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# Experimental Determination of Fiber Mat Permeability of Jute Natural Fiber

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***Abstract*: In this paper, the natural fiber which has been used was jute fiber as the materials for the vacuum infusion. The process that will be using in this experiment is Vacu-um Infusion Process (VIP). There are three specimens which will be conducted in this thesis which consists of five layers. The specimens are Fiberglass, Hybrid Fiber and Natural Fiber. The mathematical analysis of resin flow through a fiber pre-form is based on the theory of (viscous) flow through porous media, which was formulated by Darcy. So, the permeability will be determined by using Darcy's law equation and came out with the graph of the experiment. The result indicated that the jute fiber is having the constant and high value of permeability.***

***Keywords*: Fiber, Hybrid, Jute, Permeability**

## I. INTRODUCTION

Natural fibres have recently become engaging to researchers, engineers and scientists as reinforcement for fibre reinforced polymer (FRP) composites. Because of their low price, sensible mechanical properties, high specific strength, non-abrasive, eco-friendly and bio-degradability characteristics, they are exploited as a re-placement for the standard fibre, like glass, aramid and carbon. The tensile properties of natural fiber reinforce polymers (both thermoplastics and thermosets) are primarily influenced by the interfacial adhesion between the matrix and the fibres. Many chemical modifications are utilized to improve the interfacial matrix-fibre bonding leading to the enhancement of tensile properties of the composites. These natural fibers include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, henequen and many others [2]. The use of natural fiber for the reinforcement of the compo-sites has received increasing attention both by the academic sector and the indus-try. Natural fibers have many significant advantages over synthetic fibers. Currently, many types of natural fibers have been investigated for use in plastics including flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, rye, cane (sugar and bamboo), grass, reeds, kenaf, ramie, oil palm empty fruit bunch, sisal, coir, water, hyacinth, pennywort, kapok, paper mulberry, raphia, banana fiber, pineapple leaf fiber and papyrus [5].

There are few processes that being for this fiber reinforcement. One of the processes is hand lamination method. This method is the simplest process in the low-end composite products. It requires low investment, higher operating skill and versatile shapes of product that need single high-quality surface finish. Other than that, there's Resin Transfer Mold process (RTM) which are characterized by a fibre preform laid-up in a closed mould system and a pressure difference to drive the resin in the mould cavity. Traditional RTM, which uses high pressures at the resin inlet to inject the resin, has been successfully applied in the aerospace industry and in the automotive industry. RTM can result in high quality composite parts, however there are many drawbacks, such as high costs for tooling and the inflexibility of the process with respect to (minor) design changes [10] But this experiment will be using the vacuum infusion process which is a low-cost RTM variant, was developed especially for the boat building industry. Instead of two solid mould halves and high pressures, one single solid mould halve is used, combined with an airtight flexible film and vacuum pressures to force the resin to flow. This vacuum infusion process was originally introduced as an alternative for open-mould processes like spray-up and hand layup. Besides the intended environmental and health benefits, a considerable quality improvement was noticed.

This experiment will be using the Vacuum Infusion Process (VIP) and the material is jute fiber in order to determine the permeability value of this natural fiber.

## II. JUTE FIBER

Jute take nearly 3 months, to grow to a top of 12–15 toes, for the duration of season after which cut & bundled and kept immersed in water for 'Retting' procedure, where the inner stem and outer, gets separated and the outer plant receives 'individualized', to form a Fiber. Then the plant get separated and washed to put off dust from the plant. The fiber after drying is taken to Jute generators, for buying converted to Jute yarn and Hessian. From the Jute, diverse way of life merchandise is being produced and diverse into various forms, because of R&D help and also due the assist by authorities groups [4].

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**Fig. 1 Jute Fiber**

**Table. 1 Physical Properties of Jute Fiber [9]**

| | |
|---|---|
| Physical property | Jute Fiber |
| Density (g/cm$^3$) | 1.4 |
| Elongation at break (%) | 1.8 |
| Cellulose content (%) | 50-57 |
| Lignin content (%) | 8-10 |
| Young's Modulus (GPa) | 30 |

## III. METHODOLOGY

The setup of the experiment Vacuum Infusion Process (VIP) is showed in Figure 2.

