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CHARACTERIZATION OF ADDITIVE MANUFACTURED ABS AND NATURAL ABS SPECIMENS

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ABSTRACT

Additive Manufacturing (AM) is a Rapid Prototyping technique. It is used for producing any real complex parts from the desired 3D CAD models. It can also manufacture prototypes. Additive Manufacturing can utilize raw materials with very minimum wastage. There are several additive manufacturing methods are available. This research work is focused on deposition modeling process. A typical 3D printer Mechanical Part Maker is used for printing tensile ASTM D638 specimens made of ABS and Natural ABS at zero degree orientation with varying densities of 11.1%, 22.2%, 33.3%, 44.4%, 55.5%, 66.6%, 77.7%, 88.8%, and 100%.

CATIA V5-R20 software is used for modeling ASTM D638-type1 standard specimens and which can allow to save the models into STL files. After that, these STL files send to CURA15.04.6 software, then the software itself can slice the models mathematically and generate g-codes files. The g-coded file formats are sent to theFDM 3D printer via PRONTERFACE software which acts as interface between CURA15.04.5 and 3D printer and then the specimens printed by Mechanical Part Maker FDM 3D printer. Tensile test machine of model UTN-40 was used for conducting a tensile test.

Here the results of yield stress, tensile strength, the percentage of reduction in area and percentage elongation for the variation of densities at constant printing speed, feed and orientation are observed. Finally, it is concluded that the characteristics of ABS are better than natural ABS, but the smoothness is good for natural ABS by visual appearance

KEYWORDS: Mechanical Part Maker FDM 3D printer, Additive Manufacturing, ASTM D638,CATIA V5-R20, & CURA15.04.6

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INTRODUCTION

ABS Filament

ABS (Acrylonitrile Butadiene Styrene) is a commonly used 3D printing filament. It is used for making durable parts, but it is not easy to print compare to PLA. ABS plastic is less brittle and ductile compare to PLA filament. ABS plastic is impact resistance and light in weight. It can withstand extreme weather conditions and is more resistance to chemicals. This will ensure minimal wrapping or separation of layers as the piece cools.

Stability under load is excellent. Even though ABS plastics are used largely for mechanical purpose, they also have electrical properties that are fairly constant over a wide range of frequencies. These properties are little affected by temperature and atmospheric humidity in the acceptable operating range of temperature. ABS is flammable when it expose to high temperatures. It is also damaged by sunlight. ABS 3D filament comes in normal diameters of 1.75mm, 2.85mm and 3mm with 0.05mm tolerance. ABS and natural ABS are not Hazardous.

Features

i.A higher melting temperature for better mechanical strength, ii. Free from harmful or hazardous materials. iii. Lower shrinkage rate, iv. High rigidity combines with good flexibility, v. Produce objects with higher toughness, vi. Proper for objects with good toughness, higher working and with minimum warping during printing, vii. Shall be printed on heat bed, viii. Parts can be withstanding the temperature of up to 80^{o}c without losing strength, ix. Parts can be vapor smoothed for greater strength and better surface finish, X. Easy to glue with acetone.

Natural ABS Filament

Natural Acrylonitrile butadiene styrene has a long history of industrial use. Well known for its high impact resistance and toughness. It's popular in commercial and engineering applications. It's found in piping, automotive parts, LEGO toys, appliances and more. Since it has a higher temperature resistance than PLA, it's more prone to warping during 3D printing. This is why a heated buildling surface is crucial for dimensional accuracy. The specifications of Natural ABS are same as ABS. Natural ABS applications are an easy creation of vessels, home décor and designer lamp shades. The detail Comparison of ABS and ABS Natural is given in the Table.1

STL File Errors:

Almost all STL models were produced by converting CAD solid models using algorithms built into the CAD package. Unfortunately, the algorithms are not always correct. Often, due to the error, in the algorithm or the numerical data round off, an STL model becomes incorrect. An incorrect STL model will cause the slicing process to fail; then, the part cannot be built. It is important to check the validity of the model before it is sent to the machine for building. In this section, some common errors are discussed.

