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REVIEW OF EFFECT OF PROCESS PARAMETERS ON MECHANICAL PROPERTIES OF 3D PRINTED COMPONENTS

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ABSTRACT

Additive manufacturing is an emerging advance technology to obtain engineering components in a short time without use of major tooling accessories. One of powerful type of additive manufacturing applied in engineering application is as rapid prototyping using 3D printing. In this method, layer by layer is produced after importing 3D digital drawing data to the machine preferably in STL format. The product made by this method can be directly used for engineering application after proper testing of mechanical properties. Fused deposition method is a type of 3D printing in which wire is fused at particular temperature to get melted and deposited layer by layer form as per the drawing feed to machine. Different process parameters such as raster angle, orientation, rate of deposition of material, layer thickness, diameter of nozzle etc affects on mechanical properties such as tensile strength, elongation, shear strength, flexural strength, etc of fabricated component. This paper deals with review of effect of different process parameters on mechanical properties like tensile, shear, flexural strengths, elongation, etc of 3D printed products..

Keywords – Additive Manufacturing, FDM, Rapid Prototyping, Mechanical Properties, 3D Printing

Nomenclature

3D = Three-dimensional
AM = Additive manufacturing
ABS = Acrylonitrile butadiene styrene
ASTM = American Society for Testing and Materials
CAD = Computer aided design
DIC = Digital image correlation
FDM = Fused deposition modeling
ISO= International Standards Organization
PC = Polycarbonate
PEEK= Polyether-ether-ketone
PLA= Polylactide
RP = Rapid prototyping
STL = Stereo lithography

I INTRODUCTION

Additive Manufacturing (AM) is extensively used to fabricate a scale model of a physical part or assembly using 3-dimensional computer aided design (CAD) data at a faster rate. The CAD data is fed to the 3D printing machines which quickly create prototypes of its designs. 3D printing is an additive manufacturing technology where a 3- dimensional object is created by laying down successive layers of material to build the object [1].

Fused deposition modeling (FDM) is an additive manufacturing (AM) technique in which a heated nozzle laying down molten material produces layer by layer to produce a desired part for which drawing is imported to machine. Fused deposition modeling is one of the most commonly preferred techniques to produce most popular rapid prototyping components in the last decade. In this method, a part is designed by a computer aided design model which is then converted into a stereo lithography (STL) file and uploaded into a slicer program which will give command to the machine for further processing. G-code programming is used as slicer program cross-sectioning the model into individual layers of a specified height and converts the desired height as per requirement. The printer reads the G-Code, heats up a liquefier to the desired temperature to melt the polymer filament of choice, and begins extruding the material on the platform which is also heated to required temperature [2].

FDM is a procedure in RP that is dependent on surface chemistry, thermal energy, and layer manufacturing technology. In this procedure, filaments of heated thermoplastic are extruded from a tip that shifts in the x-y plane. The forbidden extrusion head deposits very thin beads of material onto the assemble platform to form the initial layer [3]. The platform is kept at a low temperature by which thermoplastic gets rapidly hardened. After the platform lowers by the particular distance (i.e., layer thickness), the extrusion head deposits a subsequent layer upon the primary. The procedure is continued to form the desired prototype of particular dimensions. Supports are built along the way as per the requirement and fastened to the part either with a second weaker material or with a perforated junction.[4].

Different process parameters such as raster angle, orientation, rate of deposition of material, layer thickness, diameter of nozzle etc affects on mechanical properties such as tensile strength, elongation, shear strength, flexural strength, etc of fabricated component. This paper deals with review of effect of different process parameters on mechanical properties of 3D printed products specifically on fused deposition machines.

II LITERATURE REVIEW

M. Iliescu [2008] et al has used finite element method simulation in 3D Printing. Simulation relating computational fluid dynamics (CFD) and heat transfer phenomena, carried out with finite element method, has been used in order to develop one of device’s elements contour, so as to get optimum laser device’s functional characteristics [5].

Mohammad Vaezi [2011] et.al has studied and found the effect of binder properties, printing layer thickness, powder size, and binder saturation level, have effects on the strength and surface finish of the three-dimensional printing. The purpose of this research was to investigate the effects of two parameters of layer thickness and binder saturation level on mechanical strength, integrity, surface quality, and dimensional accuracy in the 3D printing procedure. Diverse specimens include tensile and flexural test specimens and individual network structure specimens are created by the 3D printing procedure under different layer thicknesses and binder saturation by use of ZCorp.'s ZP102 powder and Zb56 binder. Two printing layer thicknesses, 0.1 and 0.087 mm, are assessed at 90% and 125% binder saturation levels. Experimental conclusions show that underneath the identical layer thickness, increment of binder saturation level from 90% to 125% would outcome in an augment of tensile and flexural strengths of the specimens and reduction of dimensional accuracy and surface uniformity of specimens. Alternatively, under the identical binder saturation circumstances, augment in layer thickness from 0.087 to 0.1 mm would reduce tensile strength and augment flexural strength. It also gives improved uniformity on the surface [6].

Ivan Gajdos [2013] et al researched about how the structure of the FDM prototypes, by changing of dispensation temperature and layout on base plate, is affected. In order to define the dispensation temperatures influence on building structure of the FDM prototypes, diverse head and envelope temperatures in printing of specimens were used. The ABS samples were analyzed by computed tomography to determine modification in layers structure, dimensions and the portion of unfilled volume in specimen. Obtained effects show that material distribution in the whole volume of scanned specimens is not uniform. It was found out that structure homogeneity represented by the volume of non-filled area is also affected by contour of fabricated part. This approach can be in the future used as a standard method for quality evaluation [7].

