PREDICTING FLEXURAL MODULUS OF ADDITIVELTY MANUFACTURED CONTINUOUS CARBON FIBER-REINFIRCED POLYMER COMPOSITES USING MACHINE LEARNING

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Introduction

Lightweight materials are in high demand and are usually composite materials. Composite materials are two or more materials with mechanical properties, some of these properties include elasticity, flexural strength, fatigue limit, and fatigue toughness. Composite materials are applicable in multi-disciplinary fields. Composites are now used in aerospace, automotive, energy, architecture, transportation, construction, and healthcare. Composites are conventionally fabricated using methods such as layup, injection, molding, compression molding. However, these methods take a lot of work and requires metallic materials such as steel and aluminum which can be expensive with designing, testing, and tooling requirements in place. Additive manufacturing (AM) processes are preferred over conventional fabrication methods. By using AM techniques of material extrusion, power bed fusion, and vat photopolymerization, composites can be lightweight. Carbon fiber-reinforced polymer (CFRP) composites are used because they are extremely strong. They are light fiber reinforced plastics that contain carbon fibers. However, its difficult to estimate the mechanical properties of the additively manufactured parts.

Aim

The purpose for this research project is to utilize machine learning in python to predict the flexural modulus of continuous carbon fiber-reinforced polymer (CCFRP) composites.

Methods

Researchers, previously, designed and fabricated 162 CCFRP specimens using fused deposition modeling (FDM) while taking into account the number of fiber layers, the number of fiber rings, and polymer infill patterns of the specimens. They were able to print the specimen using a commercial 3D printer. The print head has 2 nozzles to print continuous carbon fibers and short carbon fiber reinforced nylon filaments separately, horizontally, and vertically.

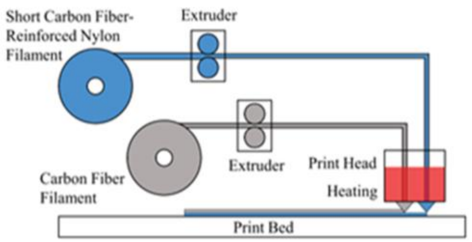

Fig. 1: Schematic of the FDM process of CCFRP

In the experimental design, there was nine levels of number of fiber layers, six levels of number of fiber rings, and three layers of polymer infill pattern. These were determined by the geometry of the specimen. The CCFRP specimens were put through flexural tests to identify load, extension, stress, and strain with the different factors of fiber layers, fiber rings, and infill patterns.

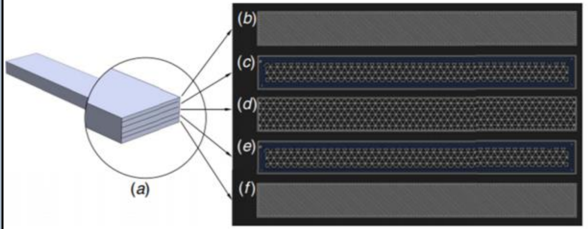

Fig. 2: Schematic of the microstructure of a flexural test specimen. Outer lines represent concentric carbon fiber rings and inner triangles represent short carbon fiber-reinforced nylon: (a) layered CCFRP specimen, (b) top view of the cross section of roof layers, (c) top view of the cross section of carbon fiber-reinforced layers, (d) top view of the cross section of polymer infill layers, (e) top view of the cross section of carbon fiber-reinforced layers, and (f) top view of the cross section of floor layers.

All the data was collected from the flexural tests and were imported as 10 specimen files into Jupyter notebook where it programmed in Python. Then, the information was organized into columns and only kept the necessary information: the load, extension, stress, and strain data.

Results and Conclusion

The stress and strain from the load and extension data was calculated and was plotted into graphs to show the tests for the 10 sample specimens. Then, the flexural modulus was programmed which is shown as slope.

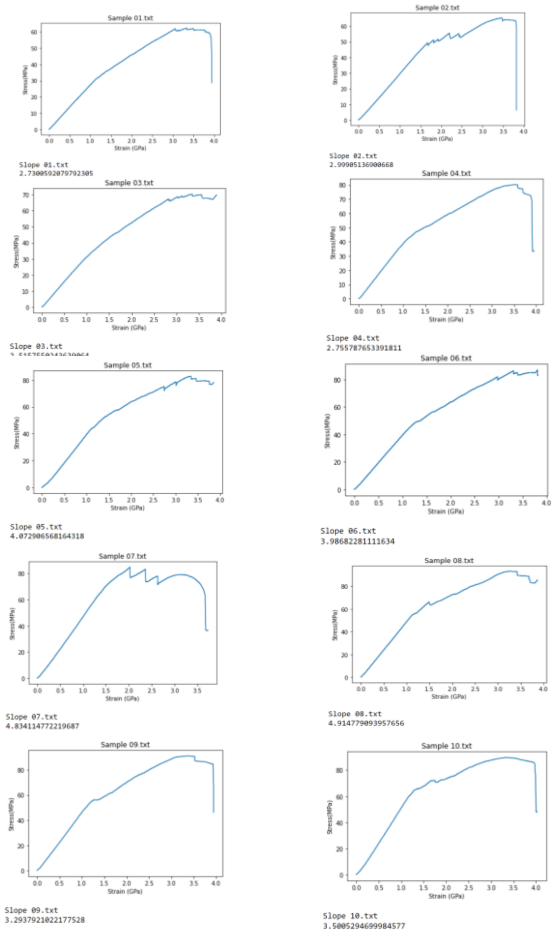

Fig 3-13: Graphs and slopes of 10 specimens

Future Work

For future work pertaining to this research project, 162 specimen data will be imported into Jupyter notebook. The graph for 162 specimens will be outputted. The flexural modulus will be calculated and outputted as well. Machine learning in python will then be implemented to take this data and will be split into training and testing data. They will then be put them through Xgboost, Randomforest, Ridge Regression, and SVM (supervised learning method) algorithms and the parameters will be hyper tuned as needed to create an accurate prediction. The purpose of splitting up the data into training and testing data is so that the algorithm is trained through that percentage of data and tested through the other percentage of data and is able to calculate outputs that are highly predictively accurate. The use of the four different types of algorithms is used to compare them to each other and see which algorithms are more likely to accurately predict the outputs. For future use, if there were specimens with different design factors, this algorithm could be used to accurately predict the flexural modulus.

References

- Zhang, Ziyang, et al. "Predicting flexural strength of additively manufactured continuous carbon fiber-reinforced polymer composites using machine learning." Journal of Computing and Information Science in Engineering 20.6 (2020): 061015.

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