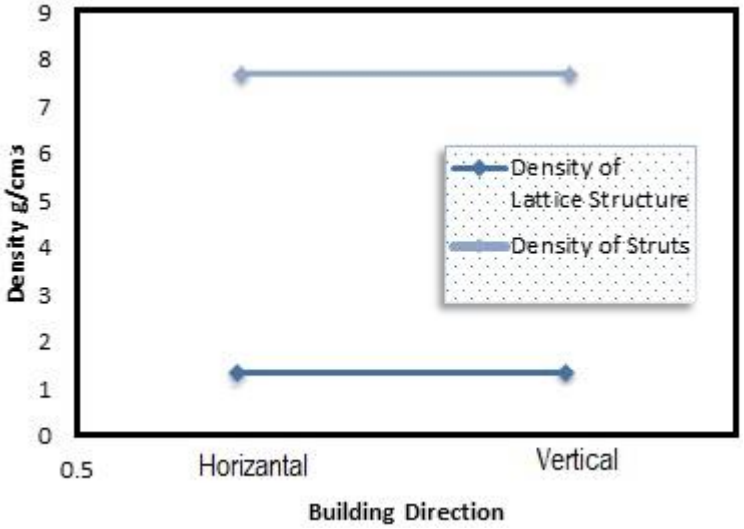


Fig 5. Variation of the struts density and lattice structure density with different building directions.

2. Effect of different building direction on strength and elongation of lattice structure

Fig 6. Stress-strain curves of the tensile tests on the cellular lattice structures

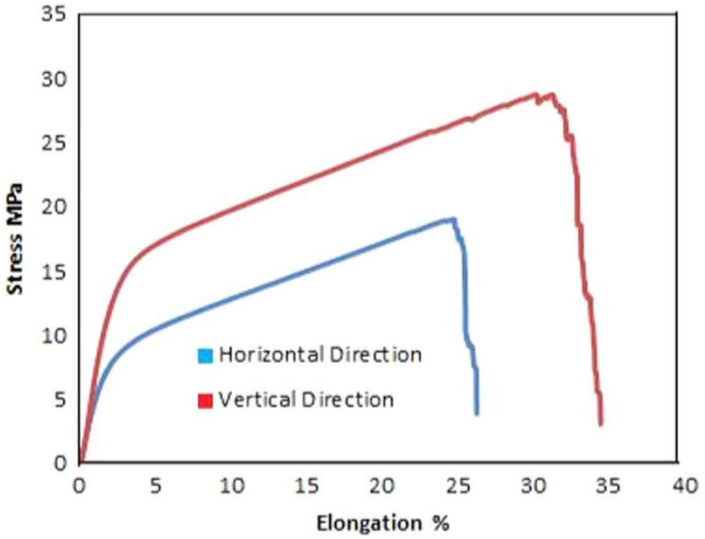
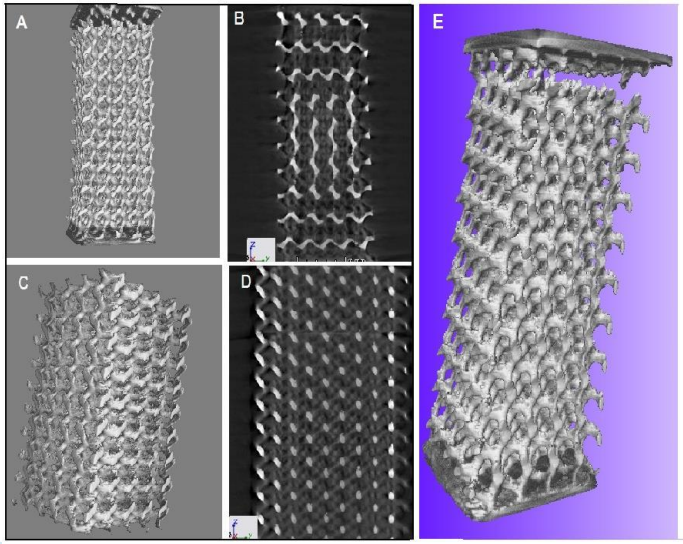


Fig 7. CT scans of the cellular lattice structure before and after a tensile test



❖ Results:

