# THE EFFECT OF FIBER ORIENTATION ON THE MECHANICAL PROPERTIES OF EPOXY BASED FIBERGLASS COMPOSITES

Mangapathi Rao Donthini and Rebecca Cruz

MECHANICAL AND AEROSPACE ENGINEERING DEPARTMENT

**Abstract:** The effect of fiber orientation on the elastic modulus and Poisson's ratio of layered fiberglass composite materials is investigated. Three different fiberglass composite samples are fabricated using epoxy resin and eight layers of fiberglass fabric oriented in three different orientations. Tensile tests are performed on all sample using a strain-gauge rosette. The results are analyzed by calculating the Young's modulus and the Poisson's ratio of all samples and observing the changes in such properties with varying orientations. The Young's modulus is calculated from the slope of linear region in stress versus strain plots. The Poisson's ratio is calculated using the dimensions of the sample and the voltage readings from the tension test. Flexural tests are performed on all samples using a 1310nm laser optical fiber loop sensor. Calibration studies are conducted on the fabricated composites and the applicability of such sensors in force or displacement measurement is studied.

**Fabrication:** Fiberglass composites of $0^0$, $45^0$ and $30^0$-$60^0$ prepared by bonding eight layers of 6 inch x 6 inch size fiberglass cut pieces with Epoxy resin. The specimens are vacuum bag treated for about an hour to reduce voids and incomplete lay-up. The vacuum bagging also provides better glass to resin ratio. The cured composites are heated at $180^0$F for an hour to further speed up the curing process and to achieve good strength to weight ratio.

Fig. 1. Marking the fiberglass sheets of $45^0$ orientation

Fig. 2. Preparation of Epoxy resin

Fig. 3. Fiberglass laminate

Fig. 4. Vacuum bagging

Fig. 5. Fiberglass composite after heat treatment

Fig. 6. Trimmed fiberglass composites

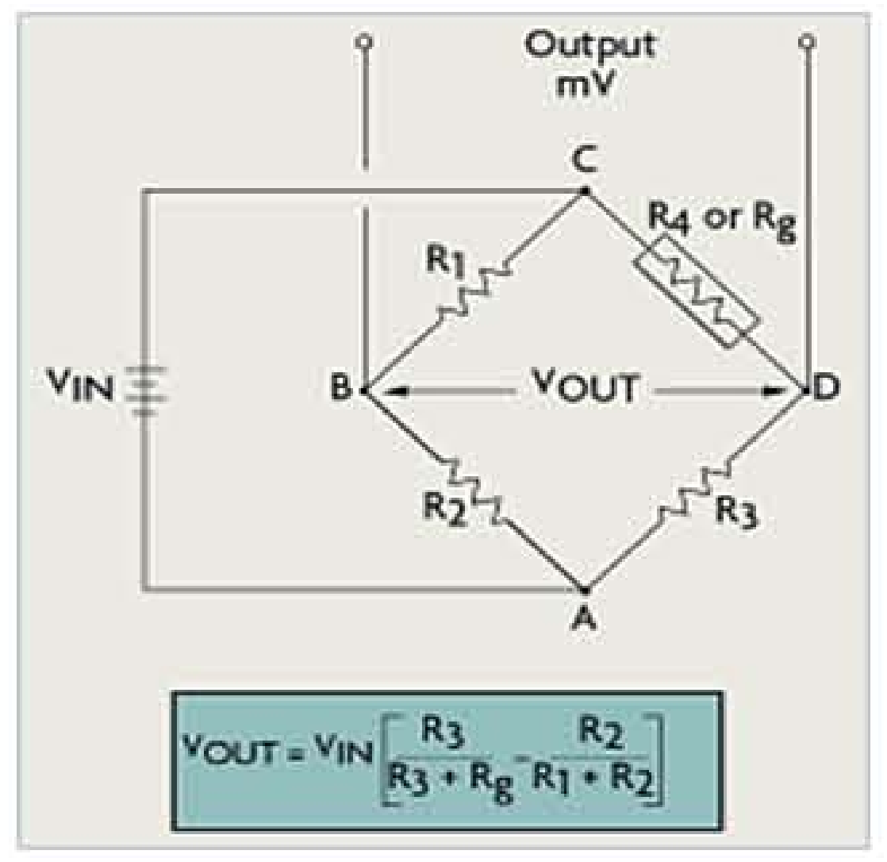
**Rule of mixtures:** It is an analytical method used to calculate the upper limit of modulus of composites. Fiberglass samples are made of glass fiber and matrix (resin). The volume percentage of each constituent in the fiberglass is calculated by finding the difference in the mass of the sample before and after burning. To perform this test, the samples are cut in 2cm x 2cm size and are burnt using Bunsen burner for about an hour until the whole matrix is evaporated. After burning, the original 8 layers of fiberglass are obtained and the mass is measured using balance.

