CHAPTER 2

LITERATURE REVIEW

2.1 Mechanical Characterization

Mechanical strengths of composites reinforced with different natural fibers have been investigated by several researchers in the recent past. During characterization of jute fiber reinforced polypropylene composites, it was observed that the mechanical properties like tensile strength, flexural strength and impact strength were better when jute fibers are pre-treated with urea than when used as raw ones (Rezaur Rahman et al. 2010). A study on jute and glass fiber reinforced epoxy laminates reported that the tensile and flexural strength of composites were enhanced when glass fibers are used as extreme plies during fabrication (Soma Dalbehera & Acharya 2014).

A research work on pine needle reinforced composites reported that, pine needles in the form of particle fibers showed better mechanical properties than when it was used as short fibers but it was more reactive to moisture (Vijay Kumar Thakur & Amar Singh Singha 2010). Steam explosion method is a technique of extracting the bamboo fibers. In a study, it was concluded that the tensile strength of steam exploded bamboo fibers were superior to jute fibers and its specific strength was equivalent to glass fibers. Hence bamboo fibers could act as a potential alternate to synthetic fibers (Kazuya Okubo et al. 2004 & Subhash Mandal et al. 2010).

Diameter of fibers and its surface treatment has more influence on composite properties. An investigation on date palm fibers reinforced epoxy laminates showed an increase in tensile strength as a result of decrease in fiber diameter and the decrease in diameter happens during surface treatment (Abdal-hay et al. 2012). Investigations on oil palm fiber reinforced phenol formaldehyde composites reported that the incorporation of chemically modified oil palm fibers in composites improved the impact resistance and tensile properties (Sreekala et al. 2000).
A research on kenaf fiber reinforced polypropylene plastic reported that the inclusion of kenaf fiber in polypropylene matrix improved the mechanical properties like young’s modulus, failure strain and impact resistance (Hamma et al. 2014). Another experiment on kenaf/glass hybrid composites developed by hot impregnation technique reported that twisted kenaf fibers when used along with glass showed better mechanical properties. This hybrid composite could be substituted for conventional materials in automobile bumper beams (Jeyanthi & Janci Rani 2011). Hybridization of two fibers in a composite always gives better behavior than single fibered composites. Mechanical properties of sisal and glass fibers reinforced hybrid composite showed best characters than the sisal fibered composites. Also stacking sequence of the fibers plays an important role in deciding the composite properties (Amico et al. 2010).

In another work a comparative study was done between sisal and banana fiber reinforced composites. The study reported that tensile, flexural and impact strengths sisal fiber composites were better than banana fiber composites. Also it concluded that 20 % fiber loaded composites behaves better than 15 % fiber loaded composites (Faizur Rahman et al. 2014). A research has been done to evaluate the influence of household waste such as mate-tea and eucalypt wood particles as reinforcements in polypropylene matrix. The outcomes of the study represented that composites made by using eucalypt particles showed better mechanical strengths than composites made by using mate-tea particles (Mattos et al. 2014). Wooden particles acts as an important natural fiber and the composite properties are comparable with that of the medium density fiber board (Majid Chaharmahali et al. 2010).

In another work areca fibers are chemically treated and reinforced in to epoxy matrix. The impact strength and hardness of composite increases directly with the fiber volume fraction and post curing time (Srinivasa & Bharath 2011). A study on flax fibers reported that tensile strength and tensile modulus of composites increased due to the inclusion of flax fibers in caseinate plastics when compared to plastics without reinforcements (Fossen et al. 2000). A research has been done to evaluate the tensile, flexural and impact strength of coir and bagasse fiber reinforced hybrid composites and concluded that a combination of 30 % coir and 10 % bagasse fibers when reinforced with polyester resin gives optimum values of mechanical strengths (Sivaraj & Rajeshkumar 2014).

In another study, okra bast fibers were used as reinforcements in phenol formaldehyde resin to make composites. The study reported that alkali treatment to okra fibers improved
the tensile strength by 21 % and flexural strength by 85 %. Also it was concluded that composites prepared with 30 % of okra fibers showed good tensile, flexural strengths (Arifuzzaman Khan et al. 2014). A study on natural rubber/wood flour composites reported that by appropriate addition of wood flour in natural rubber, mechanical properties and water absorption properties were enhanced; however, overloading of wood flour destroys the mechanical properties (Haoqun Hong et al. 2011).

