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# Effect of Raster Angle on the Mechanical Properties of PLA 3D Printed Articles

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## Abstract
Fused deposition modeling (FDM) has been emerged as the most popular additive manufacturing technologies to make the engineering components within a short span of time. In this method, 3D digital CAD data is converted directly to make a product. In the present investigation, the mechanical properties of FDM printed specimens were evaluated according to Iso-527A-5A. The specimens were printed using PLA filament at different raster angles of 0º/90º, ±45º and 60º/-30º. It was found that the raster angle is an important parameter which significantly affected on the mechanical properties of the specimens. The results showed that the tensile strength decreased with the increase in the raster angle.

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**Keywords: Additive manufacturing, Fused deposition modeling, Raster angle, Mechanical properties, Poly lactic acid.**

## Introduction
Nowadays, economic competition has forced designers and engineers to find a way to reduce the time required to make products for different markets. Additive manufacturing (AM) process offers an efficient technique for manufacturing of complicated geometries at a shorter production cycle time and also lower cost. AM is a technology to manufacture of 3D structures by accumulating the printable materials layer-by-layer [1]. There are a wide range of additive manufacturing technologies such as fused deposition modeling (FDM), direct metal deposition (DMD), 3D printing, selective laser sintering (SLS) and stereo-lithography (SLA). These systems differ in the manner of making layers and in the types of materials that can be fabricated by these processes safely. FDM has been widely used in additive manufacturing technology, providing functional prototypes by using various thermoplastic materials, due to its ability to produce the articles with any complexity in geometry and in an office-friendly environment [2]. The properties of FDM articles depend on various processing related parameters. These parameters can be adjusted by finding their optimum values. Due to the importance of the mechanical properties of the functional products, it was decided to study the influence of various processing parameters on the properties. This study is foused on the effect of raster angle (see Fig. 1) on the tensile properties of the specimens printed by FDM.

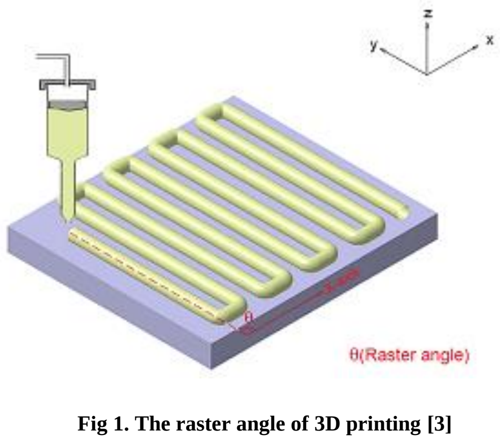


**Fig 1. The raster angle of 3D printing [3]**

## Experimental

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Specimens with three raster angles of 0º/90º, ±45º and 60º/-30º were manufactured by using a Sizan 2 3D printer (Sizan Co., Iran) using PLA filament (Filamaan, Man polymer, Iran) in accordance with Iso-527A-5A.. The tensile experiments of the dumbbell-shaphed printed specimns were performed on a universal testing machine (Santam co., Iran). For printing the specimens, the nozzle diameter and its temperature were taken to be 0.4 mm and 200ºC, respectively. The temperature of build platform was also set at 50 ºC.

## Results and discussion

The tensile strength values of the specimens printed with three different raster angles are depicted in Fig. 1. As it can be seen, the specimens printed at the angles of 0º/90º and ±45º show the highest and the lowest tensile strengths, respectively. Fig. 3 shows the microstructure of the cut plane of the specimens after being tested. No significant differences between these samples are observed. In other words, no voids or air gaps, which are usually observed within the samples, are detected to be responsible for the variation of tensile strengths in different samples. However, in the samples printed at raster angles of 0º/90º, the filaments are oriented parallel to the load direction, thus, making the strongest sample. Similarly, in the samples printed at the two other angles, there is a finite angle between the printed microstructural elements and the stress direction. Therefore, the filaments are subjected to both the tensile and shear stresses results in the specimens with lower tensile strength [3]. For the two latter specimens, the raster width in axial direction is longer than that of the samples printed at 0º/90º raster angle. Therefore, fewer filaments are required to fill the sample's width. In addition, because of more alingment of the samples printed at the angle of 30º/60º in the direction of the applied stress, they show higher tensile strength in comparision with that of the sample made at ±45º.

## Conclusion

The mechanical properties of the articles manufactured by FDM depend on several parameters such as raster angle. It was found that the tensile strength of the samples decreased with the increase of the angle. In other words, the specimens printed at the angle of 0º/90º showed the highest tensile strength in comparison with the other two raster angles studied.

## References

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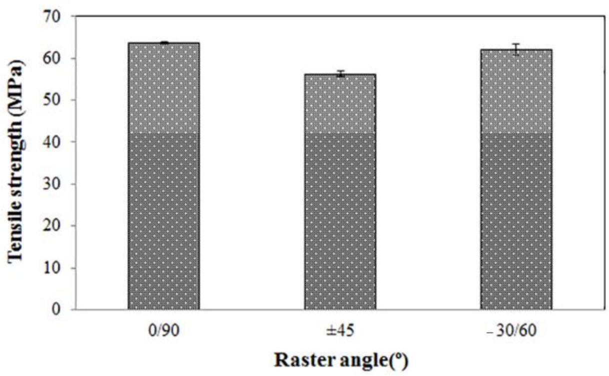


**Fig 2.Tensile strength of the specimens printed in different raster angles.**

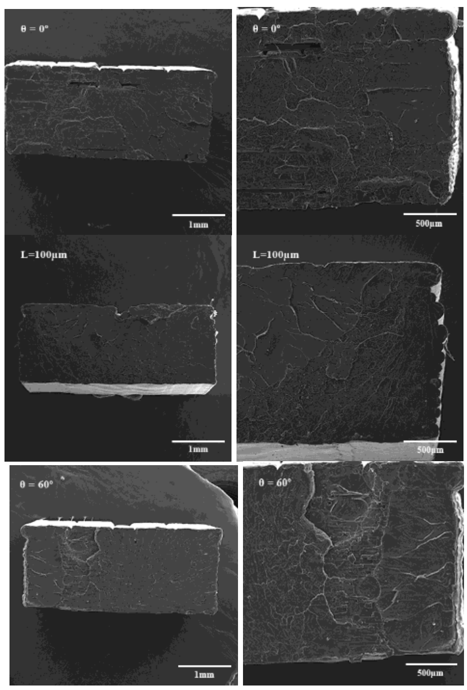

**Fig 3. SEM Images of the specimens printed in different raster angles**