CFD CHARACTERIZATION OF PRESSURE DROP AND HEAT TRANSFER INSIDE GYROID LATTICE STRUCTURES

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I Introduction

There is a growing interest in understanding the mechanical and thermal properties of minimal surface lattice structures produced with additive manufacturing. The study focuses on the gyroid minimal surface as shown in Figure 1 below. This surface represents the interface between the fluid and the solid. Whilst the mechanical properties of these lattices have been extensively studied for lightweight applications in aerospace and defence sectors, their thermal behaviour is not well investigated. In order to expand their use for thermal application, for example in compact heat exchangers, the heat transfer and flow through the gyroid needs to be investigated. The objective of this work is to develop a model for pressure drop and heat transfer of the flow through gyroid unit cell lattice as a function of the Reynolds number.

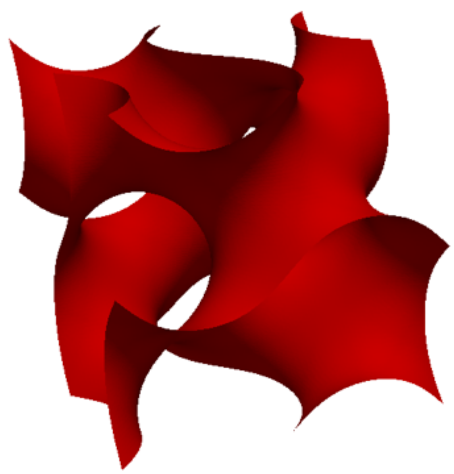

Figure 1: Gyroid Unit Cell

II Background

Lattice structures are an attractive class of materials with a mathematically defined internal structure and exhibiting specific properties of great interest in engineering. A significant amount of research has already been undertaken into the structure and mechanical properties of these materials; however, their fluid flow and heat transfer characteristics have not been thoroughly investigated. One of the biggest challenges associated with lattice structures is their manufacture and their integration into components. Additive manufacture, especially selective laser melting (SLM) allows the production of lightweight parts with a very complex architecture and with enhanced mechanical and thermal properties. In particular, gyroid topology belongs to a class of lattice structures, which are minimal surfaces periodic in three independent directions; extending infinitely and partitioning the space into two separated volumes. These structures are beneficial for applications such as lightweighting, thermal management and filtration. More specifically they can be used to develop compact, lightweight and efficient heat exchangers produced by SLM.

III Results and Discussion

This study uses CFD to characterise the flow properties and heat transfer for air flowing through gyroid. Lattice range of different parameters were investigated in order to determine the pressure drop and heat transfer for a wide range of configurations. The geometry of the gyroid was generated using CAD techniques, and then meshed using Pointwise. The CFD simulation allows us to study the flow inside this geometry. To investigate the flow distribution and performance inside the gyroid geometry, several unit cells were modelled in the flow direction, cyclic boundary conditions were applied in the other directions and the wall temperature was set up as constant. An example can be seen in Figure 2 for the volume fraction of 30 % and Reynolds number of 1000.

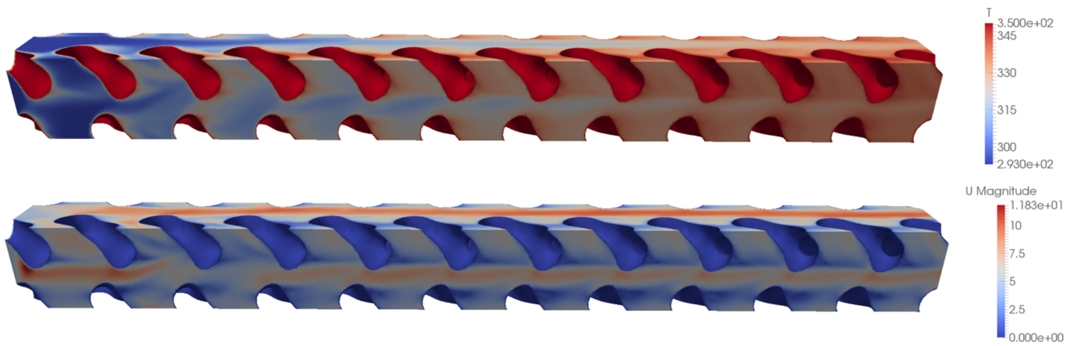

Figure 2: Temperature and Velocity magnitude of air flowing through Gyroid lattice

The parameters that were varied included the flow regimes (as indexed by the Reynolds number), the volume fraction of the cell and the cell size. For validation purposes several samples with different volume fractions and two unit cell sizes are going to be manufactured in AlSi10Mg alloy on Renishaw 250 SLM Machine and some of these will be tested for several Reynolds numbers. Micro-CT scanning technology will also be used to determine the actual manufactured geometry, enabling us to compare the CAD with the as-built geometries. In addition, CFD simulations on the actual geometry will show the impact of the manufacturing process on the pressure loss and the heat transfer.

IV Conclusions

CFD characterisation of the pressure drop and heat transfer inside a gyroid surface allows us to investigate the thermal behaviour of gyroid porous materials. A better understanding of the thermal properties of this geometry would allow us to use this class of material for both lightweighting and thermal management in the form of compact, lightweight heat exchangers. A heat exchanger produced by SLM would utilise hundreds or thousands of gyroid repeat units, which would be prohibitively expensive to model in detail. In order to circumvent this, we aim to develop models of the pressure drop and heat transfer as functions of the Reynolds number and other parameters of the gyroid, which can then be used to model a big volume of gyroid repeat units as a porous media.

Acknowledgements

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