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Effects of 3D printer nozzle head temperature on the physical and mechanical properties of PLA based product

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Abstract
FDM is one of the most common processes in 3D Printing/Additive Manufacturing (AM). The quality of the end product in this process is highly dependent on employed raw materials as well as the processing variables. In this study the effects of printing temperature on mechanical properties of printed samples were studied against samples prepared via injection molding. The results showed that mechanical properties of printed samples are highly dependent on nozzle head temperature, but can't compete against injected samples

Keywords:3D Printing, FDM, mechanical properties, PLA, Nozzle head temperature

Introduction
3D Printing/Additive Manufacturing (AM) is an emerging technology that could revolutionize the design and manufacturing approaches. By building layer by layer rather than subtraction from a block or injection in a pre-formed mold this techniques enables the production of a vast variety of shapes and forms with a fraction of the costs needed in traditional manufacturing processes and hence helps the simplification or even elimination of assembly lines and enables individual targeted manufacturing [1]. Fused deposition modeling (FDM) is one of the popular approaches among other techniques due to the relative low price of the necessary equipment's and a vast variety of raw materials that can be used [2]. The quality of the end product is highly dependent on employed raw materials as well as the processing variables such as head temperature, density of model, scaling, orientation of work part or filling pattern of each slice [2].
PLA is one of the commonly used polymers in 3D printing. It is preferred by the mainstream users over ABS filaments due to its lower melting point which in turns enables the use of less expensive printers and if degraded in the printing process, it is also less toxic in comparison to other thermoplastics like ABS[3]. Due to the semi crystalline nature of PLA, the physical and mechanical properties of the end product are prone to the processing and post-processing conditions, and hence finding the optimum process parameters are vital towards achieving higher quality products.
The aim of this paper is to study the effects of nozzle head temperature on the physical and mechanical properties of the final product.

Experimental:
The test samples were printed according to ISO 527 on an open-source 3-D printer based on Ultimaker 2 design supplied by Sizan Company Iran (Sizan 2) using 1.75 mm PLA filament produced in house with a single screw extruder with raw PLA materials purchased from Nature Works Company (2003D) without any modification or compounding. The head fan speed was set to 30% for all samples and a nozzle with 1.5 mm radius was used to print the samples. Tensile tests were performed using a universal testing machine with a 500 kg load cell and at 5mm/min head speed. To determine the difference between printed and injected material, a set os\f samples (inj) were injected and tested too. Rheological measurements were performed on PLA

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samples at different temperatures using an Anton Paar rheometer.

Results and discussion

For a better understanding of the role of extrusion temperature on the mechanical properties of final product, four samples were printed at 180, 200, 220 and 240°C.

The stress at break and Young's modulus of samples printed at 180, 200, 220 and 240 °C and also samples prepared by injection molding procedure are shown in Figure 1. In Figure 2 corresponding strain at break data is shown too. As it is evident, the increase of nozzle temperature results in enhancement of tensile strength and Young's modulus, but has a negligible effect on elongation at break of the samples. As it can be seen in Figure 3, the melt viscosity of PLA is strongly temperature dependent and hence, with the increase of nozzle head temperature during printing process, the melt viscosity of PLA decreases which results in better diffiusion of newly extruded PLA molecules in underlying layer which in turn results in a stronger interlayer adhesion. For example with increasing nozzle temperature from 180°C to 240°C the strain at break value increases from 34 MPa to 56 MPa which is close to the value of the injected sample, namely 65MPa. Due to the insufficient mixing and non-uniformity caused by printing process, the printed samples do not possess the same level of mechanical strength observed for the injection molded samples. Upon increasing printing temperature beyond 240ºC some degradation in base polymer can be observed which limits the processing window to 240ºC.

Conclusion:

The mechanical properties of end product printed with PLA filaments are highly dependent on nozzle head temperature, but cannot compete against injected samples hence other finishing steps like post curing are highly recommended.

References

1. H. Lipson, M. Kurman, Fabricated: the new world of 3D printing, 2013.
2. K.S. Boparai, R. Singh, H. Singh, Development of rapid tooling using fused deposition modeling: a review, Rapid Prototyping Journal, 22 ,2016.
3. B. Wittbrodt, J.M. Pearce, The effects of PLA color on material properties of 3-D printed components, Additive Manufacturing, 8, 110-116, 2015

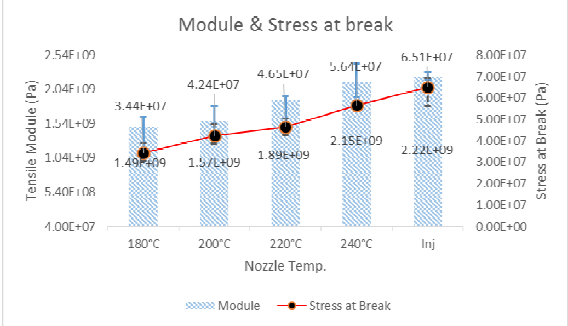

Figure 1: Effect of Nozzle temperatur on Stress at break and young Modulus of printed samples vs injected samples

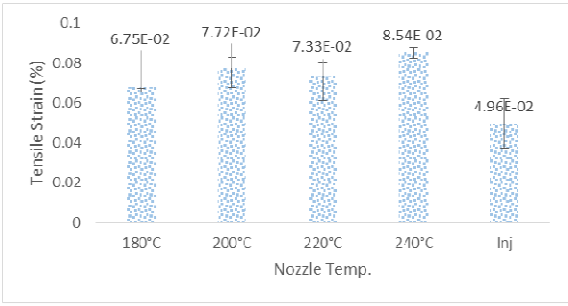

Figure 2: Effect of Nozzle temperature on Strain at break of printed samples vs injected samples

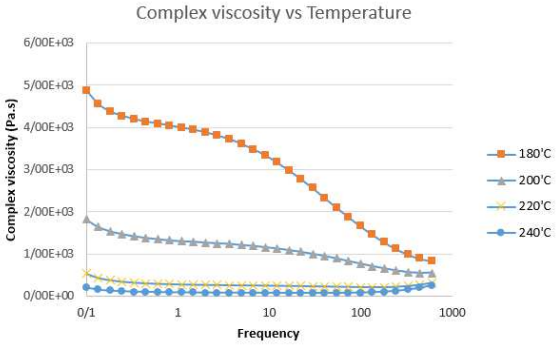

Figure 3: Effect of temperature on complex viscosity of PLA