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THERMAL DAMAGE AND MECHANICAL FAILURE ANALYSIS OF POLYMERS

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ABSTRACT

As the demand for more intricate and precise components increases, polymers continue to stand out for their flexibility, durability, and adaptability across numerous applications. From aerospace to biomedical engineering industries, polymers are valued for their versatility and customizability, enabling the creation of complex geometries or achieving specific material properties. Since polymers are widely used, analyzing their thermal and mechanical properties is essential to understand their behavior under highenergy exposure or defects. Two types of polymers were analyzed: Polydimethylsiloxane (PDMS) and 3D-printed digital materials. This thesis investigates the mechanical and thermal response of polymers through two distinct studies. The first part focuses on predicting the failure modes of polydimethylsiloxane (PDMS) with pre-defined elliptical defects. A theoretical framework was developed to verify experimentally observed failure behaviors in PDMS, complemented by finite element analysis (FEA). FEA results showed that biases in manufacturing or experimentation combined with the presence of the defect, caused 1 mm x 5 mm samples to predominantly fail in shear instead of tension. The developed theoretical model demonstrated that shear stress and shear angle could be predicted using the failure stress, maximum deformed defect height, and sample bias shift. It was found that the angle of maximum in-plane shear values from the theoretical model closely matched experimental data. The second part examines the thermal response of digital polymers—specifically ABS, Vero, and Agilus—of varying thicknesses when exposed to a laser heat source. Experimental observations aimed to identify correlations between sample thickness, power absorption, and temperature distribution across the polymer surface. It was found that color and material thickness played a significant role in determining the capability of the material subject to a heat source. White color samples transmitted more power through the sample leading to negligible absorption in the sample. Vero Black had the highest percentage of total power absorbed and reflected but was easily prone to surface damage and discoloration. Agilus had similar thermal absorption capabilities as Vero Black but demonstrated better resilience to surface damage. Together, these studies provide insight into polymer behavior under physical and thermal damage, offering guidance for designing more resilient polymer materials and predicting polymer performance in various applications.