In a study, comparative analysis between basalt and glass fiber reinforced composites was made. The results reported that, both basalt composite and glass composite showed a similar damage tolerance to impact and a slightly increased residual properties by the basalt composites (Igor et al. 2012). In a research work, natural composites were developed through compression moulding by using poly lactic acid as the resin and sweet sorghum as the fiber. The fibers were pretreated before moulding and mechanical properties were analyzed. The study reported that chemical pretreatment enhanced the flexural strength by 63 % (Jing Zhong et al. 2011).

Investigations on rice husk reinforced polyester composites reported that mechanical properties like tensile and flexural strengths were increased when fiber loading is increased. It was concluded that a 50 % rice husk reinforced composite showed best mechanical properties (Wayan Surata et al. 2014). In a study Typha Domingensis leaves were used as reinforcements in polyester resin to form composite plates. The study reported that mechanical properties increases with increase in fiber volume fraction and these composites could be used as insulating boards, electronic packages and construction industries (Ponnukrishnan et al. 2014).

In another research work, mechanical properties of three composites namely pine-polypropylene, oak wood-polypropylene, rapeseed straw-polypropylene were compared with polypropylene plastic. The results reported that all the three natural composites have a same failure strain whereas Young’s modulus and impact resistance are far higher than polypropylene (Slawomir Borysiak & Dominik Paukszta 2008).
In an investigation, composites were manufactured by using two constituents namely isostatic polypropylene and hollow glass beads. The glass beads were pretreated by using cerous trinitate hexahydrate as the surface modifier and the mechanical behaviour has been studied. The results reported that the surface modification to the glass beads considerably increased all the properties of the composite (Xiang Feng Wu et al. 2012). In a research work, wooden particles were used as reinforcement in polypropylene matrix to form composite laminates. The wooden particles were heat treated before preparing the laminates. The study concluded that, heat treated wooden particles when used as reinforcement improved the mechanical properties of composites (Svetlana Butylina et al. 2011).

A study has been done using three types of reinforcements namely coconut coir, human hair and glass. The study reported that coconut coir reinforced composites have high tensile strength than hybrid composites containing all the three fibers. Also it was concluded that the stacking sequence of the fibers play a vital in deciding the properties of the composite (Senthilnathan et al. 2014). Investigations on maize fiber reinforced epoxy composites reported that alkali treatment to maize fibers removed the excess lignin and improved the water absorption characteristics of the composites (Baranitharan & Mahesh 2014).

Although many research works on characterization had been done on various fibers like luffa, licuri, pine apple leaves and hemp (Jose Luiz Westrup et al. 2014; Leao et al. 2011; Mohamed et al. 2009; Pengfei Niu et al. 2011) many natural fibers were not used to its fullest extent. The present work investigates the mechanical behaviour of vetiveria zizanioides root, jute and glass fibers reinforced hybrid composites.

2.2 Machinability issues in FRP

Nowadays, composite products are made in the form of final finished product in order to minimize the machining operations. But, these manufactured components further requires some finishing operations like removing the excess material from the edges and surfaces, surface finishing operations in holes and slots etc. Machining associated analysis and optimization on synthetic fiber reinforced plastics has been done by several researchers. During drilling, the top and bottom surface of hole gets damaged due to several reasons. This damage of hole is measured in terms of delamination factor or damage factor.
During drilling of woven glass reinforced composites, it was observed that at higher feed rates the exit surface delamination is constant irrespective of impressed thrust force. Also during drilling of polymeric composites, heat is generated due to its poor thermal properties. This increases tool wear as a result, the machined surface roughness increases (Khashaba et al. 2013). A study on hole wall surface roughness during ultrasonic drilling on glass fiber reinforced plastics reported that the surface roughness at entrance side was less when compared to surface roughness at exit side (Kishore Debnath et al. 2014). Always there is a need to measure roughness of machined surface and this is done to measure the quality and surface finish of work piece. In a study, carbon fiber reinforced composites are prepared in the form of cylindrical rods. These rods are subjected to turning operation by using two different tools namely, cubic boron nitride and poly-crystalline diamond. The outcomes revealed that surface roughness is more at high feed rate and low at high cutting speed (Rajasekaran et al. 2011).