3. Effect of different building direction on the fracture toughness of cellular lattice structure

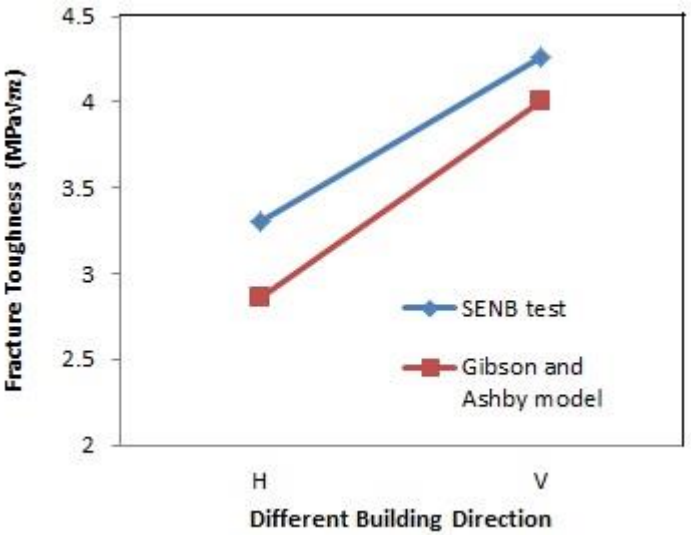


Fig 8. fracture toughness KIC vs Ashby and Gibson micromechanical models

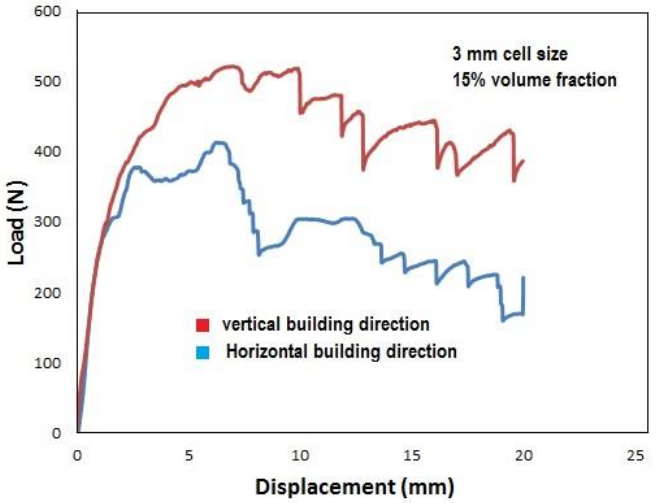
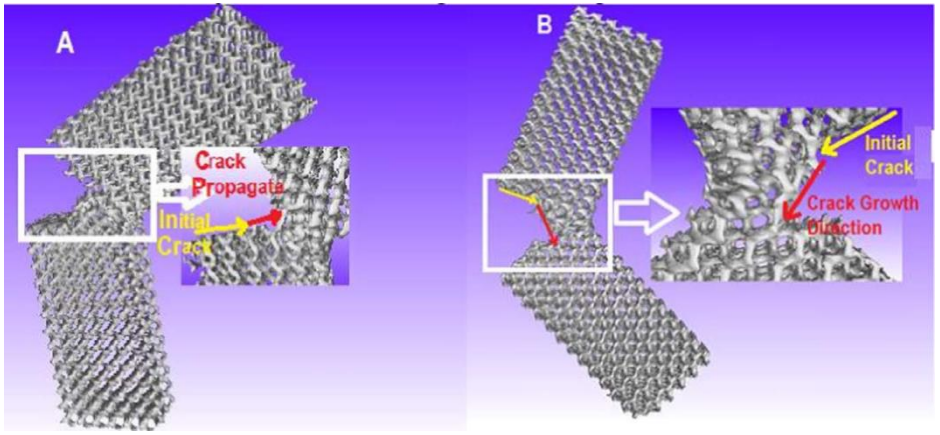


Fig 9. Load – displacement curves for different building direction of cellular structure with same volume fraction15% and cell size 3mm

Fig 10. Shows the fracture toughness test samples (a) at vertical building direction and (b) horizontal building direction



❖ Conclusion:

- The density was found at 1.35 g/cm3 for both vertical and horizontal building directions while the relative density of solid struts is 96.25%.

- The ultimate tensile and yield strength in vertical building direction samples are approximately 60% higher than those were built in horizontal direction. Also, the elongation of the vertical direction samples are approximately 40% higher than the horizontal direction.

- The fracture toughness was 4.3 MPa m0.5 in vertical direction samples and 3.3 MPa m0.5 in horizontal direction samples. Fracture toughness is strongly dependent on building direction, with other possible parameters influencing the fracture toughness being the strut density and loading rate.

- The difference between the Ashby and Gibson micromechanical model and the single edge notch bend (SENB) results from 0.2 to 0.5 MPa m0.5 and is useful tool to predict the fracture toughness of cellular lattice structure materials.

❖ **Future Work:**

Different types of cells

Different volume fraction of cells

Different sizes of cells

❖ References and Bibliographies :

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THANKS FOR YOUR LISTENING

ANY QUESTION ?

