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Study Of Acrylonitrile Butadiene Styrene 3d Printed Materials Using Fused Deposition Modeling And Evaluation Of The Mechanical Properties

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ABSTRACT

In the recent time, Polylactic acid is used in fused deposition modeling for making drug carriers, medical tools, cups, automotive parts, packaging, bottles, outdoor applications in purpose of medical, automotive, textile, constructions fields. The limitations of polylactic acid (PLA) is low melting point, not the hardest or toughest plastic, high production cost. To overcome the above problem, ABS is the best suitable polymer. The ABS material normally used in unconventional method. It has the limitations of less dimensional stability, poor surface finish, low hardest property. So, ABS polymer is used in additive manufacturing method. Because, good dimensional stability, very high surface finish, light weight and suitable for vast range applications. Now a days, polymer parts made by additive manufacturing methods (AM) have multiple applications in various industries. Additive manufacturing has the many techniques, but we are using fused deposition modeling (FDM). FDM is a procedure that uses thermoplastic filament that has been parched to its melting point and then thrust out layer to form a 3D object. The aspects associated with 3D printing such as less material wastage, ease of manufacturing, less human involvement, less post processing and energy efficiency makes the process sustainable for industrial use. In this study investigate the effects of Fused Deposition Modeling (FDM) process parameters of material the tensile strength, impact strength and hardness test of three-dimensional (3D) printed Acrylonitrile butadiene styrene (ABS) test parts were determined using the ASTM D638, ASTM D256 and ASTM.

Keywords: ABS polymer, **F**used Deposition Modeling, Binder Jetting and Manufacturing.

1. Introduction

3D printing (3DP) is one of the rapid prototyping (RP) techniques of products based on computer-aided 3D modeling. It also enables an initial and effective design process for successful and efficient end products. As a result, it comes to the forefront as a driving force in material savings in the production process It has been suggested that 3DP technology can revolutionize manufacturing practices in many industries. 3DP has gained popularity in recent years as a result of its ability to reduce the amount of time and material used in the manufacturing process. RP, functional part production, and free form production are all production types that benefit from 3DP technology. FDM is the most commercialized 3DP or another name Rapid Prototyping technology currently. The FDM process, works on the premise of adding layer by layer plastic filament material. Combining Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) technologies, items can be fabricated via Additive Manufacturing (AM) technology without traditional cutting techniques. AM also known as three- dimensional (3D) printing is a manufacturing process for fabrication of parts from a CAD model based on deposition of material layer by layer. For instance, 3D printing has exceedingly reduced fabrication cost and time with flexibility in printing complex geometries Utela et al. (2008). Indeed, the use of 3D printing provides the production of any kind of shape from a digital design with a little waste of raw materials Wimpenny et al. (2017). 3D printing has indicated advantages in fabrication of complex structures, multi-material structural elements, and thin-walled structures Amirpour et al. (2019), Yuan et al. (2020), Zhang et al. (2021). Currently, 3D printing technology has been widely used in different fields such as electronics Khosravani and Reinicke (2020), construction industry Souza et al. (2020), manufacturing Sandeep et al. (2021), and healthcare monitoring NasiriandKhosravani (2020).

1.1 CLASSIFICATION OF 3D PRINTING METHODS

In order to satisfy the need for printing intricate models with high resolutions, methods of AM have been developed. Rapid Prototyping has played an important part in the advancement of AM technologies. AM Technologies are based on three main types which are sintering where by the temperature of the material is raised without being liquified to compose complex sharp resolution prototypes, melting- where electron beams are used to melt the powders and stereolithography which uses a method referred to as photo polymerization, which uses an associate ultraviolet laser. This laser is dismissed over a photopolymer resin vat so that torque-resistant ceramic components are ready to encounter utmost temperatures.

Powder Bed Fusion (PBF)
Selective Laser Sintering (SLS)
Binder Jetting (BJ)
Fused Deposition Modeling (FDM)
Direct Energy Deposition (DED)
Stereolithography (SL)
Laminated Object Manufacturing (LOM)

As per ASTM (American Society for Testing and Materials), AM have been divided into seven processes which include VAT Photo polymerization, Material Jetting, Binder Jetting, Material Extrusion, Powder Bed Fusion, Sheet Lamination, and Direct Energy Deposition. Some of the main methods have been addressed in depth in the subsequent sections focusing on the work involved in each process, benefits and drawbacks, materials used in different processes, and applications of various 3D printing processes.