**Fig. 2 Vacuum Infusion Setup**

### The Mold

Prepare a good quality of mold is required for vacuum infusion process. The mold should be rigid and have a high-gloss surface finish. After the mold is properly cleaned, apply the mold release wax in order to avoid the mold and laminate from sticking together after infusion process

### Select the Reinforcement

Choosing reinforcement is an important decision for any laminate, but there are additional considerations when choosing one for infusion. While all fabrics will potentially infuse, different materials and weave styles can severely alter resin flow rates. The following offers some general guidelines for choosing materials, though individual experiences may vary.

### Flow Media

Vacuum Infusion Mesh is used for the flow media in this experiment that is placed after peel ply. This enhanced the flow of resin into the laminate and the availability of the material is high that we can get it from any hardware store with cheap price.

### Resin and Vacuum Lines

Resin will be fed from a standing source (usually a bucket.) The line for getting the resin into the laminate will have to be installed before closing the bag. Although the same tubing that is used for applying vacuum is fine for getting the resin to the bag, after the resin is being directed through the laminate there are some materials unique to VIP which can help direct the resin flow.

Spiral tubing sometimes called spiral wrap, is a plastic ribbon that is coiled into a tube shape. Due to its construction, air or resin can enter or leave the walls of the tube throughout its entire length. This property makes spiral tubing ideal for in-bag vacuum lines or resin feed lines. When used as a feed line, resin will quickly travel through the tube, but simultaneously seep out along the way. This allows quick wet-out of a long stretch within the laminate.

### Vacuum Bag and Attach the Resin Line

Once the dry materials are in place, it is time to build the vacuum bag. The bag should be tight, but still allow plenty of room for all the materials including networks of tubing. Too much or too little bag can result in resin pooling or improper infusion.

### Resin Trap

A resin trap is an airtight container placed within the vacuum tubing circuit between the laminate and the pump to catch any excess resin before it can enter and destroy the vacuum pump. When set up properly, the vacuum tubing will flow out of the laminate and connect directly to the resin trap. A separate tube will then leave the resin trap and connect to the vacuum pump.

With a resin trap, all excess resin will be collected in the trap, while air is still allowed to flow back to the pump. If the part is large and significant resin flow into the vacuum line is expected, any number of resin traps may be placed in sequence. As soon as one is filled, the resin will overflow into the next one.

### Vacuum Pump

Once all the components are in place, it is time to attach the vacuum pump itself. Because resin is infused through vacuum pressure, it is quite beneficial to have a stronger pump. In general, a stronger pump will help expedite infusion.

### Infusion Preparation

Polyester resins Norsodyne 3330W is used in this experiment. It has a viscosity of about 450-600 centepoise (cps) that is within the range of good flow behaviour through porous media in the mold. In addition the price is much cheaper compared to special infusion resin and it also widely used in Malaysia for marine industries.

### Resin Infusion

Once everything is in place and ready to go, mix up the resin. Double check that the resin bucket assembly is firmly in place so the tube will not leave the bucket. Once this is satisfactory, remove the flow regulator to unclamp the resin inlet. Resin should quickly be sucked through the tube and into the laminate.

### Clamp off Resin Line

Once the laminate is completely wet out, there is no need for further resin to enter. If the bucket were to be sucked dry, then destructive air bubbles would enter. To prevent this, the resin line should be clamped off once it's no longer needed. This is accomplished the same way it was before resin was introduced; crease the tube and attach a Flow Regulator. While performing this task, it is crucial that it be done carefully and without significant force that could potentially spring a new leak.

**Table. 2 Sample laminate**

| Fiberglass | Hybrid Fiber | Natural Fiber |
|---|---|---|
| CSM 600 | CSM 600 | JUTE FIBER |
| WR 450 | JUTE FIBER | JUTE FIBER |
| CSM 600 | CSM 600 | JUTE FIBER |
| WR 450 | JUTE FIBER | JUTE FIBER |
| CSM 600 | CSM 600 | JUTE FIBER |

### Resin Matrix

The matrix, in its liquid form, is the flowing material in the infusion process and needs to be as thin as possible. The experiment was used the Norsodyne wax vacuum infusion polyester resins with viscosity between 450-600 centipoise (cps) at 25oc, thixotropic and pre-accelerated general purpose orthophthalic. Gel time is also a major concern in vacuum infusion. As a resin gels, its viscosity increases dramatically, thereby slowing the flow rate. It is good practice to have a medium to long range gel time (8-11 minutes) when infusing a part. The list of sample is showed in Table 2.