Tomislav Galeta [2013] et al studied the influence of selected processing factors on the tensile strength and to determine the factor combination that provides the highest strength. Test samples of ZP 130 powder were prepared with variations in the layer thickness, building orientation and infiltrant on a 3D printer. The researcher found that strength of the samples infiltrated with alternative infiltrants was equivalent to that obtained with genuine infiltrants, thus confirming the use of alternative infiltrants [8].

B. M. Tymrak [2014] et al has studied about tensile strength and elastic modulus of printed components made by ABS and PLA. The results found that average tensile strengths of 28.5 MPa for ABS and 56.6 MPa for PLA with average elastic moduli of 1807 MPA for ABS and 3368 MPa for PLA [9].

David D. Hernandez [2015] et al has focused on dimensional precision of a consumer-grade, FDM printer. A full factorial design of experiments (DOE) analysis was conducted, resulting in an Analysis of Variance (ANOVA) design that shed light on the various factors that affect the use of FDM, in terms of dimensional. Acrylonitrile butadiene styrene (ABS) and Polylactide (PLA) are used. The goal was to evaluate the limitations of the technology, to rule out factors that do not contribute in a statistically significant fashion to print precision, and to provide a practical, quantitative guide for optimizing results of consumer grade 3D printing for application as an engineering tool [10].

F. Roger [2015] et al has studied about topological optimization to define the external geometry and then either heterogeneous internal filling or multi materials to achieve targeted usage properties. Used Fused Deposition Modelling (FDM) 3D Printer. Two thermoplastic materials are united virgin ABS and conductive

ABS filled with carbon black. Infill density distribution can be optimized to improve the stiffness in the stress concentration zones of the manufactured thermoplastic part [11].

Wenzheng Wu [2015] et al has researched on a new high-performance printing material, polyether-ether-ketone (PEEK), which could surmount these inadequacies. The researcher studied the influence of layer thickness and raster angle on the mechanical properties of 3D-printed PEEK. Samples with three different layer thicknesses (200, 300 and 400 _m) and raster angles (0_, 30_ and 45_) were built using a polyether-ether-ketone (PEEK) 3D printing system and their tensile, compressive and bending strengths were tested. The optimal mechanical properties of polyether-ether-ketone (PEEK) samples were found. Again it was found that PEEK is has better properties than ABS [12].

Aron Foster [2015] has focused to analyze the current trends in polymer additive manufacturing and determine the applicability of current American Society for Testing Materials International (ASTM) and the International Standards Organization (ISO) standard test methods for mechanical properties and failure of polymers and polymer composites generated from the additive manufacturing processes. The present approach to mechanical testing standards utilizes existing guidelines for testing materials, but this examination highlights the requirement to expand specific guidelines for testing AM materials. The progress of a program to viaduct the measurement slit between molecular architecture of AM materials (MML) and generating engineering properties for design symbolizes an opportunity for the EL effort [13].

Filip Górski [2015] et al presented the results of tensile, bending and impact strength tests performed on samples of various orientations, made out of ABS material using FDM technology. The effects of these tests certified discovering a unique phenomenon – not only the values of strength indexes change, with the changing orientation, but macroscopic material behavior under load as well.The transition between a “yield point” and “brittle” material usually happens in a certain range of orientation values, named a critical orientation by the authors. The paper designate supposed ranges of critical orientation for various types of loads [14].

Jochen Mueller [2015] et al has studied effect of parameters of the whole process of inkjet 3D printed parts. In this paper, the effect of storage conditions of the material, printing, testing, and storage of finished parts are studied. The goal was to understand the process and determine the parameters that lead to the best mechanical properties and the most accurate geometric properties. The results show that the number of intersections between layers and nozzles along the load-direction has the strongest impact on the mechanical properties followed by the UV exposure time, which is investigated by part spacing, the position on the printing table and the expiry date of the material. Minor effects are found for the storage time and the surface roughness is not so much affected by any factor. Nozzle blockage, which directs to a smaller flow-rate of printing material, significantly exaggerated the width and waviness of the printed product. Furthermore, the machine’s warm-up time is found to be a significant factor [15].

Hadi Miyanaji [2016] et al has focused on dental porcelain materials. The research was performed to obtain the optimal process parameters for the dental porcelain materials fabricated via Ex One binder jetting system. The effects also supply broad printing guidelines for the fabrication of glass ceramic materials [16].

K.G. Jaya Christiyan [2016] et al has used ABS + hydrous magnesium silicate composite to test its mechanical properties. ASTM D638 and ASTM D760 standards were followed to fabricate test specimens for carrying out tensile and flexural tests, respectively. Samples with different layer thickness and printing speed were prepared. It has been suggested on the basis of experimental results that low printing speed, and low layer thickness has resulted maximum tensile and flexural strength, as compared to all the other process parameters samples [17].

III. CONCLUSION

From above literature review, it has been understood that ABS, PLA, PEEK resins are fabricated using FDM machines, these materials are tested with respect to process parameters to find mechanical properties. In recent years, Z-UltaT, HIPS and so many new materials are also introduced in market. Its need to investigate the effect of process parameters on mechanical properties of these types of newly introduced material fabricated on FDM. It is also understood from the above literature that there is no mathematical or empirical model developed till yet in terms of process parameters like layer thickness, rate of deposition, percentage infill etc with respect to orientation.

Hence there is scope to know the effect of process parameters for newly introduced materials as well as to develop mathematical or empirical models. Optimization of process parameters as well as input –output relationship has also good scope for research.

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