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Thermo-mechanical Analysis, Process Simulation and Allowable Generation of Fused Deposition Modeling Printed ULTEM 9085

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ABSTRACT

This case study demonstrates thermo-mechanical analysis, print process simulation, allowable generation and validation of Fused Deposition Modeling (FDM) based 3D printed ULTEM 9085 material system. A nano assisted micromechanics approach is implemented to predict room temperature mechanical properties of 3D printed material system considering micro voids as inclusion calculated using thermal transport phenomenon. The case study also includes prediction of temperature dependent mechanical properties of FDM printed unfilled ULTEM 9085 material using multi-scale material modeling, cure kinetics, multi-factor technique. From print process modeling point of view geometrical and pathing errors macro size defects called "bald spot" were calculated and both modulus and strength properties were degraded in the element scale of the finite element model (FEM) accordingly. Next thermal and coupled thermal structural analysis were performed to calculate temperature distribution, deformation and residual stress during and after the 3D printing process. Service loading multi-scale progressive failure (MS-PFA) FEM analysis simulation was performed on 3D printed dog-bone specimen considering residual stress, deformed shape as well as geometrical and pathing errors. The simulated specimens showed excellent comparison with available test data. MS-PFA FEM analysis also showed damage initiation and evolution. By performing virtual sampling, the tensile strength allowables and constituents' sensitivities for ULTEM9085 printed in multiple orientations were predicted and validated with NIAR's qualification and Stratasys's equivalency test data. The generic acceptance region for parts printed by RP+M and Stratasys printers were plotted to establish FDM ULTEM9085 generic acceptance region between those two distinguished manufacturing facilities.

Keyword: **1**) Fused Deposition Modeling; **2**) ULTEM 9085; **3**) Micro Void; **4**) Nano assisted Micro Mechanics; **5**) Temperature Dependent Mechanical Properties; **6**) Geometrical and Pathing Errors; **7**) Coupled Thermal-Structural Analysis; **8**) A-B and Generic Basis Allowables