### Infusion Theory Calculation Darcy's Law

In basic infusion theory states the behavior of resin flow in dry materials that had been derived by Henry Darcy for aqueous flow through porous media (originally developed for water irrigation purposes).

$$Q = -\frac{KA}{\mu}\frac{\Delta p}{\Delta x}$$

Where, Q = volumetric flow rate [$m^3$/s]
μ = the fluid viscosity [Pa-s]
A = the cross-section area [$m^2$]
$\Delta p / \Delta x$ = the pressure gradient in the flowing resin [Pa/m]
K = the reinforcement permeability [$m^2$]

## IV. RESULT & DISCUSSION

### Fiber glass

The fiberglass infusion setup is showed in Figure 3.

**Fig. 3 Fiberglass Infusion**

**Table. 3 Permeability value of Fiberglass**

| Time (s) | Distance (m) | Permeability ($m^2$) |
|---|---|---|
| 20 | 0.11 | $9.075 \times 10^{-8}$ |
| 40 | 0.16867 | $2.6203 \times 10^{-9}$ |
| 60 | 0.22233 | $3.0353 \times 10^{-9}$ |
| 80 | 0.25167 | $2.91684 \times 10^{-9}$ |

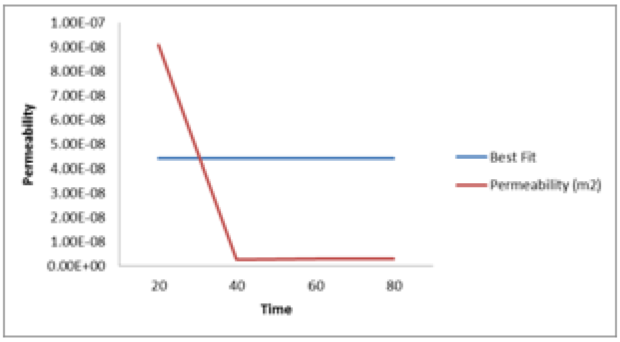


**Fig. 4 Best fit permeability value for Fiberglass**

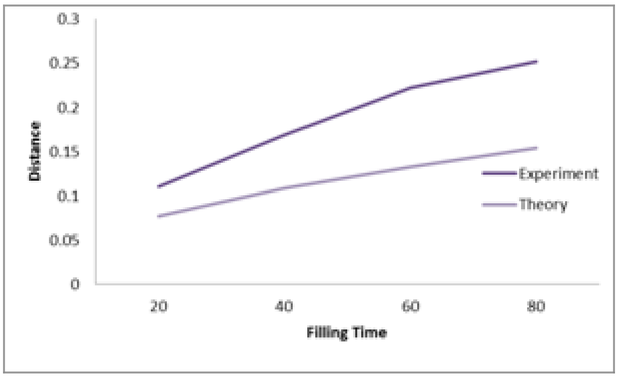


**Fig. 5 Resin flow pattern for Fiberglass**

From Table 3, Figure 4 and Figure 5 it can be seen that the distance against time between the experimental and theoretical value is not the same. This is because due to factors that contribute to the time taken for resin to flow. The resin filling time in experiment is faster than theory calculation because, in this experiment small scale of reinforcement are used to predict the resin flow. So, if the experiment done to the actual size of a boat the experiment time for the resin to flow are longer because the vacuum area and the mold are bigger.

Next, the high vacuum pressure also contributes to this matter. The vacuum pump cannot be adjusted to low pressure due to small scale of reinforcement. The high pressure is used for infusing a boat. So, as the vacuum pressure is high, it will suck the resin faster as usual.

### Hybrid Fiber

Hybrid fiber infusion setup is showed in Figure 6.

