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A LITERATURE SURVEY ON TENSILE FAILURE AND SEPARATION ANGLE OF FDM 3D PRINTING

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Abstract— **In this survey paper discuss the literature survey on different aspect of 3D printer modelling and analysis of different angle in FDM. It is discovered in this investigation that there exist different failure modes and a special separation angle which is the demarcation point of the different failure modes when FDM (Fused Deposition Modelling) 3D printing materials fail under a tensile load. In order to further understand the mechanical properties of FDM 3D printing materials and promote the use of FDM 3D printing materials, their tensile failure strengths at different printing angles and separation angles are measured and analysed theoretically. A new separate-modes of transversely isotropic theoretical failure model is established to predict the tensile failure strength and separation angle of FDM 3D printing PLA (polylactic acid) material based on the hypothesis of transverse isotropy and the classical separate-modes failure criterion.**

***Keywords*— MOS Current-Mode Logic (MCML),Ternary Full-Adder (TFA), Low Power, Area, Gate-Diffusion-Input (GDI),Very Large Scale Integration (VLSI), Ripple Carry Adder (RCA) etc ….**

I. INTRODUCTION

Layer thickness –One area of great progress in manufacturing science and engineering is the rapid development of 3D printing technology in the past two decades. Combining Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) technologies, 3D printing technology fabricates items without involving any traditional cutting techniques and the waste of raw materials caused in this process is also very little .For manufacturing thin-walled structures, complex structures and multi-material structures , this technology has inherent advantages . Nowadays, 3D printing technology has been widely applied in manufacturing, civil engineering, automotive engineering, biomedical engineering, food, clothing and so on. Fused Deposition Modelling (FDM) is a widely-used 3D printing technology for polymer and composite filaments due to its flexible and rapid printing process, low cost, diversity and non-toxicity of materials, high strength and toughness of materials.

A schematic diagram of FDM 3D printing technology is and the printing process can be described as follows. A digital 3D model should be built in CAD software and stored as a stereolithography (STL) format file. Then a slicing software module is used to slice the 3D model into thin layers horizontally and control the FDM machine. Printing parameters including printing speed, layer thickness, printing temperature, filling rate, printing orientation, support structure and so on are all set in the slicing software. During the modelling process, a printing filament is extruded into the nozzle at semi-liquid state and deposited onto the previous material layer the new material layer solidifies on the.

3D printing - The research on failure strength of 3D printing materials can be roughly divided into 3 categories. Qualitative parametric analysis is the first and most common one did tests and analysed the influences of parameters including building orientation, layer thickness and feed rate on the tensile strength and bending strength. They found that layer thickness and feed rate had a negative correlation with the two strengths. On the other hand, building orientation had an obvious influence on the two strengths. Investigated the tensile strength for a wide range of 3D printing materials. The results demonstrated that the tensile strength of 3D printing specimens depended largely on the mass of the specimen, for all materials. Evaluated the relationship between the parameters including layer thickness, orientation, raster angle, raster width and air gap and tensile, flexural and impact strength. Empirical models relating mechanical responses and process parameters were developed. Studied the effects of FDM production parameters on the tensile failure strength and the stiffness of the materials. An empirical analytical model was developed based on the process parameters. Schematic diagram of FDM 3D printing technology printing object at room temperature, the printing platform with the printing item moves down by the height of one material layer and then the next material layer will be printed. This process will continue until the entire model has been printed. At last, the support structure will be removed manually .

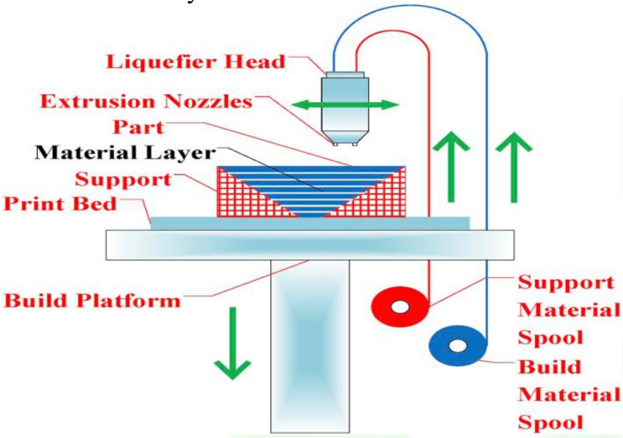

Fig. 1 Schematic diagram of FDM 3D printing technology [1].

