The analysis of the calculation of resin requirements in the process of forming carbon fibre body using vacuum infusion method

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Abstract. The aim of this research is to know the calculation of resin requirements which is used, the relative velocity of resin and filling time in body construction process of electric prototype vehicle which used carbon fibre material using vacuum infusion method. In making this vehicle body is using carbon fibre in order to have light in weight, strong and safe to fulfill the regulation or rule Shell Eco-Marathon (SEM). This light in weight vehicle is to increase power to weight ratio. So, it can be increase the efficiency of the fuel. The body of this vehicle has been included in Shell Eco-Marathon Asia which held in Singapore 2017. Based on the ideal calculation result resin in electric prototype that used carbon fibre using vacuum infusion method has obtained as much resin value as needed (RC) 3.83535 Kg, the relative velocity of resin (V) 0.005 m2/s, and filling time (t) for about 10.4 minutes and total weight body is 8 Kg.

1. Introduction

Many efforts done to economize the fuel on a vehicle. One of it is to deduct the weight in a vehicle to reduce over engine performance. The weight reduction in a vehicle has also many efforts, as an example with reduce the weight in vehicle body. It is related with the rare of fossil energy in nature. It is the result of the fuel increasingly. The research about vehicle body has been done to the eco car. Many categories about eco car and one of it is prototype concept which is vehicle design in the future with smaller in shape and more futuristic, so it can be maxium in fuel efficiency.

Prototype concept vehicle is one of race category in Shell Eco Marathon, one of it is electric prototype. This is one of place for students’ creativity in planning and making eco car. Many efforts can be done to make electric prototype body which has light weight. From the material used, production process and shape can influence the vehicle weight. One of the material used in making electric prototype is carbon fibre. Its material has enough weight characteristic and high level stiff. According to Dwinanto and Muhamad said that the characterizations of fibre carbon is has light characteristic and highest powerful and highest stiff (elasticity modulus) [1].

Body formation using carbon fibre material can be in many ways, among them hand lay up and vacuum infusion. Hand lay up is old method to body formation using composit material. Groover said that hand lay up is the oldest method in making body using composit material [2]. For the first time used in 1940 to make ship’s hold. Like its name, hand lay up is forming method where its resin layer applied
in manual in opening mold to make composit structure. Bhatnagar and Kumar said Vacuum infusion is a process that used a little modification [3]. Resin which is used for this process is has lower viscositas, to make easier resin infusion process fullfil all media.

Suitable method to produce light weight electric prototype body is using vacuum infusion method, because the resin used is more effective and not many wasted. This method used vacuum pump that can be throw the air in media, so the amount of resin can fill all the media.

The best step which must be done to do this method is in making master mall process, to make body mold with real scala. Next step, making molding master. Making molding master must be done carefully, because the result of body surface suspended on the surface of its own molding. More delicate and flat of its molding, so the body result can be maximum. After molding master, vacuum infusion process can be done.

The aim of writing this research is 1). To know the formation process of electric prototype body using carbon fibre with vacuum infusion method, 2). To know the necessity of resin and filling time in formation process of electric prototype body using carbon fibre with vacuum infusion method.

2. Method
The method in this study is the experimental method. The process of making a body made from carbon fiber uses a hand lay-up method with vacuum infusion. Then calculations are performed to determine the volume of resin needed, the relative speed of the resin and the time required for the resin to spread throughout the surface.

3. Results
3.1. Unit design and manufacture
3.1.1. The making of mall master framework. The making of this mall master is shaped and has dimension which is suitable with has we planned. The material of this master mall can be styrofoam, multiplex, polyurethan, resin or the combination of that material. The exterior part from this master mall must be smooth in order that the mall is built is really good and easy to remove.

Figure 1. Making master mall framework.

Figure 2. Smoothing mall master.

3.1.2. Mold making. This step is to make a mold from master mall with divided into several parts, so that can be easily removed from the mold.
3.1.3. Molding carbon fibre. This step begins with coating the compound mold mirror glaze with the aim that the resin doesn’t stick to the mold.

Figure 3. Moulded bottom part.

Figure 4. Material installation for vacuum infusion.

Figure 5. Hose installation, connector and sealant tape.
4. Discussion

The aim of this calculation is to calculate the required resin requirements, relative velocity of resin and the time needed by the resin to fill the entire media (Filling time).

4.1. Calculation of resin requirements needed

\[ RC = \left( \frac{FW}{1.5} + 700 \right) + 100 \]  

Where:
RC = Resin Consumption in grams
FW = Fibre Weight per square meter

There’s known value of FW 220 g/m², so it gets resin’s needed about 947 g/m², electric prototype wide is 4.05 m², so resin requirements needed for whole electric prototype is 3,835.35 gram or 3,835.35 Kg.

4.2. Relative velocity of resin

\[ V = - \frac{K}{\mu} \nabla p \]  

Where:
V = Relative velocity of resin (m²/s)
K = Permeability (Darcy)
\( \mu \) = Viscosity of Resin
\( \nabla p \) = Pressure of resin (atm)

To get velocity of resin, first it has known the value of permeability. It can be found by the formula:
\[ K = \frac{8rf^2 (1 - V_f)^3}{53 \cdot V_f^2} \]  

(3)

Where:

- \( K \) = Permeability
- \( r_f \) = Radius of fiber (m)
- \( V_f \) = Fibre Volume Fraction

But to determine the value of \( K \), first need to look for values \( V_f \), it can be determined by formula:

\[ V_f = \frac{N \cdot W}{\rho_f \cdot h} \]  

(4)

Where:

- \( V_f \) = Volume Fibre Fraction
- \( N \) = Amount of layer
- \( \rho_f \) = Density of carbon
- \( W \) = Carbon mass per unit area (kg)
- \( h \) = Thickness of fiber (mm)

Known number of layers 3, fibre thickness is 2.60 mm, density 200, whole fibre weights are 0.546 Kg. From the calculation result, value of \( V_f \) is 0.315. After the value of permeability is known, so next can be found the value of relative velocity of resin. In the experiment who is done by the writer, the pressure contained in the device of vacuum infusion shows in value -50 cmHg or -20 inHg. It can be resulted by the calculation of relative velocity of resin value.

### 4.3. Filling time

\[ t = \frac{h^2}{2KP\mu\varnothing} \]  

(5)

Where:

- \( t \) = Filling time (s)
- \( h \) = Thickness of fiber (mm)
- \( K \) = Permeability (Darcy)
- \( P \) = Difference pressure between inlet and outlet (atm)
- \( \mu \) = Viscosity resin
- \( \varnothing \) = Porosity

It has been obtained in previous calculation, the permeability value is 0.045 darcy, resin viscosity 5.0 and porosity 0.57. Calculation result of filling time is for about 624,101s or 10.4 minutes.

### 5. Conclusion

The conclusion that can be taken based on the results of the research are as follows:

a. The process of forming the electric prototype body is use carbon fibre with vacuum infusion method, as follows:
   - Determine the body design that will be made
   - Obey the safety procedure and occupational health
   - Prepare the tools and materials needed
   - Make master mall
   - Make molding
- Prepare the tools and materials to process vacuum infusion
- Adjust the material for the body
- Check the mold
- Insert resin into the media.

b. Resin calculations obtained for the process of vacuum infusion is:
- The need for resin made to make electric prototype with vacuum infusion method with 4,05 m² wide, it is 3,83535 Kg
- Relative velocity of resin in the process of vacuum infusion is 0,005 m²/s
- Filling time in the process of vacuum infusion for about 10,4 minutes.

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