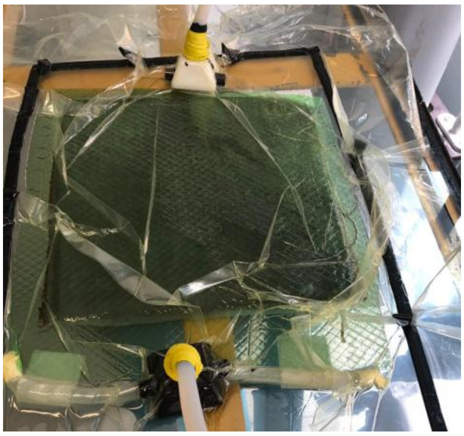

**Fig. 6 Hybrid fiber infusion**

**Table. 4 Permeability value of Hybrid Fiber**

| Time (s) | Distance (m) | Permeability ($m^2$) |
|---|---|---|
| 20 | 0.112 | $1.4070 \times 10^{-8}$ |
| 40 | 0.171 | $1.6480 \times 10^{-7}$ |
| 60 | 0.224 | $1.8816 \times 10^{-7}$ |
| 80 | 0.256 | $1.8408 \times 10^{-7}$ |
| 100 | 0.179 | $7.1958 \times 10^{-8}$ |

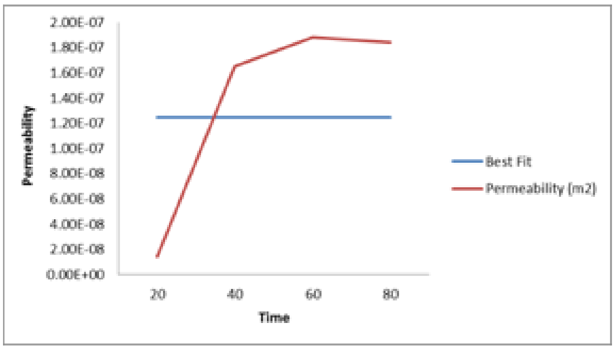


**Fig. 7 Best fit permeability value for Hybrid Fiber**

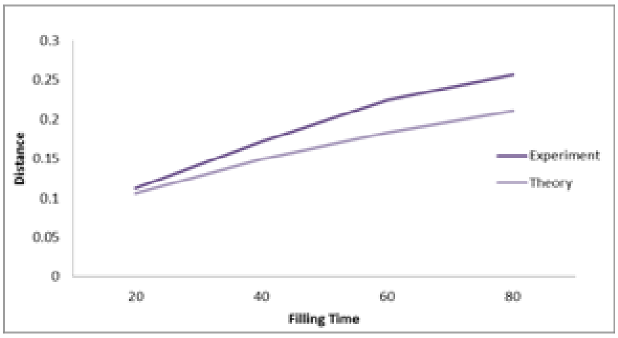


**Fig. 8 Resin flow pattern for Hybrid Fiber**

From Table 4, Figure 7 and Figure 8 it can be seen that the distance against time between the experimental and theoretical value is not the same. There is slightly different between experimental and theoretical value. This is because due to factors that contribute to the time taken for resin to flow. The resin filling time in experiment is faster than theory calculation because, in this experiment small scale of reinforcement are used to predict the resin flow. So, if the experiment done to the actual size of a boat the experiment time for the resin to flow are longer because the vacuum area and the mold are bigger.

Next, the high vacuum pressure also contributes to this matter. The vacuum pump cannot be adjusted to low pressure due to small scale of reinforcement. The high pressure is used for infusing a boat. So, as the vacuum pressure is high, it will suck the resin faster as usual.

### Natural Fiber

Natural fiber infusion setup is showed in Figure 9.

**Fig. 9 Natural fiber infusion**

**Table. 5 Permeability value of Natural Fiber**

| Time (s) | Distance (m) | Permeability ($m^2$) |
|---|---|---|
| 20 | 0.116 | $1.5138 \times 10^{-7}$ |
| 40 | 0.172 | $1.6641 \times 10^{-7}$ |
| 60 | 0.207 | $1.6093 \times 10^{-7}$ |
| 80 | 0.251 | $1.7719 \times 10^{-7}$ |
| 100 | 0.282 | $1.7872 \times 10^{-7}$ |