Similar results have been reported in another study during turning of glass fiber reinforced composites. Also, it was reported that depth of cut has minimum influence on the machined surface roughness (Syed Altaf Hussain et al. 2014). In another study, composite plates are formed by using carbon fibres as reinforcements and poly-cyclic butylene terephthalate as the matrix resin. The study concluded that drilling induced delamination and surface roughness are comparatively minimum at low speed than at high operating speeds (Lopez Arraiza et al. 2012). During drilling of glass fibre reinforced composites by using different drill angles, it was noticed that feed rate has the major influence on thrust force. Also increase in spindle speed reduces the thrust force and increase in feed rate increases the thrust force. It was concluded that a high speed, low feed and low or moderate drill diameter are suitable for reduced thrust force (Latha et al. 2011).

Similar results have been reported in another study on milling of glass fiber composites. In addition it was stated that damage of composite was higher at high speeds and high feed rates (Paulo Davim et al. 2004). In a research work multi-axial carbon fibre reinforced composite is developed and the influence of different tool lead angle on various machinability issues were investigated during surface milling. It was observed that, a tool with 19° lead angle showed reduced cutting force, tool wear and delamination than by the tool with 60° lead angle (Morandeau et al. 2013).
An investigation during drilling on glass fiber reinforced composites reported that thrust force increases when tool diameter is increased. Also, it was concluded that presence of glass fiber is highly responsible for increased thrust force during drilling (Mohamed Kaleemulla & Siddeswarappa 2011). In another work, turning operations were conducted on glass fiber reinforced vinyl ester composites and reported that the cutting force was significantly influenced by feed rate and depth of cut whereas speed and tool nose radius does not have much influence (Naresh Deshpande et al. 2014).

A study on delamination defects during drilling of glass fiber reinforced plastics concluded that high spindle speed, low feed rate, large drill diameter and selection of HSS M35 drill material are optimum conditions for reducing the delamination (Paneerselvam et al. 2014). Similar results have been reported in another research work on glass fiber composites. In addition, it was reported that drill point angle has less influence on delamination (Palanikumar et al. 2008). Another study on carbon fiber reinforced composites also revealed that low feed rate and high spindle speeds are suitable for reducing the delamination of composites (Luis Miguel et al. 2014).

An investigation was done on the thrust force, torque and delamination during drilling on carbon fiber reinforced laminates by using finite element technique. The study reported that the cutting parameters namely speed and feed rate have significant influence on the responses. The study also concluded that the selected outputs increases with increase in feed rate and decreases with increase in cutting speed (Ozden Isbilir & Elaheh Ghassemieh 2012). Tool wear is an important issue during any machining process. During drilling of glass fiber reinforced plastics at different tool angles and feed rates, it was observed that a tool with 80° point angle shows less wear than tools with 100° and 120° tool angles. Also it was concluded that at high speed and at low feed rate, the tool wear was very less (Alper Uysal et al. 2012).

Few research works have also been done on the machinability associated issues in natural fiber reinforced plastics. Coir is used as a fiber since long time during composite manufacturing due to its comparable properties with synthetic fibers. A study on drilling of coir fiber reinforced composites noticed that feed rate has more statistical influence on machinability. It concluded that a medium feed, high speed and medium drill diameter provides improved machinability (Velumani et al. 2013).
In another research work, coir fiber reinforced composites were subjected to drilling and optimization of process parameters like drill diameter, speed and feed rate were addressed. The study concluded that low drill diameter, low speed and high feed rate were found to be the optimum conditions considering the drill forces and tool wear (Jayabal & Natarajan 2010). During drilling on medium density fibre boards, it was observed that the thrust force increases with increase in feed rate and drill diameter. Also, the work piece thickness has very less statistical influence on thrust force (Prakash et al. 2012).

Drilling studies on sisal and glass fibre reinforced hybrid composites concluded that factors like drill diameter, speed of the spindle and feed rate have major influence in reducing damage of hole (Gaitonde et al. 2014). In another study, hybrid composites were developed by using banana, roselle and sisal fibers and were subjected to drilling with different drill sizes. The study revealed that thrust force and torque increases with increase in feed rate and drill diameter whereas they decreases with increase in cutting speed (Chandramohan 2014).

Similar reports have been reported in another study during drilling on banana and glass fiber reinforced hybrid composites (Santhanam & Chandrasekaran 2014). In a research work, composites were developed by using the different fibers namely, hemp, jute, banana and glass. End milling experiments have been conducted on the developed samples and a comparative study between NFRP and SFRP was done. The study reported that hemp fiber reinforced composites gives less delamination and surface roughness than other composites. Also, it was observed that speed and feed rate has major contribution on delamination and surface roughness (Dilli Babu et al. 2013a).

