3D Digital Printing and Characterization of Poly Lactic Acid-Based Self-Reinforced Composites

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ABBREVIATIONS

3D -	3 Dimensional
ABS -	Acrylonitrile Butadiene Styrene
ASA -	Acrylonitrile Styrene Acrylate
ASTM -	American Society for Testing and Materials
E M or E -	Elastic Modulus or Young's Modulus
E/M -	Young’s Modulus per unit mass
FDA -	Food and Drug Administration (United States of America)
FDM -	Fused Deposition Modelling
FFF -	Fused Filament Fabrication
G-code -	Geometric Code
GPa -	Gigapascals
Mag -	Magnification
MPa -	Megapascals
PC -	Polycarbonate
PEEK -	Polyether ether ketone
PETG -	Polyethylene terephthalate
PLA -	Poly Lactic Acid
PMMA -	Polymethylmethacrylate
PPSF -	Polyphenylsulfone
PVA -	Polyvinyl Alcohol
RMS -	Root Mean Square
Ra -	Average Roughness
Rq -	Root Mean Square Roughness
Rz -	the maximum difference between the average of the top 5 peaks and the top 5 deepest valleys
Rz Max -	The difference between the deepest valley and the highest peak
SEM -	Scanning Electron Microscopy
STL -	Standard Triangle Language or Standard Tessellation Language
TPU -	Thermoplastic polyurethane
UTS –	Ultimate Tensile Strength
UTS/M -	Ultimate Tensile Strength per unit mass
UV Light -	Ultraviolet light
μm -	Micrometre

ABSTRACT

This study investigates different additive manufacturing processes and the materials used. Then, we investigate fused deposition modelling (FDM). Parts of an FDM machine and their functions are discussed. Later steps for pre-processing, post-processing and G-code preparation are mentioned. Do's and Don'ts are noted in each section. The following section defines all the process parameters with their ranges and units, followed by all the measured parameters with their ranges and units. After printing the samples, we study the samples under a microscope to visualise the printed structures and look for microscopic defects. All the samples are then weighed and measured. The weight is noted, and correlations are drawn between measured and control parameters. The errors in manufacturing are reported, and correlations are drawn. The samples are segregated parameter-wise, and regressions are drawn between weight and parameter values. Then, a relationship between measured variables and process parameters is established. This process is repeated for all the measured parameters. The surface roughness of all the samples is measured, correlations are drawn, and regressions are done. The samples are tested on a UTM. Stress-strain curves, UTS and Young's Modulus, are then derived from the raw data obtained. Combined stress-strain graphs are drawn to visualise the effect of each parameter. Various derived values are calculated with this data, like mass deposition rate, stiffness, and mass to stiffness, and their trends are studied. The highest outliers of UTS and Young's Modulus are selected, and Scanning Electron Microscopy is performed on them to visualise the fractures. The last section correlates the process parameters to the fractography results. This study establishes a relationship between most process parameters and their effects on physical properties.

INTRODUCTION

Additive manufacturing is a great way to tackle low-volume prototyping or speciality production. Additive manufacturing is not used in high-volume production runs because, unlike many traditional manufacturing processes, the economics of scale does not apply to additive manufacturing. Conventional manufacturing methods are expensive for low volume runs because of the tooling cost. However, since additive manufacturing does not require tooling, it is cheaper in the short volume runs. Additive manufacturing can also be used as an alternative to machined products Refer to Figure 1.

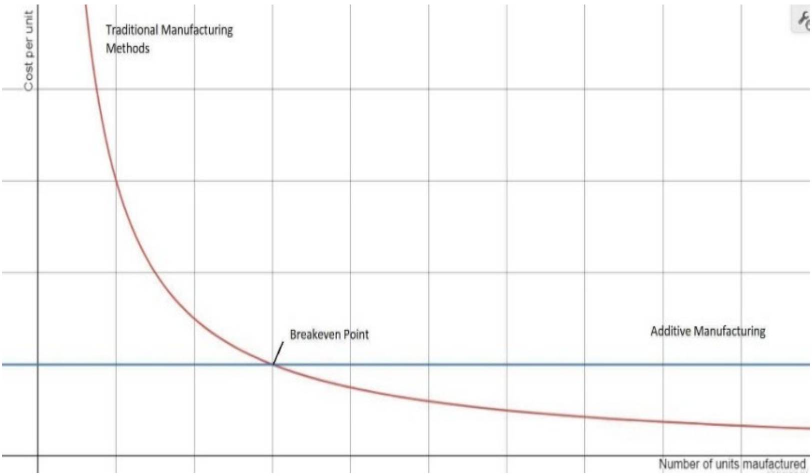

Figure 1: Cost per unit vs Number of units Manufactured.

Additive manufacturing is estimated at around 13.84 billion in 2021 and is expected to grow USD to 76.16 billion by 2030 [1]. In 2021, there were 2.2 million 3D printer exports worldwide. By 2030, 21.5 million units are projected to be supplied. North America currently holds the most significant global market share for additive manufacturing [1].

AM is gaining popularity because it can provide precise and rapid prototyping and shorten the time it takes to market. The range of materials that AM can process keeps growing. Low-volume plastics, methods, and equipment for printing on ceramics, glass, paper, wood, cement, and even living cells have been created.

Market expansion is anticipated to be fuelled by rising demand and active 3D printing research & development. Most industries, including those in the automobile, healthcare, aerospace, and others, need prototype applications using additive manufacturing.