ANALYSIS OF 3D PRINTED OBJECT

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Abstract*:* Additive Manufacturing (AM) technologies have been emerged as a fabrication method to obtain engineering components within a short span of time. Desktop 3D printing, also referred as additive layer manufacturing technology is one of the powerful method of rapid prototyping (RP) technique that fabricates three-dimensional engineering components. In this method, 3D digital CAD data is converted directly to a product. In the present investigation, ABS + hydrous magnesium silicate composite was considered as the starting material. Mechanical properties of ABS + hydrous magnesium silicate composite material was evaluated. ASTM D638 and ASTM D760 standards were followed for carrying out tensile and flexural tests, respectively. Samples with different layer thickness and printing speed were prepared. Based on the experimental results, it is suggested that low printing speed, and low layer thickness has resulted maximum tensile and flexural strength, as compared to all the other process parameters samples.

Keywords: TPU (Thermoplastic polyurethane); FDM; Additive Manufacturing; Rapid prototype; 3D printing; Tensile Strength; Flexural Strength; Mechanical Properties.

Introduction: Additive Manufacturing (AM) is extensively used to fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data at a faster rate. The CAD data is fed to the 3D printing machines that allow designers to quickly create tangible prototypes of its designs, rather than just two-dimensional pictures. 3D printing is a form of layered manufacturing / additive manufacturing technology where a three-dimensional object is created by laying down successive layers of material. The material extrusion additive manufacturing (AM) process, commonly known as **FDM**. Various types of AM techniques, such as stereo-lithography (SLA), selective laser sintering (SLS), laminated object manufacturing (LOM), **Fused deposition modeling (FDM),** 3D printing, and sanders prototyping are available in market, which works on AM principle. Among all, FDM process is second most prominent AM technique after stereo-lithography, gains popularity due to its short cycle time, high dimensional accuracy, desktop facility, and safe to use.

Literature Survey:

The survey is considered in this work is categorized in following subsections separately as 3d printing using fused deposition modelling, Process parameters for 3d printing, Optimization of process parameters of different materials.

2.1.1 Literature Survey on 3-dimensional printing using FDM (fused deposition modelling):

The following literature review is based on 3-d printing of different materials using fused deposition modelling. Lim Chin Hwa [1] they presented review on recent advances in 3-d printing of porous ceramics. The basic technology is the 3D printing techniques, which are used to fabricate porous green ceramic parts that are later sintered. Different ceramic materials are evaluated and the classification of different powders according to their 3D printing quality as well as material aspects is examined. The evaluation of 3D printing process in terms of the powders' physical properties such as particle size, flowability and wettability is also discussed. The relationship between the different 3D printing parameters and the final printing outcome are assessed. Rafael Thiago Luiz Ferreira [8] The objective of their work is the mechanical characterization of materials produced by 3D printing based on fused _lament fabrication (FFF, analogous to FDM®). The materials chosen are a polylactic acid (PLA) and a PLA reinforced with short carbon fibers in a weight fraction of 15% (PLA+CF). In view of the FFF nature, which produces specimens layer by layer and following predefined orientations, the main assumption considered is that the materials behave like laminates formed by orthotropic layers. If the 3D printing is made in the 1□2 plane, where 1 is the deposition direction and 2 is a direction perpendicular to 1, the mechanical properties obtained are the tensile moduli E1 and E2, the Poisson ratios _12 and _21, the shear modulus G12 and related strength properties. Caterina Balletti [21] present the state of art and the potential and large spectrum of applications of fabrication technologies in the CH. Through a brief history and characterization of the most com-mon 3D printer technologies, we try to present a review of the applications of 3D printing on CH, considering our experiences or those of other researcher. In the final part of this paper, a particular aspect of solid printing is analysed: the level of accuracy reachable in the creation of material models. This level of precision must be related to that of the instruments of analysis through which the artefacts are converted into digital format. We must not forget that the process that leads to the realisation of a material copy must go through a numeric model and that in this process there is a progressive loss of definition, both from the qualitative and quantitative points of view. T. Galeta, Slavonski Brod [9] have been concentrated on three-dimensional printing (3DP) technique. This process combines a layered approach from RP technologies and a conventional ink-jet printing. It prints a binder fluid through the conventional ink-jet print head into a powder, one layer onto another, from the lowest model's cross-section to the highest (Figure 1). After printing, the printed models are dried in a building box, then removed from the powder bed, de-powered by compressed air, dried in the oven and infiltrated for maximum strength. J. Mueller [11] determine and quantify the parameters that lead to the most accurate geometry and to the best mechanical properties. Using this understanding, it is possible to build accurate part models and optimize, fabricate and test them successfully. Significant impacts on the mechanical properties are found, in descending order, for the number of intersections between layers and nozzles orthogonal to the load-direction, the exposure time to ultraviolet light, the position on the printing table and the expiry date of the raw material. Nozzle blockage significantly affects the geometry and also the machine's warm-up time is an important factor. Minor effects are found for the storage time and the surface roughness is not affected by any factor. Since AM materials change rapidly and the characterization process will have to be repeated