Topology Error

An STL model must be a manifold model. In slicing a non-manifold model, the cross-section may not be closed. An open cross section is said to leak. The process used to create the layer does not know where to stop; thus it leaks. A manifold model must satisfy Euler's equation, which, for a single solid, is

$F – E + V = 2$ 1.

Where F = number of faces, E = number of edges, V = number of vertices

However, STL allows multiple solids to be present in the same file. A modified Euler's equation for a multiple solid is

$F – E + V = 2B$ 2.

Where B = number of separate solid bodies. Commonly found errors are Intersecting facets, Mismatched adjacent edges, Degenerated facets, Model errors.

Comparison of Filament Properties

Table 1: Comparison of ABS and ABS Natural

Filaments/ Properties	ABS	ABS Natural
Printing easiness	Not easier than PLA	Not easier than PLA
Hazardous	No	No
Shrinkage rate	Low	Low
Wraping	Minimum	Minimum
Odor	No	Very low
Working temperature	Withstand as solid up to 80^{o}c	Withstand as solid up to 90^{0}C
Extrude temperature	220-260^{o}C	240-250^{0}C
Bed temperature	80-100^{o}C	80-100^{o}C
Surface finish	Good	Good
Ductility	More	More
Brittleness	Less	Less
Rigidity& flexibility	High rigidity combine with good flexible	High flexibility and rigidity
Wraping resistance	Less	Low
Print quality	High	Good
Thermal strength	More than PLA, equal to HIPS, PA,PETG, less than PC,TPE,TPU	High
Toughness	More than PLA, equal to HIPS, PETG, less than PC,PA,TPE,TPU	High
Tensile strength	More than TPE,TPU, less than PLA, PC,HIPS, PA,PETG	More than PLA
Soluble	Acetone	Water
Specific gravity	1.05 gr/cm^{3}	Almost same as ABS
Durable	High	High
Applications	Automotive trim components, Bumper bars, Tool handles.	Phone back cases, laptop body etc.

EXPERIMENTAL WORK

Mechanical Part Makers

It is similar to riprap and ultimaker FDM machine. Overall size of the machine is 340mm*295mm*161mm with 2mm variation and the machine build size is 150mm*150mm*125+/-5mm**.** ASTM D638 type-1 specimens can produce by this FDM machine diagonally. Nozzle movement is in X and Z-directions and table moves in Y-direction. The FDM machine active with a CURA 15.04 6 software and orientations can kept from 0^{0} to 90^{0} in that software. Manually orientation can be in flash forge software but cannot support by the machine

SOFTWARE'S USED

CATIA V5 R20

CATIA was developed in the year 1977 by French aircraft manufacturer Avions Marcel Dassault, abbreviation of CATIA is Computer Aided Three Dimensional Interactive Applications. CATIA V5 R20 is innovated rapidly in the year 2010 and it is supported by Windows XP, Windows NT and UNIX. CATIA enables the creation of 3D parts, from 2D sketches. It allows organizations to changes in the product or develops new products utilizing a unified performance-based systems engineering approach. CATIA is used by many industrial applications such as aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction.

Designing of ASTM D638 tensile component shown in Figure 1 by using CATIA V5 R20, steps involved in designing of ASTM D638 are

Step 1: Open: CATIA V5 R20

Step 2: Click the START and select MECHANICAL DESIGN and then select Sketcher.

Step 3: Select the Axes on which we need to design.

Step 4: Select PROFILE to design the component.

Step 5: Select the 2D sketch and click on the Sketch icon on the workbench.

Step 5: Click on the PAD icon on the workbench and specify the thickness of the component. It will become the 3D model after PAD.

Step 6: ASTM D638 model is generated, then click on the File save the model into STL format.