1.2 FUSED DEPOSITION MODELING

FDM technology was introduced by Scott Crump during the early Nineteen Nineties by Stratasys INC, USA introduced this. The 3D printers used for FDM contain a support base that is related to some degree of freedom and it has an arrangement such that it will move in a vertical direction. Aboard with the bottom plate, there's an associate extruder that connects the filament and is liable for heating of the filament up to its freezing point and so extrudes it layer by layer with the assistance of a nozzle to form the required object. The extruder has the supply to maneuver in all three directions (x, y and z). The reason that it's called fused deposition modeling is that the adjacent layers get consolidated to one another whereas deposition is completed by the extruder and therefore the 3D printer is liable for modeling of the item. Counting on the surface end needed, the ultimate product is dipped in resin as similar in the SL method.

Fused deposition modeling (FDM) is an extrusion-based 3D printing technology. The build materials used in FDM are thermoplastic polymers and come in a filament form. In FDM, a part is manufactured by selectively depositing melted material layer by layer in a path defined by the CAD model. Fused deposition modeling (FDM) is an extrusion-based 3D printing technology. The build materials used in FDM are thermoplastic polymers and come in a filament form. In FDM, a part is manufactured by selectively depositing melted material layer by layer in a path defined by the CAD model. 3D printing machines that use FDM Technology build objects layer by layer from the very bottom up by heating and extruding thermoplastic filament. The whole process is bit similar to stereo lithography Firstly a special software "cuts" CAD model into layers and calculates the way printer's extruder would build each layer then the printer heats thermoplastic till its melting point and extrudes it throughout nozzle onto base, that can also be called a build platform. Once the layer is finished, the base is lowered to start building of next layer. Compared to the previous process this method is bit slower. When printing is completed support materials can easily be removed by placing an object into water and a detergent solution.

1.3 MECHANICAL CHARACTERIZATION OF MATERIAL

Mechanical testing is used to reveal information about a material's mechanical properties under dynamic or static forces. In the conservation field, mechanical tests are often used to determine whether a material is suitable for its intended purpose or whether specific environmental conditions have an impact on an object. This is done by determining different properties such as elasticity. tensile strength, elongation, impact strength, three-point bending strength, hardness, and fracture toughness. Conventional mechanical characterization methods such as the UTM typically require the destruction of large samples. Also, SEM and UV visible spectroscopy equipment's are used to finding the microstructure and nanostructure of the material.

2. LITERATURE OF REVIEW

M. AZADI, A. DADASHI, S. DEZIANIAN, M. KIANIFAR, S. TORKAMAN, M. CHIYANI, "HIGH-CYCLE BENDING FATIGUE PROPERTIES OF ADDITIVE-MANUFACTURED ABS AND PLA POLYMERS FABRICATED BY FUSED DEPOSITION MODELING 3D- PRINTING" (2021) - This study investigates, the standard samples of the fatigue test were printed in both horizontal and vertical directions and were made of two polymers, PLA and ABS. The thickness of each layer was 0.15 mm and the infill percentage of the parts was 50%. The rotary bending fatigue test was performed under conditions of fully-reversed stress-controlled loading at different stress levels. The results included the stress amplitude versus the fatigue lifetime of FDM 3D-printed PLA and ABS polymers. Besides, the scanning electron microscopy (SEM) image of the fracture surface was also depicted after fatigue testing. Results showed that PLA specimens had better fatigue lifetimes than ones of ABS samples. The SEM image demonstrated beach marks on the fracture surface of fibers (3D-printed filaments) in the PLA specimen, which proved cyclic loadings. Then, cleavage facets were the result of the brittle fracture.

MOHAMMAD REZA KHOSRAVANI, TAMARA REINICKE "FRACTURE STUDIES OF 3D-PRINTED PLA-WOOD COMPOSITE" (2022) - To this aim, 3D-printed PLA-wood specimens were fabricated and examined. Specifically, two groups of intact and defected specimens were printed and their tensile behaviors were compared. In the defected specimens' gaps are intentionally placed which is considered as a defect. The experimental results confirmed that defect in 3D-printed parts leads to decrease in fracture load and stiffness of the components. This study has demonstrated that highest strength belongs to the 0° 3D-printed parts. The presented results can be used for finite element simulation and its verification.

CAN TANGA, JUNWEI LIUA, YANG YANGE, YE LIUA, SHIPING JIANGA, WENFENG HAOA, "EFFECT OF PROCESS PARAMETERS ON MECHANICAL PROPERTIES OF 3D PRINTED PLA LATTICE STRUCTURES" (2020) - In this paper investigates, the mechanical properties of 3D printed PLA lattice structures were studied using digital image correlation (DIC), and the effect of process parameters on the mechanical properties of the samples was discussed.. The experimental results show that as the printing temperature increases, the tensile strength and elastic modulus tend to rise first and then decrease. When the printing temperature is 230 °C, the maximum tensile strength is 50.16 MPa, and the tensile elastic modulus is 4340.38 MPa. While the yield strength, plastic platform stress and densification strain of lattice structures show a downward trend. As the printing speed increases, the tensile strength and elastic modulus show an upward trend, and when the printing speed is 60 mm/min, the tensile strength and elastic modulus are 51.47 MPa and 5102.12 MPa respectively. Moreover, the yield strength, plastic platform stress of lattice structures shows a downward trend, densification strain shows an upward trend.