2.1.2 Literature Survey on Process Parameters of 3-D Printing

The process parameters considered in this work are categorized as following respectively used to determine printing speed, density, bed temperature, raster angle, etc. Tomasz Kozior [5] In this paper they presented experimental results the influence of location and direction of the models on the virtual platform on their selected mechanical properties such as Young's modulus and stress relaxation during uniaxial compression tests. Cylindrical samples were manufactured using the Dimension 1200es machine realizing the fused deposition modeling technology (FDM). The samples were located on the machine platform at different angles to the printing direction. The material used for the construction of samples was ABS P430. Ala'aldin Alafaghani [6] This presented paper provides an experimental study to investigate the independent effect of each processing parameter on the mechanical properties and dimensional accuracy repeatability of FDM parts. A total of 18 test specimen samples were printed using varying processing parameters. In order to investigate the repeatability and resulted tolerances, the dimensions of these specimens were measured and compared with a 3D CAD model. The presented work utilizes a tensile test per ASTM D638 standards to obtain the mechanical properties of each fabricated sample. In addition, the work provides a Finite Element Analysis (FEA) model for AM parts. The work suggested to simulate their behavior under mechanical loads for future investigation on the coupled effects of processing parameters. Y. Song, Y. Li [7] In this project Specimens were cut from printed blocks using conventional machining and were used to perform tension, compression an fracture experiments along different material directions. The elasto-plastic material response was found to be orthotropic and characterized by a strong tension compression asymmetry; the material was tougher when loaded in the extrusion direction than in the transverse direction. The response of the unidirectional, 3D-printed material was compared to that of homogeneous injection-moulded PLA, showing that manufacturing by 3D-printing improves toughness; the effects of an annealing thermal cycle on the molecular structure and the mechanical response of the material were assessed. Farzad Rayegani[22] In this paper An initial test was carried out to determine whether part orientation and raster angle variations affect the tensile strength. It was found that both process parameters affect tensile strength response. Further experimentations were carried out in which the process parameters considered were part orientation, raster angle, raster width and air gap. The process parameters and the experimental results were submitted to the group method of data handling (GMDH), resulting in predicted output, in which the predicted output values were found to correlate very closely with the measured values. Using differential evolution (DE), optimal processpara meters have been found to achieve good strength simultaneously for the response. Filip Górski[23]This papers includes art of research of additive technology using thermoplastics as a build material, namely Fused Deposition Modelling (FDM). Aim of the study was to identify the relation between basic parameter of the FDM process – model orientation during manufacturing – and a dimensional accuracy and repeatability of obtained products. A set of samples was prepared – they were manufactured with variable process parameters and they were measured using 3D scanner. Significant differences in accuracy of products of the same geometry, but manufactured with different set of process parameters were observed.

2.1.3 Literature Survey on Optimization of process parameters of different materials.

In this Literature survey process parameters of different material are studied as follows K.G. Jaya Christiyan[2] In this paper, 3D digital CAD data is converted directly to a product. In the present investigation, ABS + hydrous magnesium silicate composite was considered as the starting material. Mechanical properties of ABS + hydrous magnesium silicate composite material was evaluated. ASTM D638 and ASTM D760 standards were followed for carrying out tensile and flexural tests, respectively. Samples with different layer thickness and printing speed were prepared. Based on the experimental results, it is suggested that low printing speed, and low layer thickness has resulted maximum tensile and flexural strength, as compared to all the other process parameters samples. Fu-da Ning [3] carbon fiber-reinforced plastic composite parts are fabricated using a fused deposition modeling machine. Tensile tests are conducted to obtain the tensile properties. The effects of fused deposition modeling process parameters on the tensile properties of fused deposition modeling-fabricated carbon fiber-reinforced plastic composite parts are investigated. The fracture interfaces of the parts after tensile testing are observed by a scanning electron microscope to explain material failure modes and reasons. Kamaljit Singh Boparai [4]In this paper material selection is done after this material processing is done according to requirement then fabrication of filament is done following proper procedure followed with inspection and testing and parts production on FDM In addition to above, the dynamic mechanical analysis was performed, which indicate that the filament fabricated with optimum combination of parameters have adequate stiffness and is suitable for FDM system. Krishna Prasad Rajan [25] In this paper an attempt has been made to optimize these processing parameters using statistical technique as per Taguchi. Four factors and three levels were chosen for carrying out the analysis using L9 Orthogonal Array as per Taguchi methodology. Tensile strength and impact strength of the blends under different processing conditions were evaluated as the quality characteristics. It was found that a balance between the two properties were obtained when melt blending was carried out at190˚C at 100 rpm rotor speed for 9 minutes for a blend of TPU with PDMS in the proportion of 70/30 by volume. Confirmatory tests were carried out to verify the optimized formulation. Jianhua Xiao [24] a new filament made by medical grade thermoplastic polyurethanes (TPU) was produced by a single-screw extruder, and then tensile dumbbell specimens were printed by a fused deposition modeling (FDM) machine. In the FDM process, the effects of the orientation angle and printing temperature on part quality were studied. For each process, we aimed to achieve good quality parts by evaluating their tensile strength and break elongation. Microstructure analyses were performed on the dumbbell center and fracture surface of the tensile specimens, through the use of USB dignity microscopy. TPU specimens with the best mechanical properties made by FDM have 46.7 MPa tensile strength and 702% break elongation; they were processed under the condition of 215 _C temperature and a 45_ orientation angle.

Conclusion:

1. A maximum tensile and flexural strength values are reported for samples which has low layer thickness of 0.2 mm and printing speed of 30 mm/s.
2.The other samples with maximum printing speed of different layer thickness of 0.25 and 0.3 mm has exhibited a marginal reduction in strength values.
3.A low printing speed with low layer thickness gives a better bonding with the previous layer due to that it exhibited a better tensile and flexural strength.

Future Scope:

1.Given the huge bank of opportunities in this sector and the rapid development of this technology, we can say with a sense of certitude that 3D printing will soon take over many more industries soon.
2.Considering the prediction, startups and entrepreneurs in India are seeing immense potential in 3D printing technologies.

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