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Sample

# MECH 4310
# Analysis of Composite and Multifunctional Materials

DEPARTMENT OF MECHANICAL ENGINEERING
UNIVERSITY OF MANITOBA

## Assignment 3

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Latex Super Nice!

# 1 Material Analysis

## 1.a S and Q matrices

$$S = \begin{bmatrix} 1 \times 10^{-11} & -3.3 \times 10^{-12} & 0 \\ -3.3 \times 10^{-12} & 5.56 \times 10^{-11} & 0 \\ 0 & 0 & 1 \times 10^{-10} \end{bmatrix}$$

$$Q = \begin{bmatrix} 1.02 \times 10^{11} & 6.06 \times 10^{9} & 0 \\ 6.06 \times 10^{9} & 1.84 \times 10^{10} & 0 \\ 0 & 0 & 1 \times 10^{10} \end{bmatrix}$$

## 1.b Strains

$$\varepsilon_x = 1.10 \times 10^{-3}$$
$$\varepsilon_y = -2 \times 10^{-3}$$
$$\gamma_{xy} = 6 \times 10^{-3}$$

## 1.c Qbar and Sbar matrices at 30° from x-direction

$$\bar{S} = \begin{bmatrix} 2.66 \times 10^{-11} & -8.52 \times 10^{-12} & -2.58 \times 10^{-11} \\ -8.52 \times 10^{-12} & 4.94 \times 10^{-11} & -1.37 \times 10^{-11} \\ -2.58 \times 10^{-11} & -1.37 \times 10^{-11} & 7.91 \times 10^{-11} \end{bmatrix}$$

$$\bar{Q} = \begin{bmatrix} 6.83 \times 10^{10} & 1.89 \times 10^{10} & 2.55 \times 10^{10} \\ 1.89 \times 10^{10} & 2.65 \times 10^{10} & 1.07 \times 10^{10} \\ 2.55 \times 10^{10} & 1.07 \times 10^{10} & 2.28 \times 10^{10} \end{bmatrix}$$

## 1.d Strains at 30° from x-direction

$$\varepsilon_x = 1.37 \times 10^{-3}$$
$$\varepsilon_y = -3.16 \times 10^{-3}$$
$$\gamma_{xy} = 2.58 \times 10^{-3}$$

## 1.e Effective Properties

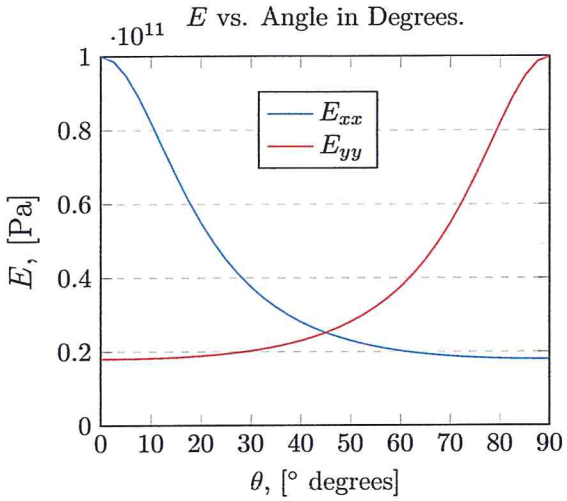


**Figure 1:** The effective modulus of elasticity changes with varying fibre orientation.

It can be seen in Figure 1 that the stiffness of the material in the x-direction decreases as the angle between the x-direction and applied force is increased, and the opposite goes for the stiffness in the y-direction. It can also be seen that there is a significant change in x-direction stiffness from 0 to 30 degrees.

