CHAPTER 7
CONCLUSION AND FUTURE SCOPE

Based on the analysis conclusion for different sets of experiments which have been conducted and future scope for VARTM process has been discussed in this section.

7.1 CONCLUSION

Among various manufacturing process for making FRP composites, VARTM is one of the popular manufacturing techniques, applicable for large scale FRP composites. Preliminary experiments were conducted by developing basic experimental set up and learning from these experiments were used to conduct further sets of experiments. It is identified that VARTM process involves many important parameters, which may be interdependent also.

Research review was performed to identify various parameters affecting VARTM process and critical parameters have been categorised as pre-process, in-process and post–process parameters. Among all these parameters, total 8 parameters were selected for conducting experiments which includes effect of number of layers, position of resin supply, location of vacuum supply, effect of degassing, effect of inclination of table, amount of vacuum supply, GSM of fabric and RPM of peristaltic pump.

Experiments were performed in four different sets, excluding preliminary experiments. For every set of experiments, three parameters with three levels were chosen, except for degassing experiments, wherein only two variables with three levels were chosen.

Indigenous experimental setup was designed and developed to perform these experiments. The learning outcomes of the experiments performed were well observed noted and incorporated in the next set of experiments. Learnings have been highlighted in materials and method chapter.

Various designs available to conduct experiments were learnt by studying the concept of design of experiment. Taguchi L_9 and full factorial design were used to design experiments. Minitab 17 software was used to design and analyze experiments.

Process sheet and check list were developed before performing the experiment to ensure that the experiments were conducted error free. This can be used by any researcher and industry using VARTM process for quality purpose.

In case of natural fiber, jute fabric was chosen as reinforcement for conducting three sets of experiments. Glass fabric with different GSM was used, as reinforcement, for the last set of experiments. Polyester resin was used as matrix for all sets of experiments. The selection of materials was based on availability.

The response measurement was performed in two ways, in-process and post-process measurement and testing. During in-process measurement flow velocity, flow rate and thickness variation during flow was measured. For post-process tensile strength, flexural strength, thickness variation of cured laminate, microscopic examination, density measurement and fiber volume fraction were performed with applicable ASTM standards.

Following important observations are noted after result and discussion for all sets of experiments.

- The maximum tensile strength was achieved by increasing number of layers, increasing GSM of fabric, maintaining uniform part thickness, increasing fiber volume fraction, high vacuum and middle resin supply location.
- The flow velocity increases by increasing pressure head, reducing number of layers, increasing inclination of table and by increasing inlet supply for resin.
- It has been found that increase in flow velocity does not mean increase in tensile strength.
- Radial flow of resin is better than linear flow
- Solvent method can be used to find fiber weight fraction for jute laminate and up to 70% fiber weight fraction was achieved

- Degassing can be used for jute polyester resin laminate to reduce void generated during mixing. 3 minute degassing at full vacuum is effective method to remove bubbles from resin.
- Tensile and flexural strength has increased after degassing which shows improved inter-laminar bonding of resin with fabric.
- The flow velocity reduced after degassing due to increased viscosity of resin. It reduces along the length of composite due to pressure drop during unsaturated flow between inlet and outlet.
- Degassing reduces air content and gives dark colour to the resin.
- Top layer side velocity is higher compared to bottom due to use of HPM.
- The thickness reduction due to fiber wetting can be observed more clearly for more number of layers.
- As number of layers increases or GSM increases thickness variation increases in cured laminate.
- Table inclination should be 0°, more the table inclination, faster the flow which deteriorates the laminate quality**.**
- For 4 layers and 8 layers, there was no variation in the thickness during flow, however for 12 layers there was variation in part thickness during the resin flow at 0° inclination of glass table.
- Interactions between variables was found between GSM, RPM and Vacuum
- Good flexural strength can be achieved by reducing number of layers, reducing flow rate and reducing amount of vacuum supply.
- For glass fabric, the flexural strength was less than tensile strength, but for jute fabric the flexural strength was higher than tensile strength. This shows that the jute fabric laminate have more flexural strength than tensile strength.
- The fiber volume fraction increased as fiber GSM increased. Fiber volume fraction varied from 34% to 57 % with increased GSM.

7.2 FUTURE SCOPE

1) Advanced method can be adapted to monitor and control flow velocity for VARTM process.
2) Development of hybrid composites using developed VARTM set up and integration of various parameters.
3) Development of complex curved structure by VARTM process.