Considering the fabrication process, a FDM 3D printing item can be simplified as a transversely isotropic material and the plane of transverse isotropic is the material layer plane. As a new fabricating process for a new class of materials, one shortcoming of this 3D printing technology is that the mechanical properties are still unclear, and the constitutive models and strength models dedicated for FDM 3D printing materials are not yet available.

II LITERATURE SURVEY

Cristina Vălean et al, This research work investigates the tensile behaviour of 3D printed specimens. Among the Additive Manufacturing (AM) technologies, the Fused Deposition Modelling (FDM) process was considered, while Poly lactic acid (PLA) was used as the filament material. The experimental tests were performed on standardized dog-bone specimens and the main process parameters (printing orientation-PO and layer thickness/size effect) were analyzed. The following conclusions can be drawn: The main geometric parameters (thickness-t and width-W) of the specimens have relative errors below 4%; however, the W errors are approximately double that of the t ones **[1].**

Shilpesh R. et al, In the present study, the tensile properties of PLA specimen printed using an open-source 3D printer are characterized through a standard tensile test to determine the ultimate tensile strength and strain at break. These results indicate that specimens printed with open-source 3D printer are comparable in tensile strength to those of the specimens printed on a commercial 3D printer. The tensile properties of the specimen can be improved through the proper adjustment of the process variables.Based on the analysis of the experimental results made, it was found that the parallel arrangement of the fibers to the loading direction obtained the higher tensile strength for parts printed with 0° raster angle. The larger bonding area at the lower layer height and higher raster width are resulting in the higher strength of the printing part. Microscopic examination of the part with 0° raster angle specimen shows the fiber discontinuity and voids in the fillet region, which may be the reason for the premature failure of the part. Furthermore, voids have also been observed on the cross-section of the printed PLA **[2].**

Kentaro Sugiyama.et al, This research work examined increasing the flexibility of core shape design and generating integral continuous fiber reinforced thermoplastics sandwich structures. Researchers used a continuous carbon fiber 3D printer that prints resin-impregnated continuous carbon fiber filaments. Dividing the core shape into unit cells and satisfying the unit cells periodic boundary conditions permitted printing the core shape as a continuous line. Because the core portion becomes an enclosed space after printing, the supports required for printing the bridge space cannot be removed; however, using fiber tension during production facilitated printing the structure without supports. The prototype results demonstrated that CFRTP sandwich structures with various core shapes and surface roughness superior to PLA sandwich structures can be printed. Furthermore, three-point bending tests on the sandwich structures with various core shapes demonstrated that their mechanical properties are largely dependent on core shape. Based on these results, we showed that the mechanical properties of CFRTP sandwich structures can be manipulated using a continuous carbon fiber 3D printer to freely design and print core shapes **[3].**

Oleg Volgin et al. [4] This research work an isotropic material model that captures the viscoplastic material behavior of FDM printed PLA parts subjected to the uniaxial loading was validated. The parallel network material model was calibrated to the experimental data. The model predictions were then also validated during the tension experiment of plate with concentrator and the results showed favorable comparison between FE model and experiment. The current work shows that it is possible to predict the mechanical response of FDM material by application of the inelastic material model and identification of its parameter set. There are still many open problems awaiting investigation in the future. Further mechanical testing should be carried out to gain a deeper understanding of the mechanical behavior of FDM printed

PLA as well as developing an anisotropic constitutive model for non-uniaxial loading cases **[4].**