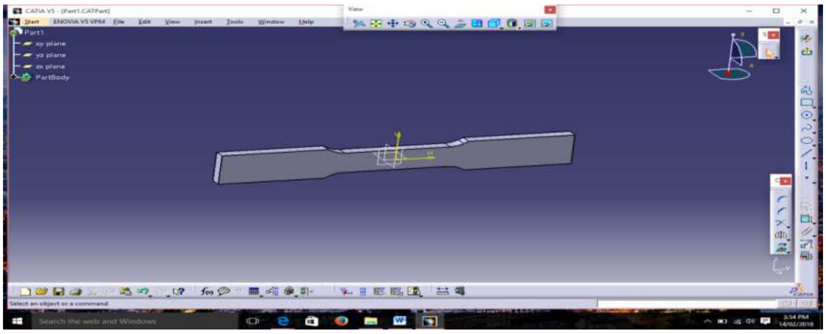

Figure 1: ASTM D638 3D CATIA Model

CURA 15.04.6 and Pronterface

The 3D CATIA model is sliced in CURA 15.04.6 is shown in figure 2. After the slicing, generate G-code file and save it. In Pronterface the saved g-code file is loaded as shown in figure 3, PRONTERFACE software consist of machine movements in X,Y and Z axes, here in this software need to specify the temperature of the extruder as well as bed temperature based on the type of filament. The green color indicates the printed portion and red color indicate non printed portion

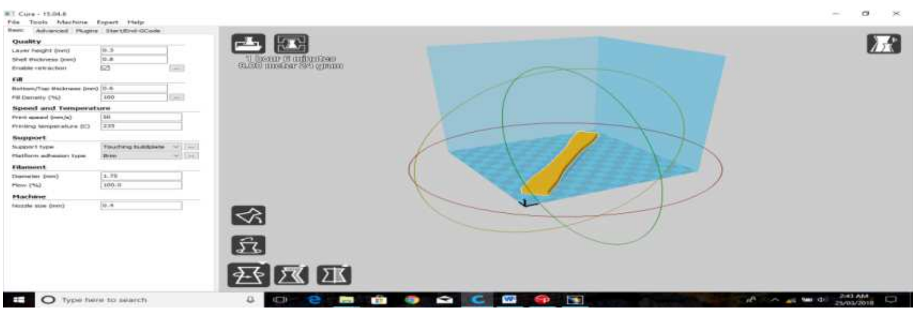

Figure 2: Sliced ASTM Model in CURA 15.4.6

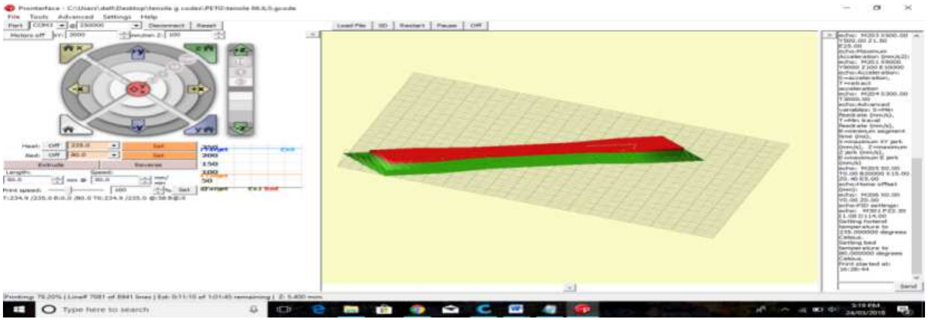

Figure 3: Partially Printed ASTM D638 in Pronterface Software.

Testing Method

C series stands for ABS components, D stands for ABS Natural components, by these notations specimens are identified. Table.2 for the input and functional parameters for printing (ASTM D638 type1) tensile components with filaments ABS and ABS Natural. Tensile tests were performed on these specimens using UTN-40 having400KN capacity and failure components are shown in figure 4 and figure 5

Table 2: The input parameters for printing ABS, ABS Natural

ABS Specimens	**1C**	**2C**	**3C**	**4C**	**5C**	**6C**	**7C**	**8C**	**9C**
ABS Natural Specimens	**1D**	**2D**	**3D**	**4D**	**5D**	**6D**	**7D**	**8D**	**9D**
Density %	11.1%	22.2%	33.3%	44.4%	55.5%	66.6%	77.7%	88.8%	100%
Orientation (Degree)	0	0	0	0	0	0	0	0	0
Feed (mm/min)	100	100	100	100	100	100	100	100	100
Speed (mm/sec)	50	50	50	50	50	50	50	50	50

