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Characteristic Study of Rapid Prototyped Parts at Different Build Orientation

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Abstract: ***Rapid prototyping has come around the industrial revolution helping product designers to produce prototype with high geometric complexity in less cost .It is crucial that these parts can withstand the stress developed during the application life span .since rapid prototyping works on layer by layer manufacturing process it is imminent that the mechanical characteristics as well as quality may be affected. This paper investigates the effects of build orientation on mechanical strength of the produced product using any rapid prototyped systems and selection of build orientation based on end use application of the product. For the current study solid based FDM technology is been considered but the investigated results shows nearly constant through any rapid prototyping system.***

Keywords: Rapid Prototyping, Fused Deposition Modeling, Build Orientation, Stair Casing Effect**.**

1. Introduction

3D printing has revolutionized the way physical objects are produced directly from the digital CAD data [1]. This interned helped designers, product developers to work and experiment with prototypes without undergoing tedious and conventional process of manufacturing to produce the prototype.

Its ability to produce objects consisting of complex geometry helps many to hang on these technologies which could produce accurate and high finishing which would not be possibly obtained in any other process [2].

3D printing can be providing great saving since it can print job finish products. This helps the product developers and researchers to experiment with prototypes without going through tedious and numerous design iteration to produce the parts. They can decide if products concepts would be feasible and if not could easily produce a modifies design with just changing in cad design.Today RP technology is widely used in industry to produce prototype parts for a variety of purposes like visualization, quotation preparation and as patterns for investment casting[3] . FDM process produces part from low melting polymer such as Polylacticacid(PLA)or Acrylonitrile butadiene styrene (ABS) by extrusion through the heated nozzle which is deposited on the bed on layer basis Fig 1.RP processes offer several advantages but have limitations like low productivity (large build time), low part quality (dimensional accuracy) and low yield. A need thus exists to carry out research and development on RP process to enable it to produce functional part of good quality with mechanical property in end uses application [4][5].

2. Direction of build

Since RP technology works on layer by layer deposition technique, build direction refers to the direction in which the part is being produces either at normal to the print bed (along x- axis) as shown in figure 1 or at perpendicular to the print bed (along z-axis) figure 2

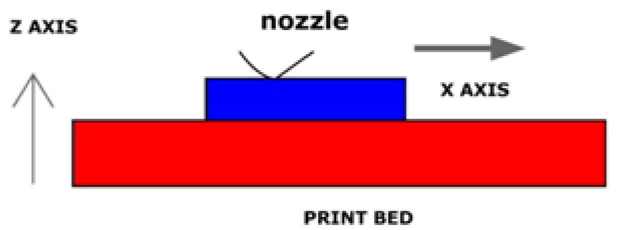

Figure 1: schematic of build at normal to the print bed (x-axis)

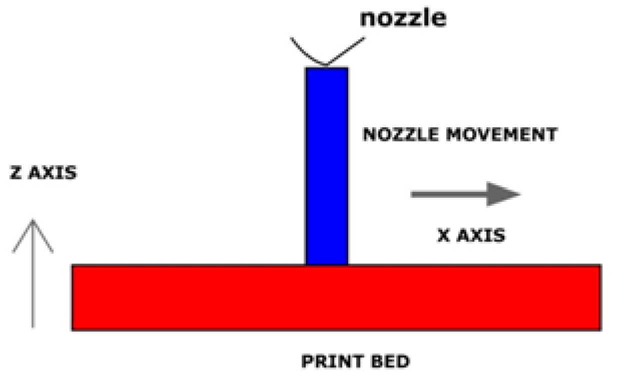

Figure 2: schematic representation build at perpendicular to the bed (z-axis)

Build orientation not only effects mechanical strength of the part but also causes quality defects and increase in build time as per the study [6].Production of circular structure often causes stair casing effect when part is subjected to different build orientation [7] figure 3 a,b . But as for this paper we have been Focusing only on effects on mechanical strength.

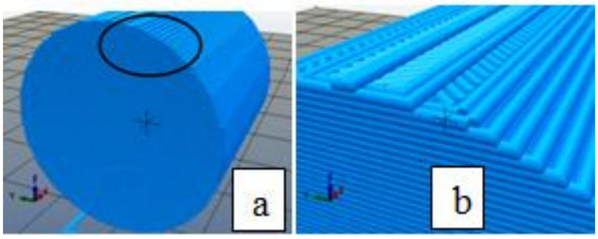

Figure 3: a, b shows the stair casing effect due to build of a cylinder at perpendicular orientation with respect to the bed.