E(composite) = E( fiberglass) x V(fiberglass) + E( matrix) x V(matrix)
Where E – Elastic modulus ; V - Volume

Fig. 7. Burning and recovery of original fiberglass from composite

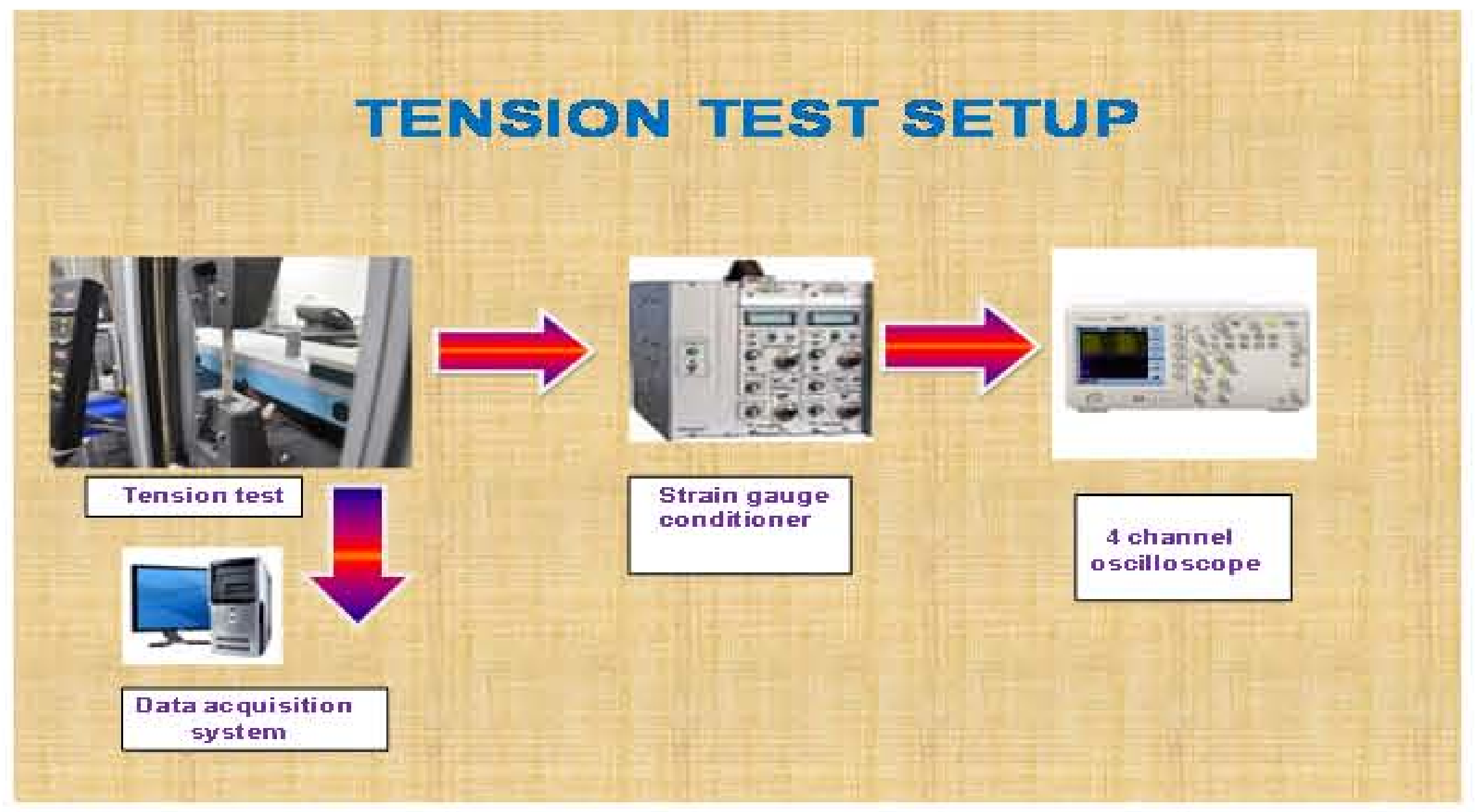
**Tensile Test:** The samples for test have been prepared by cutting 110mm x 15 mm size pieces from the fiberglass composite sheets of all orientations. The bi-axial strain gauge is bonded at the middle of the sample using an adhesive. The resistance of the strain gauge foil changes with the applied pressure. The strain gauge works on the principle of wheat stone bridge circuit. The gauge acts as one of the arms of the bridge. The measured differential output voltage of the bonded strain gauge is proportional to the amount of deformation produced in the composite. Load versus extension data will be obtained from Tensile test. The stress-strain curves of all samples have been drawn using sample dimensions and the test data.