Kentaro Sugiyamaet al. [5] This study examined increasing the flexibility of core shape design and generating integral continuous fiber reinforced thermoplastics sandwich structures. We used a continuous carbon fiber 3D printer that prints resin-impregnated continuous carbon fiber filaments. Dividing the core shape into unit cells and satisfying the unit cells periodic boundary conditions permitted printing the core shape as a continuous line. Because the core portion becomes an enclosed space after printing, the supports required for printing the bridge space cannot be removed; however, using fiber tension during production facilitated printing the structure without supports. The prototype results demonstrated that CFRTP sandwich structures with various core shapes and surface roughness superior to PLA sandwich structures can be printed. Furthermore, three-point bending tests on the sandwich structures with various core shapes demonstrated that their mechanical properties are largely dependent on core shape. Based on these results, we showed that the mechanical properties of CFRTP sandwich structures can be manipulated using a continuous carbon fiber 3D printer to freely design and print core shapes **[5].**

Grasso, Marzio,et al. [6] In this research work presents, the effects of the temperature on the mechanical response of PLA 3D printed specimens was studied. The standard process parameters were changed to identify the correlations between the printing parameters and the temperature values. The response surfaces were used to derive the required relationship among process parameters, temperature, the tensile stiffness, the UTS, the strain and stress at failure. The analysis of the experimental results made it possible to understand the impact of control factors on the mechanical properties of specimens produced using the Fusion Additive Manufacturing. The tensile tests carried out on single filaments before and after the extrusion process with the 3D printer have shown a reduction in stiffness from 30% in plain PLA filaments to 16% in 3D printed filament as temperature increases from 40^0C to 50^0C. This was explained by the cold crystallisation effects of such polymers and molecular chain realignment along the testing direction **[6].**

Jorge Manuel Mercado-Colmenero et al. This paper presents a numerical-experimental study for obtaining the mechanical properties of FDM for a real part subject to a stress field of uniaxial compression and to the specific requirements of the industrial product into which it is integrated .The new product consists of an innovative mechanical device for the displacement of heavy loads in olive harvesting manufactured completely in PLA and with FDM technology having been designed so that most of its components work under uniaxial compression stresses, a favorable state of operation of the PLA. The part object of the study consists of a hollow bar of slender geometry subject to uniaxial compression stresses and to the technical specifications in quality and costs of the commercial product. In order to obtain the mechanical properties of the material that fulfills the manufacturing specifications to perform the part simulation, two experimental tests have been carried out. The first experimental test used a set of specimens manufactured with the same requirements as the final part in accordance with the conditions and requirements established in the ISO 604 standard for a uniaxial compression stress field **[7].**

Harshit K. et al. [8] In the present study, the tensile properties of PLA specimen printed using an open-source 3D printer are characterized through a standard tensile test to determine the ultimate tensile strength and strain at break. These results indicate that specimens printed with open-source 3D printer are comparable in tensile strength to those of the specimens printed on a commercial 3D printer. The tensile properties of the specimen can be improved through the proper adjustment of the process variables. Based on the analysis of the experimental results made, it was found that the parallel arrangement of the fibers to the loading direction obtained the higher tensile strength for parts printed with 0° raster angle. The larger bonding area at the lower layer height and higher raster width are resulting in the higher strength of the printing part. Microscopic examination of the part with 0° raster angle specimen shows the fiber discontinuity and voids in the fillet region, which may be the reason for the premature failure of the part. Furthermore, voids have also been observed on the cross-section of the printed PLA, which indicates a low degree of diffusion among layers and rasters that results into brittle failure **[8].**

Nicholas Herbert,et al. [9] In this research work presents,have demonstrated that 3DP printing technology may be used to fabricate prosthetic sockets that patients find comfortable. Faster than other RP technologies, the 3DP printing equipment is straightforward to install and does not require special facilities to ensure operator safety. It is simple to use and should allow prosthetists to exploit all the advantages offered by CAD/CAM technologies. Currently, the strength and durability of sockets produced with this technology remain unproven. However, having demonstrated here that the technology may be used for prosthetic applications, we will be conducting further studies to assess the dimensional accuracy of the process and the mechanical characteristics of the products compared to the mechanical characteristics of currently used materials. The results of our studies will be the subject of future publications **[9].**