3. Experimentation

Tensile specimen (dog bone type) structure is printed using FDM machine at normal and perpendicular direction to the print bed. The material used for print is abs material. While printing the part in perpendicular direction raft layers are used as the support so as to increase the surface contact towards the bed so as to adhere the printing during the build since small part of the sample is in contact when printed in perpendicular direction as shown figure 4 a,b.

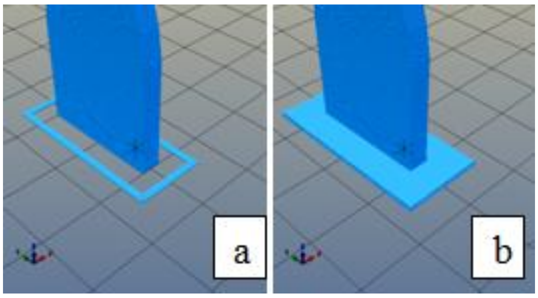

Figure 4: a shows the model without raft layer.
Figure 4: b shows the models printer with raft layer.

Three samples each in normal and perpendicular orientation are printed with respect to bed (figure 6) are taken into consideration taking printing parameters constant. The models are tested for tension using tensometer apparatus figure 5.

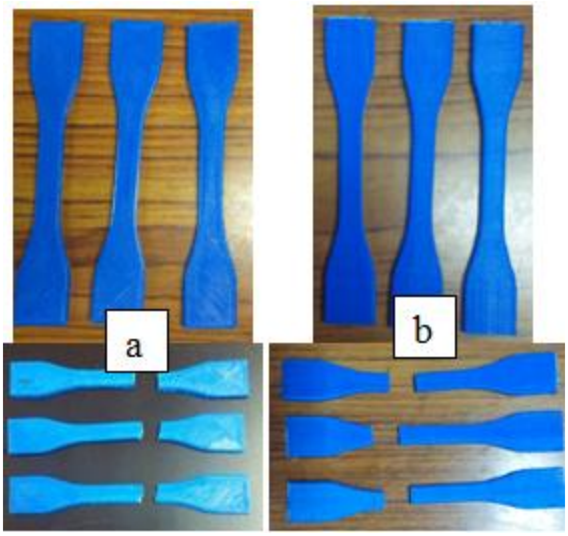

Figure 5: a test sample printed using ABS at normal to the bed before and after the tensile test.
Figure 5: b test sample printed using ABS at perpendicular to the bed before and after the tensile test

Current studies have shown during experimentation that part produced at perpendicular orientation can withstand greater compressive stress than tensile.

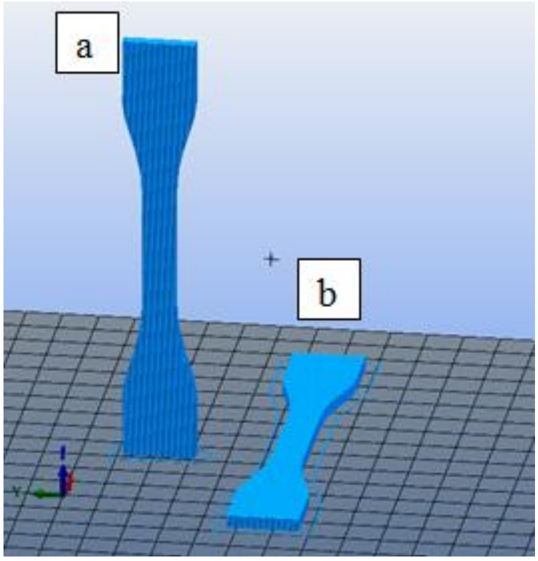

Figure 6: a. Samples 3D printed at perpendicular orientation and figure 6 b .Normal orientation with respect to print bed.

4. Observation

When the part is being built in normal direction the strand of each fiber is along the application of the force figure 7 .Hence the will fail at the ultimate load capacity of the material used while printing.

The parts produced along the perpendicular direction exhibits more compressive strength since the structure is similar to stacks of bags placed one above the other provides maximum resistance to the applied force figure 9.

Due to the layer by layer manufacturing technique some layers found to have weak points due to entrapped air molecule during the printing when observed under image analyzer figure 10.This effect is one of causes where the parts printed at perpendicular direction exhibits less tensile stress when compared to part build at normal orientation

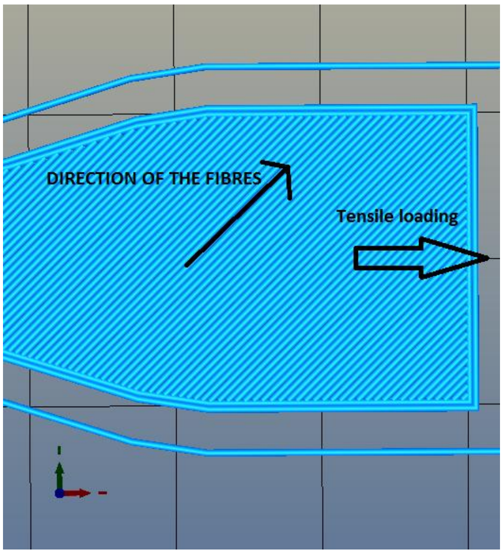

Figure 7: a shows the alignment of fibers when build at

normal orientation (along x- axis) with direction of load applied.

