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IMPACT ON STRUCTURAL AND MECHANICAL PROPERTIES OF COMPOSITES DURING MACHINING AND CUTTING: A REVIEW

Deepa A., Padmanabhan K. and Kuppan P.
School of Mechanical Engineering, VIT University, Vellore, India
E-Mail: deepa.a@vit.ac.in#

ABSTRACT

Recent trend in reduction of cost, durability, reliability, and less weight with excellent mechanical properties and resistance to corrosion, composites find a huge application in all fields of engineering and are greatly used in day to day life in many fields. Properties like high specific weight, stiffness etc. made everyone to look for replacing the conventional metals and alloys with composites. In order to use them effectively according to our required size and shape machining is necessary, but during machining an appreciable amount of heat is generated and this affects the structural properties of composites. The present paper aimed at presenting the past work done in this area.

Keywords: mechanical properties of composites, machining of composites, machining methods, processing, composites.

INTRODUCTION

In order to reduce the cost of construction, it is attractive to make automobile, aerospace and ship bodies lighter in weight but stiffer in strength with the help of composite material. Although the composite material provide great opportunities due to its distinct properties, however being non-homogenous, anisotropic and reinforced by stiff component these material are very difficult to machine. Selection of the tools for machining the work piece of composite material is a challenging factor for the engineers and also to perform the machining operation with less amount of heat generation which in turn helps in fulfilling the operation without any structural changes in the material.

Although the composite material provide great opportunities due to its distinct properties, however being non-homogenous, anisotropic and reinforced by stiff component these material are very difficult to machine. In view of availability of equipment and experience, Composite material can be widely machined by conventional methods. But some of materials used as reinforcement in the composites are sometime even harder than the tool material. Then by conventional approach brittle fracture and material separation of the reinforcement is obtained like fiber pull-out and delamination. When wedo cutting of the specimen by non-conventional process like Laser jet machining, the reinforcement in the composite undergo damage in form of excessive HAZ. A number of works show that this damage is influenced by the choice of the machining parameters, the geometry of the cutting tool tip, and the nature of its material as well as the process of manufacturing of the composite parts chosen.

Morgan and Weager [12] studied all about SRPC and particularly about SRPPC. The work was to formulateefficient and cost effective manufacturing processes while maintaining the highest mechanical properties the materials can offer. Novel forming techniques and post-processing technologies, including coating, bonding and trimming were introduced and developed to allow the manufacture of high quality, commercially ready products. Manufacturing processes that are used to form components from these materials will be discussed along with the considerations to be taken into account, that are specific to SRP composites, such as accurate temperature control to avoid over heating of the reinforcement fibers/tapes and degradation of the materials properties.

Materials made of thermoplastics can be simply re-melted and re-moulded into new components, however this is not possible with the inclusion of fibers such as glass or carbon as these cannot be melted down. Thus, the composite materials must be shredded and used as lower performance short fiber reinforced polymer composites. To meet the demand of recyclable fiber reinforced polymer composites, fibers which can be melted along with the polymer matrix and be compatible with that melt must be used; this has led to the development of Self Reinforced Polymer (SRP) composites.

According to the study all the self-reinforced polymer composites offer significantly higher properties than the virgin polymers. For example Cabrera shows that at room temperature the all-polypropylene material displays a Young's modulus of 5.9GPa. This is significantly above the modulus of isotropic polypropylene which has a modulus of around 1.1GPa. Cabrera is supported the findings; Hine and Ward show that the modulus of Curve which is another all-polypropylene material manufactured using a different method to pure is also significantly higher than unmodified polypropylene and reaches 5GPa.

Self-reinforced polymer composites made from materials other than polypropylene are much less mature and not yet commercially available. However, the properties they exhibit even in the development stage have been no less impressive. Hine demonstrates that self-reinforced polyethylene terephthalate can be made showing a modulus of 5.81GPa which is more than twice that of isotropic PET. Also Rein gives figures between 10-12GPa for self-reinforced polyethylene, a dramatic shift upwards in the stiffness of this material.

Strength, heat deflection temperature and impact performance are all increased while offering little increase in the density of the material. It can be clearly seen from

Hine's work that the most drastic increase comes in the form of impact performance. It is suggested by Alcock that this dramatic increase in impact performance is due to interfacial failure between the polymer tapes/fibers and the matrix material around them. This is a failure mechanism which does not exist in virgin unreinforced polymers as obviously there are no tapes/fibers and no interfacial bonds, and thus the materials react as they traditionally would. Although Alcock suggests that interfacial failure between tapes/fibers and matrix material is the main reason for the increase in impact performance there are of course other mechanisms within the material. As with all fiber reinforced composites, these materials gain their properties by transferring loads from the relatively low property matrix material into the high performance reinforcement fibers. Due to the very high level of molecular orientation within the reinforcements of self-reinforced polymer composites resulting from high draw ratios (up to 20 for polypropylene)

Advantages and disadvantages of the SRPC were discussed. Advantage is that SRP composites are 100% thermo-plastic, recycling is a very simple process. Unlike more traditional fibre reinforced composites, SRP composites do not require the reinforcement to be separated from the matrix before effective recycling can take place, as with glass and carbon reinforced materials. At the end of product life a component can simply be re-melted and re-granulated. These granules can then be reprocessed into new components. Secondly SRP composites are reinforced with the same polymers from which the matrix made. This means that although gaining a significant increase in properties there is no increase in density of the material. This means extremely light weight materials can be manufactured and so very significant weight savings on finished components can be achieved.

