EFFECT OF SCAFFOLD POROSITY AND LENGTH ON THE SURFACE CURVATURE OF TPMS STRUCTURES

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Introduction

When designing surfaces for cellular growth a factor that influences the cells behaviour is the curvature of the surface the cells are placed [1]. Taking this into account, the present work is focused on analysing the average surface mean curvature of Triply Periodic Minimum Surfaces (TPMS) scaffolds and how changing their design parameters influences their curvature.

Methodology

A TPMS is a zero mean curvature surface that divides a given space in two. The method used in previous works [2] adds an equal thickness to this surface on both sides, resulting in two volumes: the actual scaffold and the empty space. Furthermore, because of the nature of this method, the empty space is divided into two independent volumes, one on each side of the scaffold, which in turn results in two separate scaffold surfaces.

To evaluate the average mean curvature of these surfaces, three different scaffold configurations were created: the original and two each possessing only one of the two possible structures (henceforth referred to as negative and positive side) (Figure 1). This was done for both the Schwartz Diamond and Gyroid designs with 1 mm sided scaffolds with porosities between 50% and 80%. Afterwards, Meshlab was used to smooth the interior surfaces [2] and measure the mean surface curvature and standard deviation of each structure.

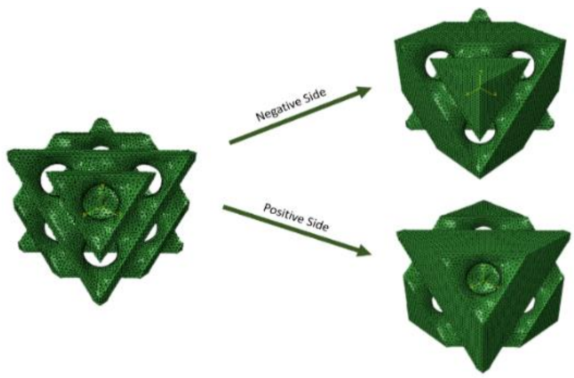

Figure 1: Example of the three studied scaffold surfaces (original, positive side and negative side) for SD70.

Results

The results showed that the average mean curvature and standard deviation were very similar across all three configurations for each of the eight studied scaffolds (Table 1). Regarding the scaffold design parameters, two different factors were analysed, which were the length of the scaffold and its porosity. To test the influence of scaffold length, five different scaffolds lengths between 0.5 and 2.5 mm were analysed for both the SD and SG scaffolds (Table 2).

SG70 Original	SG70 Negative	SG70 Positive
-0.919	-0.913	-0.925

Table 1: Average Mean Curvature for different SG70 scaffold configurations.

SG70 0.5 mm	SG70 1.0 mm	SG70 1.5 mm	SG70 2.0 mm	SG70 2.5 mm
-1.824	-0.919	-0.610	-0.456	-0.365

Table 2: Average Mean Curvature for SG70 scaffolds with varying scaffold lengths.

Discussion

Table1 illustrates that the curvature on both surfaces of the TPMS scaffolds are almost identical. Furthermore, the results also showed a negative mean curvature across all eight scaffolds, meaning that adding volume to a TPMS surface will decrease its mean curvature on both sides. Finally, the relatively low standard deviation of the results showed that the interior surfaces of these TPMS designs possess a constant surface mean curvature. In terms of the influence of scaffold length Table 2 showed a decrease in the absolute value of the mean curvature average of the scaffolds with the increase in the scaffold length. In fact, the parameters are inversely proportional with a constant of proportionality of -0.913 for the SG70 scaffold and -1.189 for the SD70 scaffold. Regarding the effect of scaffold porosity on the mean curvature of the scaffolds, the results showed that for both the SD and SG scaffolds, the higher the porosity, the closer the average mean curvature is to zero. This is expected, seeing as the higher the porosity, the lower the wall thickness, meaning these scaffold surfaces are closer to the original TPMS surfaces which have a zero-mean curvature.

References

1. Ehrig et al., Sci. Adv., 5(9), 2019.
2. Pires et al., Materials (Basel), 15(20): 7375, 2022.

Acknowledgements

This work was supported by FCT, through PhD Grant 2020.04417.BD and through IDMEC, under LAETA project UIDB/50022/2020.