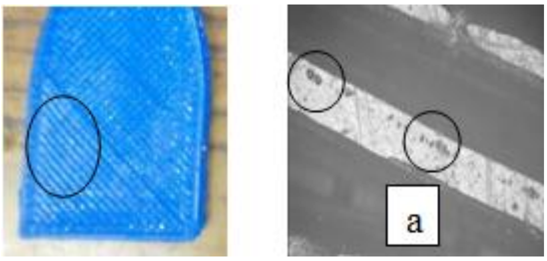

Figure 8: a surface of the part build at normal orientation under image analyzer

Black circle in figure 8.a represents entrapped air molecule in the print

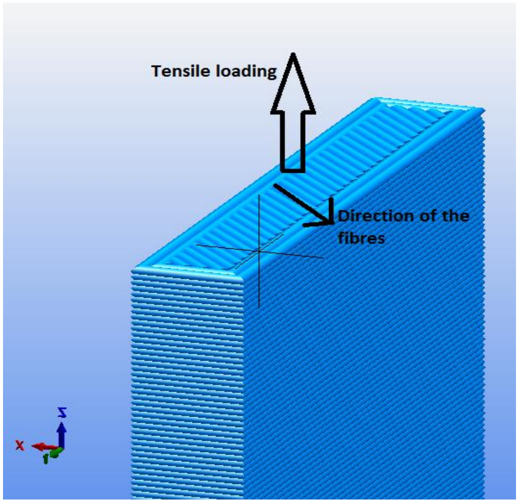

Figure 9: shows the alignment of fibers when build at perpendicular orientation away direction of load applied.

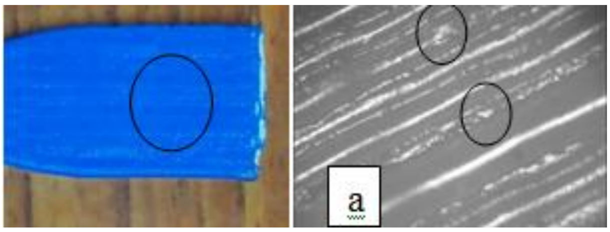

Figure 10: a: Surface of the part build at perpendicular orientation (along z -axis) under image analyzer.

While the print is normal orientation the filament stands are in line with the force acting as shown in fig and will break at the point of failure related to the break point of the material used. In this case ABS material was considered and in 3 trails for normal build orientation the break load was recorded around 693 N at tensile loading whereas while in perpendicular orientation was 392N which nearly half the stress at normal orientation (x-axis) . The below results represents the load vs displacement graph for sample size of 3 each for normal build orientation(x-axis) and perpendicular build orientation(z-axis) Figure 10-16.

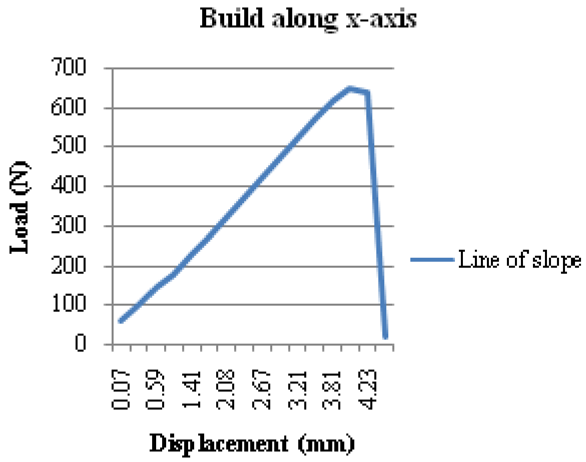

Figure 10: a. Sample 1 data at tensile loading for normal orientation (along x-axis).

