Effect of mesh-peel ply variation on mechanical properties of E-glas composite by infusion vacuum method

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Abstract. Composite materials made of glass fiber EW-135 with epoxy lycal resin with vacuum infusion method have been performed. The dried glass fiber is arranged in a mold then connected to a vacuum machine and a resin tube. Then, the vacuum machine is turned on and at the same time the resin is sucked and flowed into the mold. This paper reports on the effect of using mesh-peel ply singles on upper-side laminates called A and the effect of using double mesh-peel ply on upper and lower-side laminates call B with glass fiber arrangement is normal and ± 45° in vacuum infusion process. Followed by the manufacture of tensile test specimen and tested its tensile strength with universal test machine 100kN Tensilon RTF 2410, at room temperature with constant crosshead speed. From tensile test results using single and double layers showed that double mesh-peel ply can increase tensile strength 14% and Young modulus 17%.

1. Introduction
There is an increasing interest to use composite materials rather than conventional materials in structural applications for aircraft, aerospace, automotive, marine and other structures [1]. Due to the advantages of this composite material in its use has been widely used in the aerospace industry. The advantages of composites are among others have excellent mechanical properties and low structural weight. In fact, most of the costs associated with high performance composites are associated with manufacturing techniques. And along with the necessity of improving the nature, is the reason why some techniques are developed to automate the process. Much of the progress towards obtaining low-cost composite structures has occurred in the application of textile technology in its manufacturing methods. Traditional laminate structures generally exhibit poor interlaminar toughness, which makes them vulnerable to delamination while supporting interlaminar pressure. Where impact loading, manufacturing defects, geometric discontinuities such as free edges will result in delamination. The decrease in structural integrity is a result of the growth of delamination cracks under the influence of external loads resulting in catastrophic failure of the structure. [2].

During the past decade, the vacuum infusion or resin infusion processes have become popular for manufacturing structural polymer-based composites. Resin infusion processes have been identified as cost-effective alternatives to conventional autoclave manufacturing techniques. The resin infusion process is possible to produce or work on complex and thick parts with excellent mechanical properties and with less waste than traditional methods. However, the process is somewhat difficult to control, firstly because the infusion-stage driving mechanisms are quite complex, and secondly, with existing industrial technology parameters such as thickness or resin in small dimensions inaccessible [3]. The most popular terms to describe vacuum infusion processes are: Some types of infusion resin include Vacuum Assisted Resin Transfer Molding, Vacuum Assisted Resin Infusion Molding,
Composite Seemann Resin Infusion Process Molding, Vacuum Resin Transfer Molding Bag, Infusion Vacuum Assisted Resin Process, Liquid Resin Infusion [4]. All involve basically the same technology, and describe methods based on the impregnation of a dry reinforcement by liquid thermoset resin driven under vacuum.

From experimental studies of the tensile properties of hand lay up plain-weave woven glass fiber reinforced polymers (GFRP) panels [5] have resulted in characteristic tensile deformation of different lay-up arrangements and preservation pressures have shown relatively significant value.

Goren A and Atas C. [1] has been studied manufacturing of polymer matrix composite using vacuum assisted resin infusion molding with double (upper and lower) peel ply but single mesh on the upper side.

This paper describes about the effect of upper and lower side mesh-peel ply used in vacuum infusion or liquid resin infusion process to mechanical properties of the glass fiber reinforced polymer (GFRP). The objectives are to know the differences between single (upper) mesh-peel ply and double (upper and lower) mesh-peel ply used in vacuum infusion to tensile properties of the composite.

2. Experimental Method

2.1 Material

Woven glass fibers have been used in this research as reinforcing material, while epoxy resin (lycal type) has been utilized as the matrix material [6]. Fiberglass is a composite material consisting of glass fibers in a matrix of polymer [7]. It used e-glass cloth 135 (EW 135 cloth) from justus. The laminated consist of normal and ±45° cutted EW135 cloth fibers.

2.2 Vacuum Infusion Process

As has been explained above that to drive resin into laminate is by using vacuum pressure where this technique is called Vacuum Infusion Process. The material is placed dry into the mold and vacuum is applied before the resin is introduced. Once the complete vacuum is reached, the resin is literally sucked into the laminate through a carefully placed tube. This process is aided by a variety of supplies and materials [8].