GURCAN ATAKOK, MENDERES KAM, HANIFE BUKRE KOE "TENSILE, THREE-POINT BENDING AND IMPACT STRENGTH OF 3D PRINTED PARTS USING PLA AND RECYCLED PLA FILAMENTS" (2022) - In this study investigates, the Taguchi methodology was used to investigate the effects of Fused Deposition Modeling (FDM) production parameters tensile strength, three-point bending strength, and impact strength of three-dimensional (3D) printed polylactic acid (PLA) and recycled polylactic acid (Re-PLA) test parts. As FDM process parameters, filaments (PLA, Replay), three different layer thicknesses (0.15 mm, 0.20 mm, 0.25 mm), occupancy rates (30%, 50% and 70%), and filling structure (Rectilinear) were determined in the experimental design. The results showed that layer thickness is the most efficient factor for improving tensile strength, three-point bending strength, and impact strength rather than occupancy rate or filament materials. The optimum results were obtained in layer thickness (0.25 mm), occupancy rate (70%), and filament material (PLA), respectively. Also, Scanning Electron Microscopy (SEM) has been utilized to investigate the morphology and topography alterations in the fractured surface of test parts.

MOHAMMED HIKMAT, SARKAWT ROSTAM, YASSIN MUSTAFA AHMED, "INVESTIGATION OF TENSILE PROPERTY-BASED TAGUCHI METHOD OF PLA PARTS FABRICATED BY FDM 3D PRINTING TECHNOLOGY" (2021) - In view of this, the present paper experimentally and statistically studied the effect of various printing parameters namely build orientation, raster orientation, nozzle diameter, extruder temperature, infill density, shell number, and extruding speed on tensile strength using Polylactic acid (PLA) filament. Based on Taguchi's mixed model fractional factorial design, eighteen experiments were set and the specimens of PLA are printed on an FDM 3D printer and tested for tensile strength using the universal testing machine. The results showed that the part strength influenced by the selected process parameters, where only three of them, build orientation (on-edge), nozzle diameter (0.5), and infill density (100%) statistically were significant and highly impact the result. While build orientation has the most influential effect on tensile strength (44.68%). Lastly, the confirmation test showed that there is a good agreement between the experimental and statistical data.

3. EXISTING SYSTEM

3.1. POLYLACTIC ACID (PLA)

Polylactic Acid (PLA) ranks as one of the most popular materials for 3D printing, particularly FDM. Its ease of use and minimal warping issues make PLA filaments the perfect starting point for 3D printing PLA is also one of the most environmentally-friendly 3D printing materials.

Property	Values
Density	1.24 g/cm³
Tensile Strength	50 Mpa
Impact Strength (Unnotched) IZOD (J/m)	7J/m
Shrink Rate	0.37-0.41%
Flexural Strength	80 Mpa
Melting temperature	210°C
Printing temperature	190-220°C

Fig: 1 properties of PLA

3.2 PLA USED IN FUSED DEPOSITION MODELING

PLA is an organic polymer that lends itself to multiple applications. It is commonly used in fused deposition modeling technology (FDM), which operates by depositing successive layers of material. The material extrusion, in the form of a wire, follows an imposed pattern, which influences the static and dynamic behavior of the final component. In the literature there are many works concerning the mechanical characterization of the PLA but, due to the natural orthotropy of the FDM process and, above all, to the ascertained influence of the particular technical system with which the operations are performed, it is necessary to characterize the extruded material through different metrological techniques. In order to allow the use of this technology for structural elements production, in the present work, quasi-static tests have been carried out to characterize the material and the process considering the three spatial growth directions (x, y and 2). In particular, uniaxial tensile tests were performed for the determination of mechanical strength, modulus of elasticity and percentage elongation.

4.METHODOLOGY

This section describes the methodology implement to carry out the proposed research to characterize the mechanical and the properties of 3D printed material using ABS polymer. It also includes material selection, printing of the parts. experimentation, characterization methods and assessment procedure. The mechanical and thermal behaviors of various filament materials were accounted for in this study. The detailed plan of the investigation is shown in next phase Each stage in the scheme of investigation is discussed elaborately.