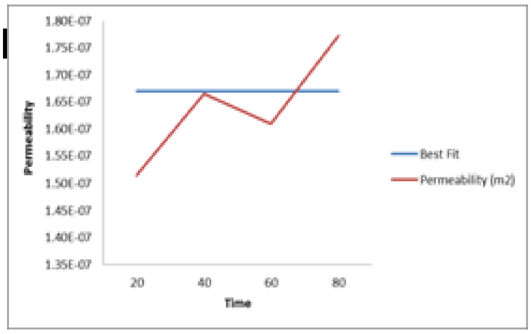


**Fig. 10 Best fit permeability value for Natural Fiber**

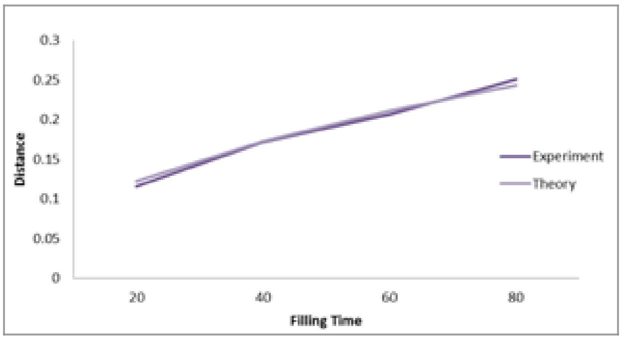


**Fig. 11 Resin flow pattern for Natural Fiber**

From Table 5, Figure 10 and Figure 11 it can be seen that, the resin filling times into the laminate for the experimental and theoretical value are closely to be same value. This is because due to the factors that contribute to the time taken for resin to flow. The resins filling time in experiment is a little bit slower in the beginning compare to the theoretical but getting faster in the end because, in this experiment small scale of reinforcement are used to predict the resin flow. So, if the experiment done to the actual size of a boat the experiment time for resin to flow are longer because the vacuum area and the mold are bigger.

Next, the high vacuum pressure also contributes to this matter. The vacuum pump cannot be adjusted to low pressure due to small scale of reinforcement. The high pressure is used for infusing a boat. So, as the vacuum pressure is high, it will suck the resin faster as usual. Figure 12 showed the comparison the permeability value for fiberglass, hybrid fiber and natural fiber

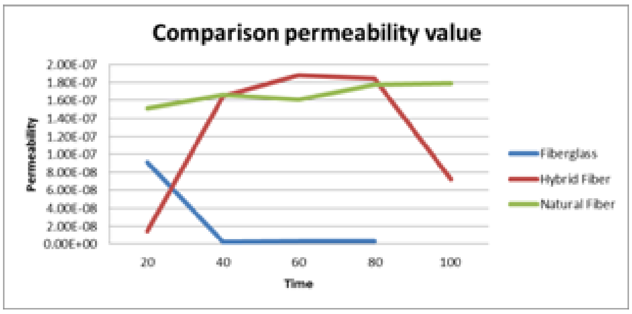


**Fig. 12 Comparison permeability value**

## V. CONCLUSION

It can be concluded that, the resin flow into the porous media which is the laminate consists of 5 layers was successful although the time taken for resin flow is not the same for each materials. The value of the natural fiber infusion has the high and constant permeability value.

The vacuum infusion process was a good process to build a boat compare to hand laminating as the strength of the bonding between each layer is very strong due to the pressure it has from the vacuum. So, the weight of laminate can be reduced as the thickness is small compare to hand laminating process.

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**Kamarul Nasser Mokri** is a Senior Lecturer in the Maritime Engineering Technology Section at Universiti Kuala Lumpur Malaysian Institute of Marine Engineering Technology with 15 years of teaching experience. He received a Master of Engineering in Mechanical – Marine Technology from Universiti Teknologi Malaysia. His specialize area are in Composite Marine Construction, Non-destructive Testing and Occupational Safety and Health. Mr.Kamarul Nasser Mokri is an established teacher and researcher in Wood Technology and Processes, Composite construction especially for Marine Vessel. He also possed Non-destructive Testing Professional Certificate including Magnetic Particle Testing, Penetrant Testing, Ultrasonic Testing, Phased Array Ultrasonic Testing and Welding Inspector. He is currently teaching in Occupational Safety and Health Course.

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Upon his returned to Malaysia, he started to work as a lecturer at Universiti Kuala-Lumpur, Malaysian Institute of Marine Engineering Technology (UniKL MIMET) in July 2016. Until now he had supervised more than 30 final year projects and had published 8 journals as a main and co-author.