Fig. 8. Strain gauge bonded to composite specimen using Epoxy



$$V_{OUT} = V_{IN}\left[\frac{R_3}{R_3 + R_g} - \frac{R_2}{R_1 + R_2}\right]$$

Fig. 9. Schematic of Wheatstone bridge circuit.



TENSION TEST SETUP

Fig.10. Flow chart of Tension test setup

**Flexural Test:** The optical fiber is used as a sensor to detect the stress developed in the specimen in terms of variation in the intensity of transmitted radiation. The intensity of the radiation coming out of the optical fiber decreases with the increase in the loop's diameter. The composite bonded with optical fiber loop is subjected to force and the deformation caused in the specimen is measured as the power output of transmitted radiation. LABVIEW software is used to measure the output radiation. The collected data is analyzed using the high level technical computing language – MATLAB.

The composite samples for calibration are prepared by bonding 8mm diameter fiber loop at the middle of the composite specimen.

Fig.11. Composite bonded with optical fiber loop

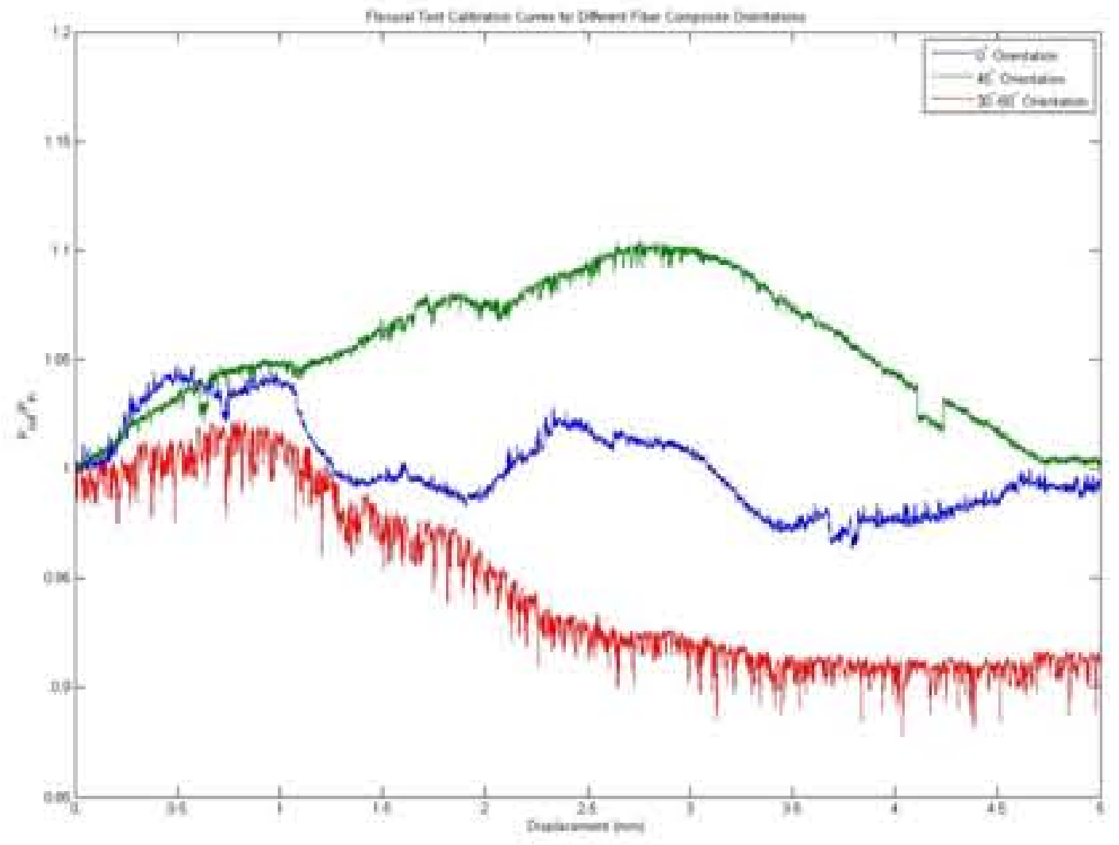


Fig.12. Flexural test calibration curves of $0^0$, $45^0$ and $30^0$-$60^0$ orientations