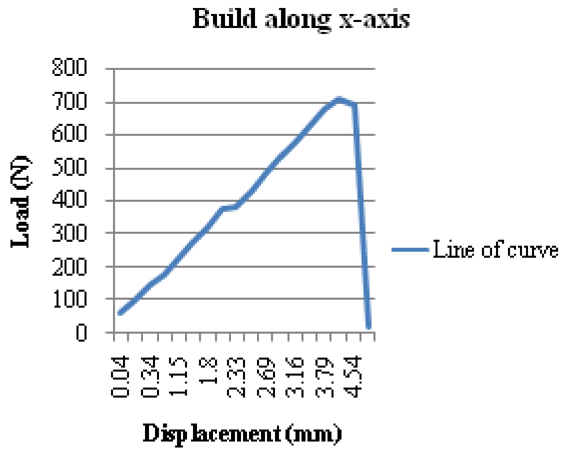

Figure 10: b. Sample 2 data at tensile loading for normal orientation (along x-axis).

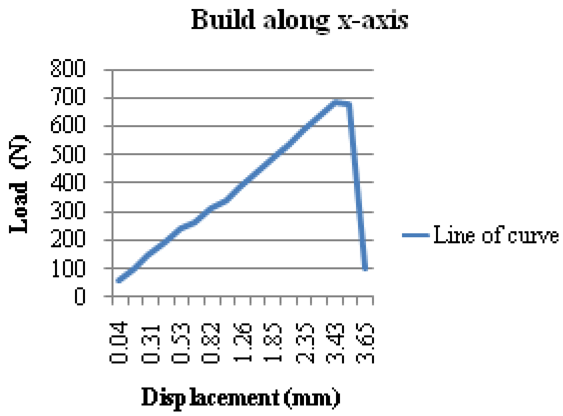

Figure 10: c. Sample 3 data at tensile loading for normal orientation (along x-axis).

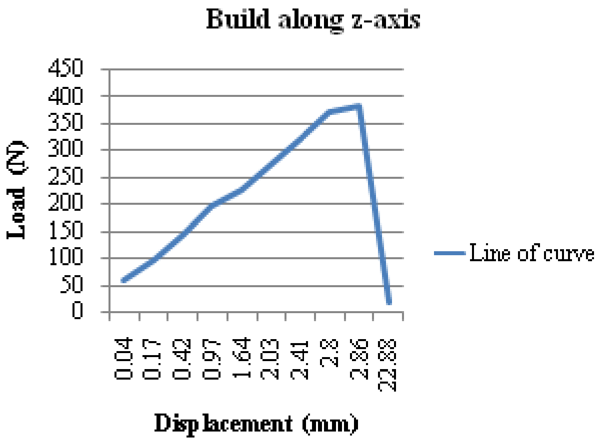

Figure 11: a. Sample 1 data at tensile loading for perpendicular orientation (along z-axis).

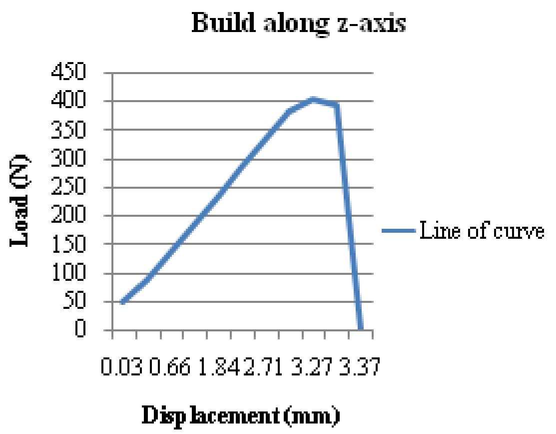

Figure 11:b. Sample 2 data at tensile loading for perpendicular orientation (along z-axis).

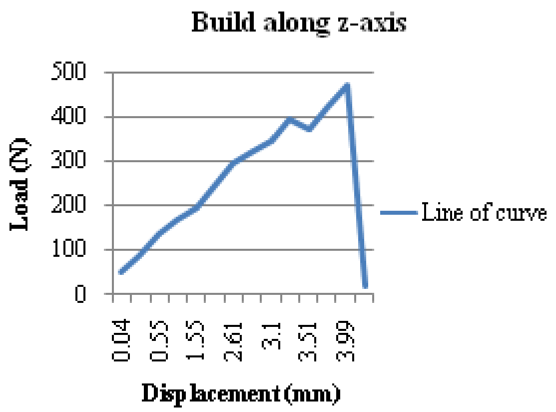

Figure 11:c. Sample 3 data at tensile loading for perpendicular orientation (along z-axis).

5. Conclusion

The paper studied the characteristics such as mechanical and quality effects at different build orientation. It is clear from the obtained results that parts build at normal orientation (along x-axis) have more tensile strength when compared to part build at perpendicular direction (z-axis). The paper also studied the reason behind the less load capacity of the part produced at perpendicular orientation.

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