Fig. 1 showed the normal procedure of composite manufacturing using vacuum infusion process. There are much runner in the upper side of normal procedure although the resin didn't fully wet through the laminates. To improve the resin absorption through fibers, it needs to add peel ply and flow mesh as resin distribution media in the lower side of fibers. The experiment manufactured composite with normal procedure vacuum infusion and by adding peel ply and flow mesh in the lower side to be compared then.

![Figure 1. Normal procedure for vacuum infusion process [9]](image-url)
3. Tensile Test

The woven glass fiber-reinforced lycal was used in this test; the total thickness of the laminate is ±2.5 mm. Tensile specimens were cut out of the laminates according to ASTM D3039. The number of tensile specimen is ten specimen manually cut out.

3.1 Testing Method

The tests was conducted from the beginning to the failure using a 100kN universal testing machine, Tensilon RTF 2410, at room temperature ±23°C with constant crosshead speed [10]. Load and strain measurement were automatically recorded during each test using a tensilon software. The displacement rate was 2 mm/min.
4. Results and Discussion
The purpose of the static tensile tests was to determine tensile strength and Young modulus of woven glass laminates. Fig. 6 shows the typical stress-strain curve of woven glass laminate normal vacuum infusion (single mesh-peel ply) under tensile loads. Fig. 7 shows the typical stress-strain curve of woven glass laminate with adding mesh-peel ply in the lower side (double mesh-peel ply) under tensile loads.

Figure 4. 100kN UTM Tensilon RTF 2410

Figure 5. Tensile test set up
The tensile characteristic stress-strain results for single and double mesh-peel ply all have shown a similarity in trend growing from non-linearity and eventually develops into linear slopes after about 0.3% amount strain. Mohd Aidy Faizal et.al. 2011 [5] said that the initial non-linearity is basically attributed to the deformation of the glass fibers. Thereafter, the characteristic linear slope predominantly reflects the deformation of the glass fibers. However, J. C. Chen et.al 2011 [11] said
that for the certain curves displayed yielding and post yield strain hardening, indicating the reinforcing effect and structural homogeneity for the composites. The slope between the yielding to failure point (called the post-yield modulus) represents the reinforcing efficiency of the composite. Therefore, the Young modulus value divided into two category; tensile modulus (before yield) and post-yield modulus (between yielding to failure point) [9]. This paper determined the Young modulus value in the 0.1% to 0.3% strain range according to ASTM D3039 for both single and double mesh-peel ply. In all tensile failure, the characteristics are very distinct and abrupt without plastic strain. The strain to failure is found to fall over a range 3.9% to 5% amount of strain for single mesh-peel ply and 4.5% to 5.4% amount strain for double mesh-peel ply, which can be explained as due to the resin absorption to the laminates effect. The stress to failure is also found to fall over a range 125 to 145 MPa for single and 135 to 160 MPa for double mesh-peel ply.

![Image](image1.png)

**Figure 8.** Specimens fracture for single mesh-peel ply

![Image](image2.png)

**Figure 9.** Specimens fracture for double mesh-peel ply

Fig. 8 and 9 showed the specimens after fracture. For both single and double mesh-peel ply had typically fracture region near the grip and in the gage length. Visual inspection showed that the fracture type is in the plus or minus 45° direction of fibers. It means the weakness of the specimens is in the ±45° fiber direction. So the ±45° fiber direction is not good for the longitudinal tensile loading. It could be reference for design a structure which subjected by tensile load.

The average value of tensile strength is 136.76 MPa for single and 155.78 for double mesh-peel ply. It means the average value of tensile strength increase 14% with double mesh peel ply. The average value of Young modulus is 5.06 GPa for single and 5.91 GPa for double mesh-peel ply. It means the double mesh-peel ply could improve the Young modulus for about 17%.
5. Conclusions
This paper showed the used of double mesh-peel ply in the vacuum infusion process for composite could improve the tensile properties of the composite. Tensile strength increased 14% and Young modulus increased 17%. However, both process had typically stress-strain curve and fracture type based on visual inspection.

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