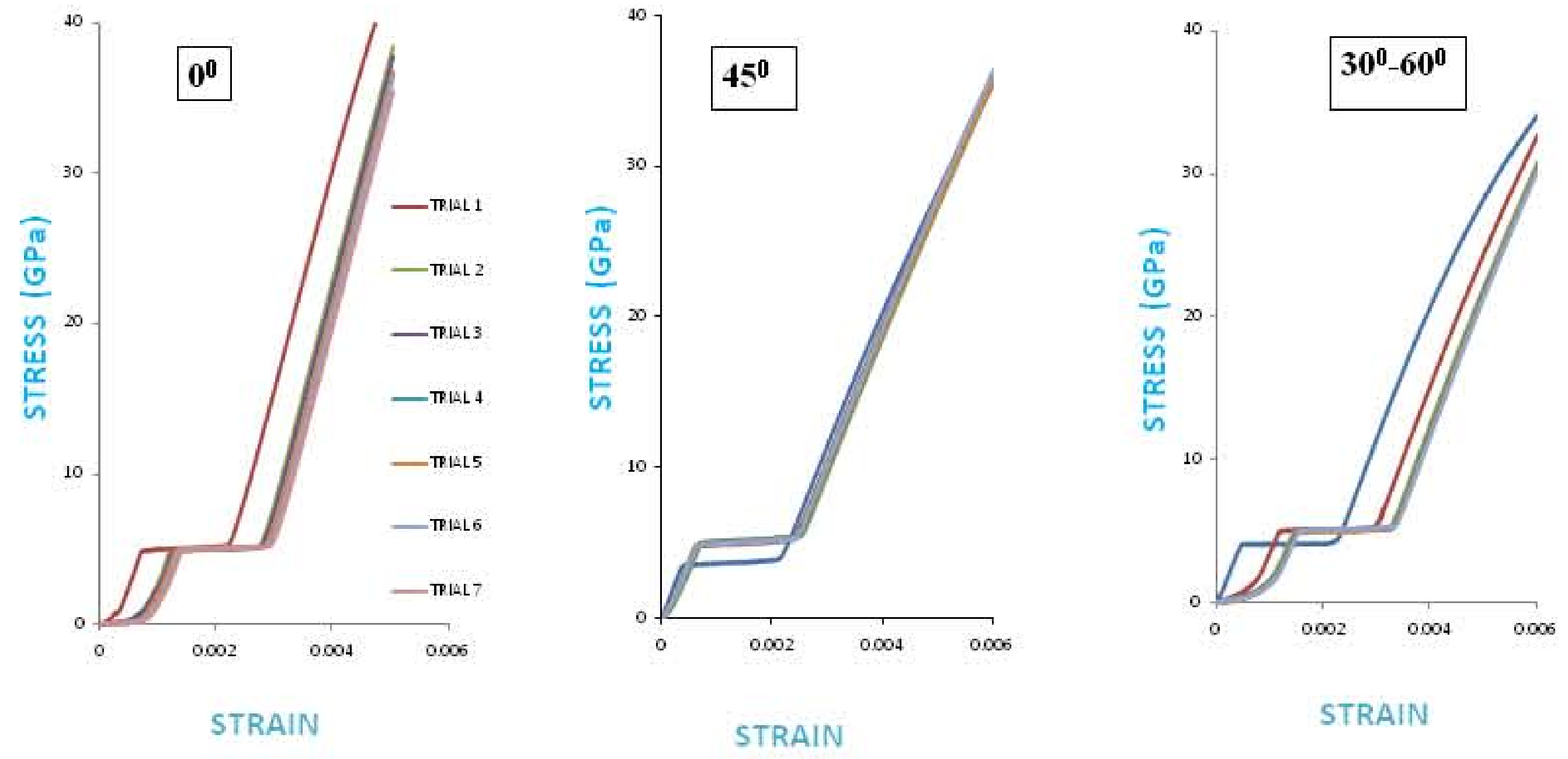


Fig. 13. Stress versus strain plots of all fiberglass composite specimens

**Results :** Samples of all orientations have shown similar behavior with a significant change in the slope of linear region between the range of strain values 0.003 to 0.006. The plateau region between the range of strain values 0.001 to 0.003 may be due to slip in the grip of clamp fixtures of the tensile testing machine or due to readjustment of matrix particles in the eight layered fiberglass composite upon the application of load. The Young's modulus is calculated by finding the slope of linear region of each stress-strain plot. The Young's modulus of zero degree oriented sample is more than other orientations. The results clearly show the effect of orientation on the young's modulus of the fiberglass composite.

The Poisson's ratios are calculated for all orientations using the tangential and longitudinal voltages.

The Young's modulus values calculated using tensile test are well below the modulus values calculated using the rule of mixtures.

Flexural test results show that the output response of zero degree oriented samples is greater compared to other samples. These results are in agreement with the both Young's modulus and Poisson's ratio values calculated from the tension( tensile) test.

**Conclusion:** A significant change in the mechanical properties such as Young's modulus and Poisson's ratio has been observed with a change in fiber orientation.

- The mechanical properties calculated using tensile test are well below the upper limit modulus values calculated using rule of mixtures.
- The fiber alignment between the successive layers plays a key role on the consistency of mechanical properties of multilayer composites.
- A significant difference in the power output response has been observed with fiber orientation.
- Since , the response of optical fiber output is very sensitive to load , Flexural test using the optical fiber loop is a promising technique to be used in the study of shear modulus.

**Acknowledgements:** Professor Nikhil Gupta for guidance and advice; the National Science Foundation for funding and NYU – Poly for facilities