EFFECT OF FDM PROCESS PARAMETERS ON MECHANICAL PROPERTIES OF THERMOPLASTIC ELASTOMER SUBJECT TO HIGH-STRAIN RATES

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1. Introduction

3D printed products have been used extensively in product development cycle to test kinematic functionality and design verification. Now, aerospace [1] and medical [2] [3] industries are exploiting the advantages offered by additive manufacturing as it outgrows its roots of rapid prototyping. Fused deposition modeling (by Stratasys Inc.) is a process of 3D printing in which a thermoplastic material is extruded in layers to create a three dimensional object. The finished 3D part takes the form of a vertically stacked laminated composite with a network of fibers and voids. FDM process produces parts with unique characteristics. Moreover, overall quality and performance of a 3D printed part is also affected by the build parameters such as printing direction, percentage amount of infill and resolution (layer height); recently huge amounts of attention have been paid to analyzing and characterizing their effects [4] [5]. A similar study done by Sood et al. [6] investigated the influence of layer thickness, raster angles, infill width and air voids on the bonding and distortion within the 3D printed part and its meso-structural configuration. Further they investigated the effect of these parameters on the compressive strength of the specimens and analyzed the importance of fiber-to-fiber bonding [7]. Compressive strength is also shown to be affected by the anisotropic behavior due to build direction, showing a reduced strength in transverse direction as compared to axial [8].

The goal of this study is to analyze the directional anisotropic effect. While a lot of attention has been devoted to understanding the performance of process parameters on popular thermoplastics, new and game changing materials (e.g. thermoplastic polyurethane) have been neglected in this respect. An important aspect that this study covers is the performance of build parameters under high strain rate impact like conditions. In past research quasi static loading conditions were implemented to test compressive strength and response at high strain has been neglected. The requirement of highly specialized testing equipment and non-commercially available load frames has created a barrier limiting knowledge with respect to high strain rate loading. This study aims to cover this knowledge barrier by incorporating non-linear hyper-elastic materials under high strain rate.

2. Design of Experiment

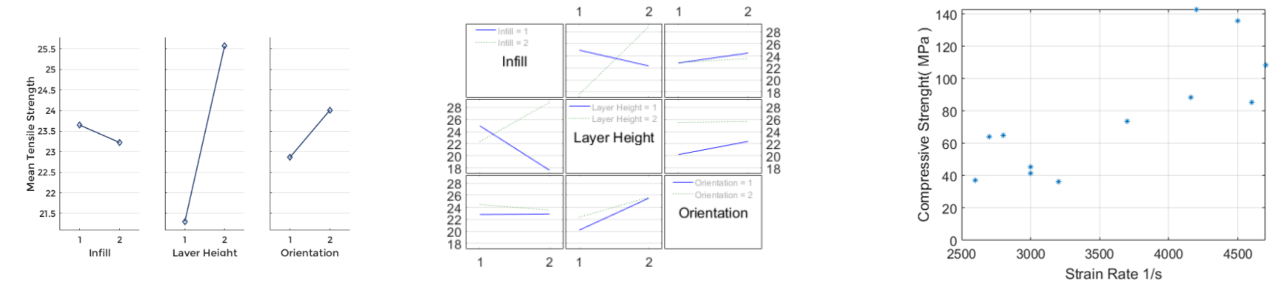
In this study build parameters including sample orientation and layer thickness are considered at different infill percentages, and we used filament rolls from NinjaFlex as our TPU material. For each category, a total of 5 samples were fabricated and tested to assure consistency in the results. Quasi-static tension tests were conducted using a commercial load frame (MTS Criterion 43) in accordance to ASTM D638 Standard Test Methods for Tensile Properties of Plastic. To test at high strain rates, a Kolsky bar (also known as Split Hopkinson Bar) was constructed. As this apparatus is usually used to test high strength materials like metals; to test softer samples, some modifications were required. The detailed design of the testing system and parameter optimization process used can be found in earlier works of the authors [9]. Full factorial design of experiment technique was used to study the process parameter effect under static loading conditions. Table 1 illustrates the three factors and 2 levels considered for this study. This would help us to optimize the build parameters to achieve enhanced mechanical performance in 3 printed parts.

Parameter	Level	Value
Raster Direction	1	0º/90º
	2	45
Layer Thickness	1	200 µm
	2	400 µm
Infill%	1	80%
	2	100%

Table 1: build parameters considered for the study

3. Discussion and Conclusion

In this study the effect of and interaction between printing parameters with respect to the tensile strength of the samples was analyzed. Preliminary results revealed that the most significant factor affecting the tensile strength is the resolution or layer width of the specimen Figure (1a). Furthermore, a significant multi factor interaction exist between infill percentage and resolution followed by infill percentage andorientation Figure (1b). Test samples were subjected to various strain rates between the range 2500-5000 /s. Strain rate not only effects the typical shape of static stress-strain response curve, but also effects the initial modulus at low strains and the compressive strength Figure (1c). The compressive strength was found to be the largest for the vertical orientation, as these samples provided aligned orientations of fibers as load carrying members as compared to increased interlayer boundaries in the horizontal orientation. Future work includes employing predictive statistical model to estimate and optimize the mechanical performance of thermoplastic elastomers in additive manufacturing process.



(a) (b) (c)

Figure 1: (a) main effect plot ,(b) interaction plot for build parameters. (c) strain rate vs comprssive strength of samples.

4. References

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