The same authors in another work on hemp fiber composites reported that a low feed and high speed are suitable for reduced delamination effects during drilling and at high cutting speeds the damages severely affects the residual tensile strength of drilled composites (Dilli Babu et al. 2013b). A research has been done on machinability issues during drilling of sisal, jute and glass fiber reinforced hybrid composites and concluded that a low feed rate and high or medium spindle speeds were suitable for reducing the surface damages (Ramesh et al. 2014).
Machinability of any machining operation could be improved by reducing the parameters like delamination, surface roughness, cutting forces, torque, wear of tool etc. These parameters are affected by machining factors like speed, feed, depth of cut, tool angle, tool diameter etc. Hence, by appropriate selection of levels for these factors machinability could be comparatively improved (Rahamathullah & Shunmugam 2013). The present research is done to investigate the influence of natural fibers on machinability issues during drilling of hybrid composites.

Machining input factors like spindle speed, feed rate, depth of cut, tool diameter, tool material etc were studied by earlier researchers by considering two or three different input combinations. Input factors like tool angle and work sample were not given more importance during machining. Among spindle speed, feed rate and depth of cut, speed and feed rate are primary input parameters which majorly affects the output responses when compared to depth of cut. Hence the present study does not deals with the depth of cut. Damage of tool majorly takes place during machining of materials with high hardness like metals, Alloys, metal matrix composites and ceramics. Here the tool is subjected to high cutting forces leading to damage. As the present study deals with machining of plastics, the cutting forces involved is less and hence the tool damages is also less. Hence tool damage is not considered in the present study.

2.3 Response Surface Methodology

Response surface methodology (RSM) is an important technique for creating and optimizing a statistical model. The performance of the developed model is demonstrated by using checking tests given by Analysis of Variance (ANOVA). Response surface plots are used to analyze the surfaces and to locate the optimum point (Montgomery 2009). In a research work Taguchi and RSM has been used for minimizing the surface roughness during machining of glass fiber reinforced plastics (Palanikumar 2008). An investigation on the surface quality during end milling used RSM for optimization of surface roughness and to study the influence of machining parameters on surface roughness (Routara et al. 2009).

In another study, Taguchi and RSM were used to optimize the burr height and surface roughness during drilling. The author suggested that RSM provides large amount of
information with minimal experimentation (Kilickap 2010). During end milling, RSM based central composite rotatable design method was used to develop mathematical models and prediction of vibration amplitude (Sivasakthivel et al. 2011). In another study, RSM was used to optimize the surface finish and dimensional accuracy during laser micro-machining (Wee et al. 2011).

Multiple response optimization is another important tool in RSM to optimize a combination of several responses under study. A desirability based approach is always used to predict the responses by using scale values. A scale value closer to unity is desirable and a scale value closer to zero is undesirable. Desirability analysis is used to convert a multi-response function in to a single response function. As a result, optimization of a complicated multi-response characteristics could be converted in to optimization of single response characteristic termed as composite desirability.

This method does not involve complicated mathematical theories and hence could be effectively used by engineers without more statistics (Li et al. 2007; Palanikumar & Karthikeyan 2006). This method has been used for optimization of machining parameters by minimizing the delamination during drilling of medium density fiber boards (Prakash et al. 2009). In another study, this method was used along with neural network and genetic algorithm for optimal selection of input factors in a multi-response electro jet drilling experiment (Mohan Sen & Shan 2006).

D-optimal design is another important technique which works effectively when a design involves a combination of both numerical and categorical factors. This technique has been used by very few researchers for design and optimization of process parameters (Ivana Grcic et al. 2010 & Chih-Cherng Chen et al. 2011). The present study uses RSM based D-optimal method for design and optimization during drilling of newly developed natural hybrid composites.
Summary

- The literature indicated that, mechanical characterization on natural fiber reinforced composites have been done by using several natural fibers.

- Though several literatures are available on mechanical characterization, many natural fibers were not used to its fullest extent.

- The present work introduces a new natural fiber namely vetiveria zizanioides roots as a reinforcement along with jute and glass fibers to develop hybrid composites.

- The study focusses to investigate the mechanical properties of developed samples and to finally select the best samples for its machinability studies.

- Research investigations on machinability issues have been done by several researchers on synthetic fiber reinforced composites and a few has been done on natural fiber composites.

- The present study is also aimed to investigate the influence of natural fibers present in the composite on machinability during drilling operation.

- RSM was used by several researchers for experimental design and optimization by using several tools available in it.

- The present research uses D-optimal design as one of the tools in RSM for design and optimization.