CONCLUSIONS AND SCOPE FOR FUTURE WORK

9.1 CONCLUSIONS

The Experimental, Statistical and Finite Element analysis carried out on the machining of unidirectional and bi-directional GFRP composite specimens have drawn the following conclusions.

➢ It is observed that flat specimens with higher fiber percentage (60 & 70) fabricated by hand lay process possess voids; however it is possible to minimize the voids by proper selection of curing temperature and rolling pressure.

➢ During the fabrication of unidirectional pipe specimens by filament winding process difficulty in fiber control has been experienced. However, control in resin feeding is possible by designing a proper device to squeeze and suitably drain the unused resin in to the collecting vessel in order to maintain the accurate fiber/resin percentage.

➢ In the specimen produced, the orientation of the filaments was slightly disturbed. This may be because of larger guiding ring diameter. However this limitation can be avoided by proper design of the guiding ring.

➢ Occasional errors in the locking of the filaments were observed. As the locking was performed manually, these errors can be prevented if automatic locking facility is provided.
Results of drilling on UGFRP specimens revealed that, higher rotational speed and feed rates produced poor surface quality. Use of pad support and optimum-cutting parameters effectively reduced the delamination and resulted in improved surface quality.

Drill tools of varying diameters used on FRP materials at similar cutting conditions deteriorated the surface quality. Poor surface quality was observed on the holes of larger diameter. However to work with same cutting condition for different diameters, modification in drill tool geometry is preferable.

The magnitude and direction of the effect of each parameter on the end results evaluated by the 2k design can help the FRP designer to know which parameter is more effective and important, on which parameter much attention and control is required for better machinability.

The sequence of the parameters effecting on surface quality based on the lowest to highest magnitude evaluated statistically was observed to be drill speed, feed rate and fiber percentage. Higher thrust force values at high feed rates and higher fiber percentages are the main reason for poor surface quality. Proper control in feed rate and fiber percentages could improve the surface quality.

The delamination force results predicted by FEA model revealed that, a small thrust force is enough to delaminate specimens with higher fiber content. However the increase in thickness of uncut portion increased the delamination force. An optimum fiber percentage in the laminate and the
feed rate control when the tool approaches near the extreme surface layers is very much essential to reduce delamination.

- The FEA model constructed to predict the thrust force causing delamination can be used as a tool to control the feed rates in order to minimize the delamination in drilling FRP composites possessing any fiber proportion within the range considered in the present analysis.

- The hole surface quality on unidirectional GFRP specimens was observed to be relatively better than bi-directional specimens. As in bi-directional GFRP specimens few fibers oriented against the cutting edge got pulled out during cutting causing poor surface quality.

- In fastening joint analysis, though the increase in W/D ratio causes increase in the joint strength, the effect of fiber percentage should also be considered. As the holes produced on specimens with higher fiber content are found to be fuzzy with heavy delamination and fiber pullout causing much variation in hole dimension. Variation in hole dimension causes variation in the clearance between hole and rivet. Higher clearance between rivets and hole causes reduction in the joint strength.

- In face turning of bi-directional GFRP pipe specimens excessive tool wear was observed due to negative fiber orientation. The carbide tipped tool gave better performance when compared to HSS tool. The cutting & feed forces tend to decrease when the rake angle increases; however larger rake angle values weakens the tool cross-section, hence an optimum tool rake angle between $5^\circ-10^\circ$ is suggested.
The present work examined how best the less expensive and less wear resistant HSS tool can be used to machine the highly abrasive glass fiber composite. Suitable cutting parameters to use HSS tools on GFRP materials for better machinability were recommended.

Specimens with higher fibre percentages are strong. However due to high fiber proportion the machined surfaces are fuzzy, highly delaminated and larger fiber pullout. Cutting force values evaluated by FEA model revealed that the specimens with higher fiber proportion require higher cutting forces. The FEA results have shown good agreement with the modified Merchant’s model.

The statistical and FEA models developed based on the experimental results and mechanical properties of the composites respectively can provide suitable cutting and tool parameters for better machinability of GFRP composite possessing wide range of fiber proportion. These models will save the expenses, time and risk involved in fabrication and machining experimentation.

As the cutting and tool parameter data presently available is for the composite with a specific fiber percentage, however the present investigation can show the direction to establish a detailed record of cutting and tool parameter data for any composite with wide range of fiber proportion.

Based on the surface quality requirement it is possible to select the fiber percentage, cutting and tool parameters and vice versa. In many cases
higher cutting parameters produced poor surface quality. However if the achievable surface quality at higher cutting parameters is within the acceptable range then those parameters can be selected for better quality as well as for better productivity.

9.2 SCOPE FOR FUTURE WORK

➢ It is possible to fabricate a simple filament winding machine based on the mechanism explained in this work, with necessary modifications to achieve accuracy in maintaining filament winding angle and resin percentage.

➢ It is possible to perform similar type of drilling and turning experiments on GFRP composite in a cryogenic condition or by using cryogenized tools to examine the performance.

➢ Since the machining performance was observed to be different when tools of different diameters were used at same cutting condition, it is require identifying the exact criteria for drilling a hole of a particular diameter.

➢ An attempt can be made to use drill tools of different shapes and geometry on GFRP specimens with varied fibre content, a sequence of drill tools based on the degree of their performance on different specimens can be identified.

➢ It is possible to examine the influence of machining on the mechanical properties of the composites.
The present work was performed on unidirectional and bi-directional GFRP specimen, the work can be continued in the similar lines on the specimens prepared by different type of chopped strand fibre materials.

By varying tool material, tool shape and tool geometry on a specific type of fibre composite material, the cost analysis can be made to identify the cheapest method for a better performance.