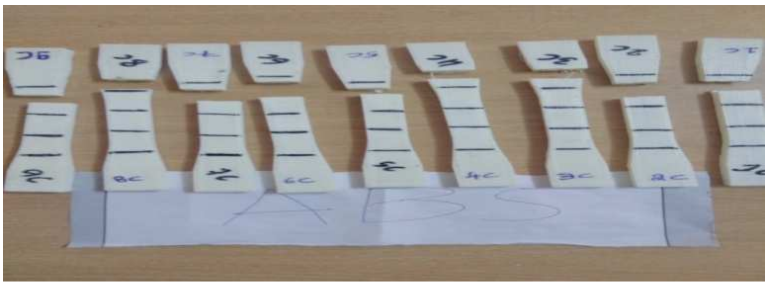

Figure 4: ABS Failure Specimens

Figure 5: ABS Natural Failure Specimens

RESULTS AND DESCUSSIONS

Each specimen of ABS and Natural ABS are built at 0^0 orientations with nine different densities are tensile tested and results as shown in table 3 and table 4. The tensile test is performed by the Universal Testing Machine of model UTN-40.

Table 3: Test Results of ABS Specimens

ABS									
Specimen	**1C**	**2C**	**3C**	**4C**	**5C**	**6C**	**7C**	**8C**	**9C**
Orientation (Degrees)	0	0	0	0	0	0	0	0	0
Density (%)	11.1	22.2	33.3	44.4	55.5	66.6	77.7	88.8	100
Load at yield (KN)	0.42	0.76	0.88	0.8	1.5	1.78	1.64	1.76	2.68
Elongation at yield (mm)	3.75	7.41	3.50	7.70	7.72	8.31	8.18	8.68	10.13
Yield stress (N/mm^2)	4.60	8.21	9.56	8.63	16.24	19.4	17.8	19.071	28.97
Load at peek (KN)	0.54	0.90	1.14	1.02	2.14	2.10	2.06	2.20	3.08
Elongation at peek (mm)	4.95	8.51	3.73	9.50	8.08	9.87	9.70	9.76	11.74
Tensile strength (N/mm^2)	5.92	9.73	12.38	11.01	23.17	22.88	22.42	23.83	33.30
Load at break (KN)	0.08	0.20	0.10	0.02	0.02	0.16	0.08	0.20	0.04
Elongation at break (mm)	5.41	9.85	9.57	10.46	10.50	10.47	10.51	10.08	12.43
% reduction area	3.10	1.76	1.76	2.25	3.00	4.83	4.48	5.29	7.16
% Elongation	1.58	1.44	1.56	1.72	1.76	1.82	2.02	2.22	2.42

Table 4: Test Results of ABS Natural Specimens

Natural ABS									
Specimen	**1D**	**2D**	**3D**	**4D**	**5D**	**6D**	**7D**	**8D**	**9D**
Orientation (Degrees)	0	0	0	0	0	0	0	0	0
Density (%)	11.1	22.2	33.3	44.4	55.5	66.6	77.7	88.8	100
Load at yield (KN)	0.42	0.42	0.66	0.58	1.02	1.04	1.42	1.2	1.96
Elongation at yield (mm)	2.95	3.27	4.33	3.76	5.2	5.03	5.72	4.46	7.86
Yield stress (N/mm^2)	4.62	4.56	7.14	6.27	11.09	11.36	15.43	13.07	21.23
Load at peek (KN)	0.54	0.54	0.82	0.76	1.24	1.40	1.76	1.60	2.58
Elongation at peek (mm)	4.18	4.36	5.70	5.01	7.04	6.63	7.29	5.67	9.51
Tensile strength (N/mm^2)	5.94	5.87	8.87	8.22	13.49	15.29	19.13	17.43	27.95
Load at break (KN)	0.04	0.10	0.02	0.06	0.12	0.02	0.06	0.04	0.10