Shilpesh R et al. [10] In the present investigation, effect of raster angle, layer thickness and raster width has been investigated on the tensile properties of the FDM printed PLA part. Raster angle has the highest effect on the tensile strength of the specimen. Higher tensile strength has been found at 0° raster angle, while lower tensile strength has been found at the 90° raster angleHigher tensile strength is noted at the lower layer height due to larger bonding area between layer interfaces. At higher raster width, higher tensile strength can be obtained due to higher thermal mass of raster up to certain extent; thereafter, there is a void formation between rasters, voids are major source of crack initiation and propagation, which weaken the parts, results into less tensile strength. Further, the effect of parameters on intermediate levels is unclear which may be due to large number of parameters conflicting or interaction with each other. So, it is further required to undertake detailed study of process parameters for proper understanding of the tensile behaviour of PLA specimen**[10].**

From the above literature study, it has been observed that there are work have been carried out and still going on, some of work has been done on sheet metal forming based on V-bending die, Spring back on edge bending die process, stress deformation using various materials such as hence there is scope to work on it.

III. PROBLEM FORMULATIONS

- Thus actual FDM 3D printing structures cannot be modelled and analysed accurately. This lack of knowledge has seriously hindered the development and application of FDM 3D printing technology and calls for its research.
- The research on the mechanical properties of FDM 3D printing materials has mainly focused on two aspects: failure strengths and elastic properties. Among them, there has been more research on their elastic properties. However, the research on their failure strength is still rare.
- Obviously, two problems exist in the previous research. Firstly, only qualitative results have been obtained in most previous parametric analyses of FDM 3D printing materials. Meanwhile, the empirical models constructed are rarely based on a mechanics principle. Secondly, theoretical models were only established on rough experimental phenomena and did not clearly classify the tensile failure modes of these materials.
- An accurate prediction of tensile failure strength (TFS) is very important for analysing the structures fabricated by FDM 3D printing technology, for the sake of structural safety. In order to promote and develop the 3D printing technology, a quantitative theoretical failure model which is consistent with experimental phenomena and based on experimental data is urgently needed.
- A large number of experimental results obtained during this investigation demonstrate that there are two different failure modes, inter-layer failure mode and in-layer failure mode, when the FDM 3D printing PLA material fail. In addition, a special separation angle which is the demarcation point of the two different failure modes exist during the failure experiment.
- Therefore, a separate-modes of transversely isotropic theoretical failure model is established to predict the TFS and separation angle of the FDM 3D printing PLA material based on the hypothesis of transverse isotropy and classical separate-modes failure.

IV. MATERIAL AND 3D PRINTING MACHINE

The testing material used during this research is polylactic acid (PLA) which is an amorphous, durable, strong thermoplastic, healthy and pollution-free material with excellent printing capability. Therefore, it is one of the most commonly used materials in 3D printing. The PLA filaments used are produced by Polymaker Industries (Shanghai, China) and their properties are given in . Desktop 3D printer (Makerbot Industries, Brooklyn, USA) is used to fabricate the test specimens. 3D printing software is used to control the printing parameters including printing angle, printing speed, and temperature and so on. Printing temperature is set to 215 ◦ C, which is suitable for the PLA filaments. The printable layer thickness is 0:05 ~ 1:2 mm. considering the printing speed and mechanical properties, 3 levels of layer thickness are chosen in this research: 0.1 mm, 0.2 mm and 0.3 mm. 2.1.2.

V.CONCLUSIONS

In the survey paper discuss the different 3D printer model and analysis of different Martials. In the last decade 3D printer grow rapidly. There are many researchers are working on it. This survey paper focus on these study and present a related work Tensile Failure and Separation Angle of FDM.

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