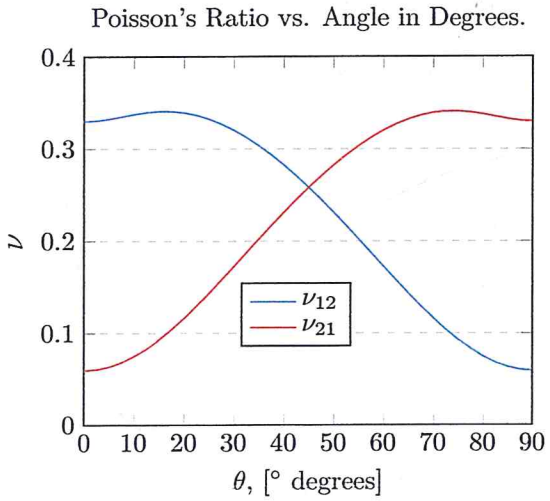


**Figure 2:** The effective Poisson's ratio changes with varying fibre orientation.

It can be seen in Figure 2 that $\nu_{12}$ and $\nu_{21}$ are mirrored and react oppositely of each other. As the angle between the applied load and fibre orientation is increased, $\nu_{12}$ behaves oppositely to $\nu_{21}$. At 45°, both $\nu_{12}$ and $\nu_{21}$ equal to each other. This is due to the applied force have the same

amount of angle away from the fibre orientation, thus the material will expand and shrink the same amount in certain directions.

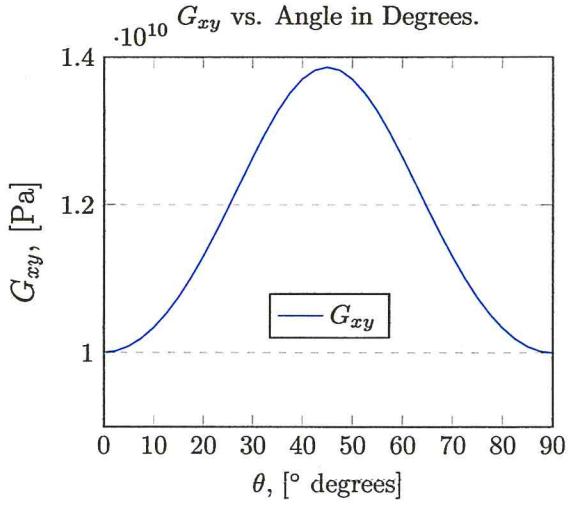


**Figure 3:** The effective shear modulus $G_{xy}$ changes with varying fibre orientation.

It can be seen in Figure 3 that the effective shear modulus of the material reaches the maximum when the angle between the fibre orientation and the applied load is at 45°. At 0° and 90°, the shear modulus is at its minimum values. This seems to be an unusual case since a typical material would have the lowest effective shear modulus at an orientation of 45°, which in turn will show a "U" shaped plot rather than an upside-down "U" observed in Figure 3.

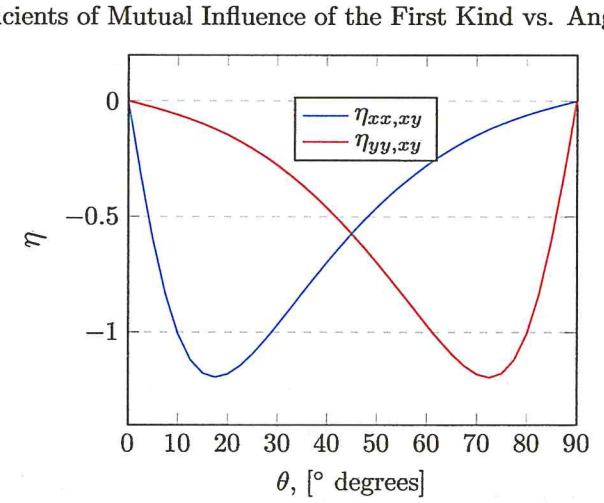


**Figure 4:** The coefficients of mutual influence of the first kind changes with varying fibre orientation.

Coefficients of Mutual Influence of the Second Kind vs. Angle in Degrees.

