Abstract of the Thesis

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Title of the Thesis : EXPERIMENTAL AND NUMERICAL INVESTIGATIONS ON FRACTURE CHARACTERISTICS OF 3D PRINTED MATERIAL BASED ON SIZE EFFECT LAW

Abstract

The integration of cutting-edge manufacturing techniques is gaining momentum among both researchers and industry professionals. Additive manufacturing, frequently referred to as 3D printing, continues its rapid development, revealing novel applications in diverse fields. Within the spectrum of additive manufacturing processes, Fused Deposition Modeling (FDM) stands out as a popular choice for part fabrication. However, employing FDM-produced components in larger constructions necessitates a consideration of how their mechanical properties scale.

The primary objective of this work is to characterize, both experimentally and numerically, the size effect of FDM materials. The fracture behaviour of FDM parts is assessed based on their ductility level; if parts exhibit quasi-brittle behaviour, the Size Effect Law (SEL) is used to evaluate fracture parameters, whereas if the behaviour is ductile, the Essential Work of Fracture (EWF) method is employed.

This study investigates the mechanical and fracture properties of FDM parts made from Carbon powder-reinforced Polylactic Acid (CPLA) and Polycarbonate (PC). Dogbone specimens were fabricated according to ASTM D638-14 to evaluate mechanical properties such as the modulus of elasticity (E).

Quasi-brittle behaviour was observed for CPLA parts; thus, the size effect method was applied. This research examines laminates of three different thicknesses, maintaining a constant raster angle while varying sizes and layer thicknesses. The length-to-width ratio for all size effect specimens was kept constant at 2.225, with width varying in a ratio of 1:2:3:4. From SEL fracture parameter are derived for all specimens.

Furthermore, the study employs both experimental tests and numerical simulations to validate the application of size effect laws to investigate the fracturing behaviour of FDM specimens. Two types of specimens, Single Edge Notched Tension (SENT) and Double Edge Notched Tension (DENT), were assessed. The findings show that as the specimen size increases, the nominal strength decreases Finite Element (FE) simulations were conducted using Abaqus on DENT and SENT specimens, employing a calibrated Traction Separation Law (TSC) for crack propagation analysis. The Cohesive Zone Model (CZM) technique was utilized to model crack propagation, with parameters derived from the size effect analysis of CPLA parts. The FE results correlate well with the experimental results, confirming the acceptability of the CZM model derived from SEL.

Regarding PC parts, specimens with a raster angle greater than 45^0 exhibited quasi-brittle behaviour, which shows the applicability of the size effect method. In this work, PC parts with different raster angles were fabricated using the FDM process. The results show that fracture energy decreases with increasing raster angle. Conversely, if PC parts contained even one layer with a raster angle as 0^0, they exhibited ductile behaviour, and the EWF approach was applied to derive fracture parameters.
This PhD Thesis will help in for extraction of Fracture parameter for Component Manufactured using FDM process. Also it will help to extract necessary parameter for FEM simulation of cracked FDM specimens

List of Publication(s):
1) Sumit Patel and C.K.Desai, "Experimental and Numerical Investigation of Fracture Energy and Size Effect in Carbon Powder Reinforced PLA Parts Manufactured by Fused Deposition Modelling," Journal of The Institution of Engineers(India): Series C, May 2024.
2) Sumit Patel and C.K.Desai, "Effect of Layer Height on Tenile Strength of Fused Deposited Modelling Printed Carbon Poly-Lactic Acid Part," International Journal of Scientific Research in Engineering and Management ISSN: 2582-3930, Volume: 08 Issue: 08, Aug 2024.

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