Table 4: Contd.,

Elongation at break (mm)	4.51	4.45	6.10	5.34	7.44	6.9	8.38	6.44	10.18
% reduction area	1.10	2.85	4.18	5.31	7.29	7.94	8.38	6.16	9.94
% Elongation	1.76	1.04	1.36	1.72	1.82	1.86	2.06	2.08	2.24

The research is focused on load carrying capacity, yield stress, tensile strength, the percentage of reduction in area and percentage elongation for the variation of densities at constant printing speed, feed and orientation. The load carrying capacity of ABS specimens is than ABS natural specimens at yield, peek and breaking conditions. But load at peek is same for 1C and 1D specimen. For the same densities, almost the elongation at yield is more for ABS specimens than ABS natural. Tensile strength is almost same for specimens 1C, 1D and more variation for specimens 5C, 5D. The maximum Tensile strength is observed for ABS at 100% density.

Percentage of elongation at break is less for ABS and more for ABS natural in all cases. Percentage of reduction in area is more for all ABS natural specimens, but less for 1D component. Percentage of elongation is same for 4C and 4D workpieces and maximum elongation 2.42mm is observed for ABS.

CONCLUSIONS

ASTM D638 specimens are manufactured by mechanical part maker FDM 3D printer in this research work and the following conclusions are made.

- Maximum tensile strength is obtained 33.30N/mm^2 for 9C ABS specimen.
- Maximum yield stress is 28.97 N/mm^2 for 9C ABS specimen.
- Maximum Percentage Elongation is a Maximum of 2.42mm for 9C ABS workpiece.
- Load carrying capacity, Elongation at yield, Elongation at peek is also more for ABS at 100% density component.

Almost all the properties of ABS are dominating ABS natural, but for a particular application having less elongation ABS natural is recommended.

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REFERENCES

1. *Design and Development of Cartesian coordinate based 3D printer by D. Dev Singh and Gopi Rahul, in the international journal of Mechanical and Production Engineering Research and development, ISSN(P):2249-6890, ISSN(E):2249-8001; Volume:8, Issue 1, Feb 2018*
2. *Characterization of Fused Deposition Modeling of PLA+ and Carbon Fiber -PLA Components by D. Dev Singh, Avala. Raji Reddy and Suresh Arjula in International Journal of Latest Trends in Engineering and Technology, Vol.(10)Issue(2), pp.010-016, April 2018 DOI: http://dx.doi.org/10.21172/1.102.03, e-ISSN:2278-621X*
3. *Effect of Laser Intensities on Additive Manufacturing Process – Review by D.Devsingh and A.Raji Reddy. IOSR Journal of Mechanical and Civil Engineering, e-ISSN: 2278-1684, p-ISSN: 2320-334X, Dcember2016.*

4. *The influence of parameters of FDM technology on the selected mechanical properties of models by Tomasz kozior[1] and Czeslaw Kundera[2].*
5. *The effect of orientation difference in FDM of ABS polymer on the processing time, dimension accuracy, and strength by Yopi Y. Tanoto et al.*
6. *Safwat, G., et al. "Assessment level for complex additives in the tissue culture media of Philodendron Red Emelard plants." International Journal of Agricultural Science and Research (IJASR) 4.6 (2014): 155-163.*
7. *Rapid Prototyping (Laser-based and other technologies) by Patri K. Venuvinod and Wei yin Ma, City University of Hong Kong*
8. *Rapid Prototyping, Principles and Applications; Second edition by CHUA C.K, LEONG K.F and LIM C.S*
9. *Rapid Prototyping Technology-Volume 18, Number 2, 2010 lincoln laboratory journal, by Huynguyen and Michael vai.*
10. *Computer-Aided Manufacturing by Tien-Chienchang, Richard A. Wysk and Hsu-Pin Wang*
11. *www.filatech.com*
12. *www.reprap.org*
13. *www.Stratasys.com*
14. *www.3d-alchemy.co.uk*
15. *www.kiracorp.co.jp/kira/rp/pr-E.htm*
16. *www.solidimension.com*
17. *www.cubictechnologies.com*