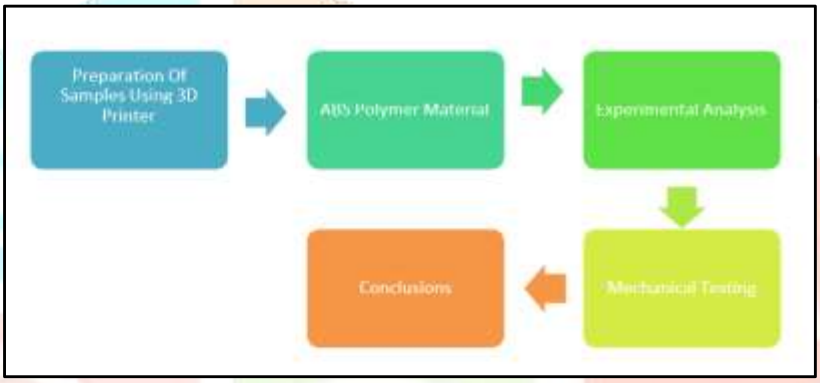

Fig :2 Methodology

5.Software

5.1 Software Installation and Start-Up

Decompress the zipped file or start the installation program, and then install the software according to the direction. Start the software with the start menu shortcut or by clicking the software icon.

5.2 Machine Type Selection

After starting Flash Print, you need to select the target machine type first. When you start Flash Print, a dialog box will pop up. Just select Flash Forge Guider IIS in the machine type list and click [OK]. You can also change the machine type via clicking [Print]--[Machine type].

5.3 Generating Design

Load a pang, jpg, jpeg, bmp picture file into the Flash Print. And the following dialogue box will pop up. The setting box includes settings for shape, mode, maximum thickness, base thickness, bottom thickness, width, height, top diameter and bottom diameter.

Shape: including plane, tube, canister and lamp.
Mode: including "darker is higher" and "lighter is higher".
Maximum thickness: Z value of the model.
Base thickness: The minimum raft thickness and the default value is 0.5mm
Width: X value of the model.
Depth: Y value of the model
Bottom thickness: For tube, canister and lamp to set up bottom thickness
Top diameter: For tube, canister lamp and seal to set up the top diameter
Bottom diameter: For tube, canister, lamp and seal to set up the bottom diameter.

5.4 Print

Preview: Choose to enter preview interface or not

Print when slice done: Print or not when slice done

Supports: When print suspended structure models, support is necessary. Click [supports] to create support part for the printing.

Raft: This function will help the model to stick well on the platform.

Wall: During dual color printing, this function will help to clear the leaking filament of another extruder.

Brim: Expand the outline of model's bottom layers to a Brim which helps anchor the edges of the model to the plate to avoid warping.

5.5 Layer

Layer: Layer thickness of the printing model. With a small value, the surface of the model will be smoother.

First Layer Height: This is the first layer of the model, which will affect the sticking performance between the model and platform. Maximum is 0.4mm, usually the default is OK.

Shell: Contains the outside shell value, capping layer value (under vase pattern, top solid layer setting is invalid.)

Perimeter Shells: Maximum is10

Top Solid Layer: Maximum is 30, minimum is1.

Bottom Solid Layer: Maximum is 30, minimum is1.

5.6 Speed

Print Speed is the moving speed of the extruder. Generally, the lower speed is, the better print you will get. For PLA printing, 80 is recommended.

Travel Speed is to control the moving speed of the extruder under non- printing Status during work. For PLA printing, 100 is recommended. Modify parameters settings to get better prints as different models need different parameters.

5.7 Temperature

Extruder Temperature: Recommended extruder temperature is 220°C.

Platform Temperature: To set the temperature of Platform.

5.8 Others

Cooling Fan Control: Set up the time to turn on the cooling fan. You can pre-set the height and make the cooling fan begin to work at the point.

6. MATERIALS PREPARATION

First create the test parts using solid works Computer Aided Design (CAD) program and then it is converted to G-code using the simply 3D slicer program. The important design features, such as dimensions, color, material type, are included in the files. The slicer program used in the 3D printer is Flash print. Using Flash Print, you can turn STL files into G-code files for printing. Then the files can be transferred to your Guider IIS via USB cable, USB stick, Wi-Fi or Ethernet cable.

Tensile test parts in accordance with ASTM D638 standards, Charpy impact test parts in accordance with ASTM D256 standards, and Hardness test parts in accordance with same standards of ASTM D256 were used to test the ABS filament. The Flash forge Guide IIS was chosen since it is one of the most suitable and high-quality devices for individual usage on the market in terms of price/performance. The accurate alignment of the 3D printer's elements during setup is a crucial requirement for high-quality 3DP.

7. CONCLUSION

In this study, ABS filaments and FDM from additive manufacturing techniques were used. The area covered in the paper are process parameters and functions of FDM machine. Test parts of different production parameters are produced using layer thickness and printing speed. The mechanical properties obtained as a result of the test has detailed in next phase.

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