

Image-Driven Prediction of Mechanical Properties in Fiber-Reinforced Nylon Composites Fabricated via 3D Printing Using YOLOv8 and CNN

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INTRODUCTION

Additive manufacturing enables lightweight and complex designs across many industries. Fiber-reinforced nylon, combining strength and flexibility, is widely used where durability and precision are required [1–3]. Its tensile behavior, revealed through load–displacement curves, is essential for structural evaluation [4].

This study introduces a deep learning approach combining YOLOv8n and CNN models to predict the tensile performance of 3D-printed fiber-reinforced nylon from microscopy images. The framework maps microstructural deformation to mechanical response, enabling image-based material characterization without direct testing.

METHOD

A dataset of 250 data augmented SEM images [5] of 3D-printed fiber-reinforced nylon composites was used, including pre- and post-tensile test samples. The YOLOv8n model detected deformation regions, while a CNN predicted deformation rates from post-test images. Combining these outputs, the maximum deformation rate was computed to estimate ultimate tensile load and reconstruct load–displacement curves, achieving strong agreement with experimental data.

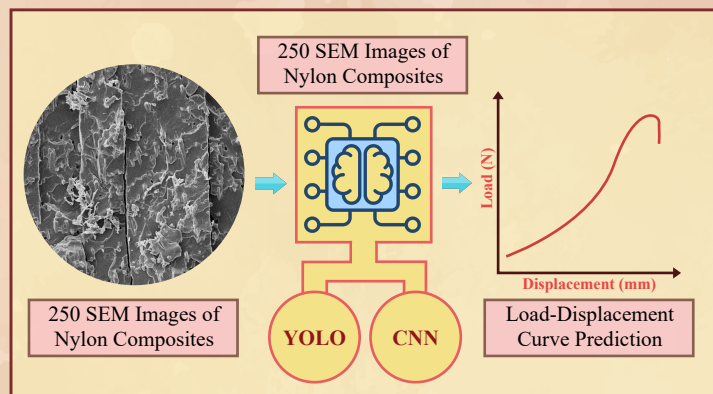


Figure 1. Method for Predicting the Load-Displacement of Nylon Composites

RESULTS & DISCUSSION

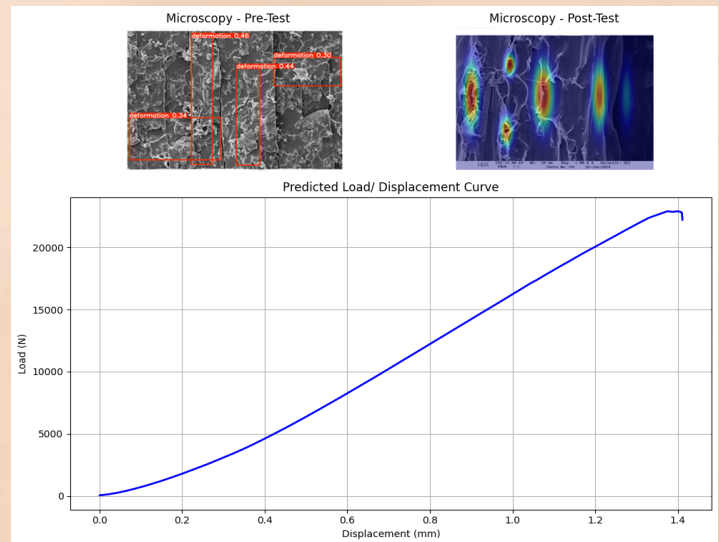


Figure 2. Output Example of Deep Learning Aided Prediction System

By combining deformation area detection with CNN-based deformation rate estimation, the model quantifies microstructural damage and links it to mechanical response. A strong correlation ($R^2 = 0.9995$) validates the image-based formulation. Compared to prior parameter-driven models, this approach relies solely on morphology, enabling generalization across variable fiber distributions and manufacturing inconsistencies. These results highlight the capability of deep learning to extract interpretable mechanical insights from high-resolution micrographs.

CONCLUSION

The proposed YOLOv8n–CNN framework quantitatively predicts tensile response of 3D-printed fiber-reinforced nylon directly from SEM micrographs. It reconstructs load–displacement curves by computing deformation-based features, achieving strong correlation with experimental results. This image-driven approach enables non-destructive mechanical evaluation. Future work will extend the framework to diverse additive composite systems.

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