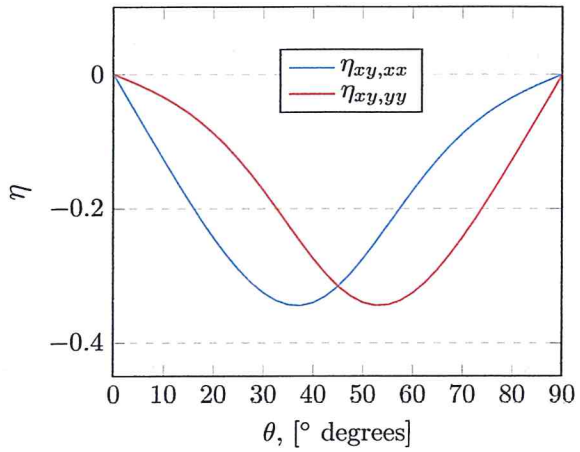


**Figure 5:** The coefficients of mutual influence of the second kind changes with varying fibre orientation.

# 2 Fabrication

## 2.a Application of fabrication techniques

### 2.a.i Sailboat Hull

Wet/Hand Lay-up - The shape of the hull can be easily produced with use of a mould, in which the fabric and resin can be layered over on. It is a low-cost and straightforward method in comparison to other methods of fabrication.

### 2.a.ii Fishing Rod

Filament Winding - This method of fabrication is an efficient way of manufacturing long rods.

### 2.a.iii Snowboard

Vacuum Bagging - With this method there can be even applied pressure on the entirety of the snowboard to ensure proper shape.

#### 2.a.iv Propane Tank

Filament Winding - Using this method allows for hollow objects to be produced in an efficient way.

#### 2.a.v Bicycle Wheel

Prepreg Moulding - This method allows for the complex shape of the bicycle wheel to be formed easily.

## 2.b Role of materials used in the vacuum bagging process.

- **Sealant Tape**
  Seals the bag to the mould. This ensures that the vacuum pressure is maintained.
- **Release Film**
  An optional component to the vacuum bagging process and is used to retain more resin on the laminate surface.
- **Release Coated Mould**
  The mould determines the desired shape of the final product.
- **Laminate**
  The material that will be the final product.
- **Peel Ply**
  Allows for ease of removal between the laminate surface and the breather/absorption fabric. It also helps to provide a smooth and consistent surface finish on the laminate.
- **Breather/Absorption Fabric**
  Traps and holds the excess resin from the laminate. It also ensures that the vacuum is distributed evenly within the bag.
- **Vacuum Bagging Film**
  A bag that covers and applies vacuum pressure over the entire laminate.
- **Vacuum Pump**
  Provides the vacuum pressure as it removes that air from the bag.

## 2.c Wet lay-up and prepreg composite manufacturing techniques.

The key differences between wet lay-up and prepreg are:

- **Resin Application** - The resin must be applied or impregnated on the fabric by hand with use of rollers or brushes in wet lay-up method, whereas the fabric is pre-impregnated by resin for prepreg moulding technique.

- **Pressure** - In the wet lay-up method, the laminate is left to cure under standard atmospheric conditions. For prepreg, additional pressure is applied by an autoclave.
- **Temperature** - The manufacturing process for wet lay-up method is usually under room temperature, whereas prepregs are heated to 120°C-180°C to allow the resin to reflow.

When selecting between wet lay-up and prepreg methods, there are primary concerns to take under consideration.

- **Cost** - Material cost is higher for pre-impregnated fabrics and involve extra steps of applying heat and pressure to reach the final product. The application of heat and pressure involve tools that are high in cost. The wet lay-up method is a simpler method involving less steps and tools to perform.
- **Product Shape** - The shape of the product must be taken into consideration. For complex shapes, the most suitable method would be the prepreg method. The wet lay-up method is limited to certain shapes.
- **Production Safety** - Wet lay-up involves low molecular weights of resins which are harmful and can penetrate clothing etc. due to the low viscosity. Prepregs on the other hand are clean and safe to work with.