And the disadvantage is temperature sensitivity. During processing, temperature must be controlled very accurately in order to melt only the matrix material while keeping the reinforcement un-damaged by the heat. This is very difficult due to the relatively small processing windows these materials present. Secondly, these materials are 100% thermoplastic, and as such they cannot be used for high temperature applications as they would lose properties very rapidly.

Then the process involved in formation of SRPCs is studied. We are mentioning about Hot Compaction only i.e., a method by which highly oriented polymer tapes are very accurately heated (±0.5°C). This heating allows approximately 10% of the polymer tapes to melt. With the application of pressure this molten polymer flows throughout the lattice work of tapes to form a continuous matrix. The sheet is then cooled while still under pressure to solidify the matrix.

MACHINING OF COMPOSITES

R. Teti [9] provided the basic introduction to composites and their classifications like PMC, MMC, CMC composites and problems faced during machining and the influence of various cutting tools and the different tool wear mechanisms arises during machining of each type which depends on fibre orientation and volume fraction of both matrix and reinforcement phases, these two strongly determine the strength and mechanical properties of composites. The problems are mainly due to their non-homogeneity and orientation of fibers.

In case of PMC the possible wear mechanisms are abrasion and surface damage and sometimes adhesion are significant for machining of FRP materials. Tool wear mechanisms are mainly related to physical and mechanical properties of material. Glass and carbon fibers show very strong abrasive nature because of their extreme abrasive nature on other hand aramid fibers cause problems due to its low heat conductivity and their ductile characteristics.

MMC can be machined using the conventional machining processes like turning, drilling, milling etc. PCD tools can be effectively used to perform the machining operations. The too wear is less in case of PCD tools compared to any other tools like carbide tools, TiN coating of carbides etc. in any case, fractured and pulled out particles are particularly unavoidable in MMC machining, and the subsurface damage is more subsequent fiber reinforced MMC than in particle reinforces MMC materials formation of built-up-edges can be avoids by using water based cutting fluids but at the cost of tool life.

Machining of CMC is very difficult by using any conventional methods like milling, drilling etc. laser machining is appreciable since tool wear in comparison with any other conventional processes is less but it is very difficult to machine CMC material.

In the machining process for trimming Morgan and Weager [12] suggested three non-conventional methods to maintain high order of accuracy and size and shape namely

- Water jet cutting
- Laser Beam cutting
- CNC machining with both abrasive and shear cutters

One of the suggested methods we had chosen for our machining purpose and based on availability and cost parameter is LBM. It was suggested to avoid WJM as it caused too much of delamination and supported CNC machining as it gave the best result.

A. Experimental methods

A study was carried on self-reinforced composites (SRC) to determine the optimum consolidation process conditions of a co-extruded polypropylene, considering its structural characteristics, static and time-dependent deformation behaviour. It was done by Mechanical testing via T-peel, tensile, creep tests and structural testing as DSC and XRD.

[11] The repeated impact behaviour of self-reinforced polypropylene composite which were characterised by tensile impact and instrumented falling weight tests. The self-reinforced polypropylene composite investigated here was supplied by Propex fabrics under the trade name of Curve, which is a plain weave tape. The samples were square (100 ×100 mm2) with a thickness of 2.2 mm (4 tapes) for falling weight impact tests and a

thickness of 0.55 mm (one tape) for samples recommended in ISO 8256:2004 for tensile impact tests. Instrumented tensile impact tests were carried out on a CEAST pendulum with a mass equal to 1.098 kg and an impact velocity of 2.06 m/s at room temperature. Stress strain tensile curves have been obtained in accordance with the method proposed. Low velocity impact tests were carried out in a falling weight machine (Fractovis-Plus, Ceast) equipped with a 20 KN load cell attached to the striker which measured contact force history. This force/time curve provides a measurement of the energy absorbed by the impact. In this paper we found that Self-reinforced polypropylene tapes are highly anisotropic with strain hardening failure mechanisms and the elongation at break is relatively high (>20%) even at impact strain rates. Up to 5 J there is no plastic deformation, whereas at higher energies permanent deflection increases rapidly with impact energy until perforation (31.4 J). Up to 13 J the fatigue life exceeds 500 impact events, but for slightly higher energies the maximum number of allowable impact events drops sharply. So, it can be postulated that the transition from plastic deformation of the fibres to breakage is the origin of this reduction in fatigue life, and that this transition takes place in a very narrow impact energy range. Due to the strain-hardening, the peak load increases with the number of impacts, but decreases when tape breaking takes place, Due to the strain-hardening, the peak load increases with the number of impacts, but decreases when tape breaking takes place, Absorbed energy decreases with impact events when plastic deformation is induced, but when the tape breaking starts the absorbed energy increases.

[5] The interface between fiber and matrix resin plays a major role in stress transfer between fiber and matrix, adhesion bond at interface. If they are weakly held then composite start to form matrix cracks and also if they held strongly, matrix cracking is delayed and composite fails catastrophically. Matrix cracks are observed more in composites small cracks come closer and form bigger cracks and grow along the thickness, mainly due to tensile loading, Fatigue loading as well as by thermal cycling. This result in significant reduction of stiffness and leads to damage like de-lamination occur mainly at the free surfaces, machined ends and holes surfaces. On application of external loads growth of delamination takes place and rapid reduction of mechanical properties take place and ultimately lead to failure of the material. When a tensile load is applied on a uni-directional composite, the individual fibers break at the weak points and results in the reduction of overall strength of the material by breaking the other fibers too while stress transferring to other fibers. [7] A strong interface displays an exemplary strength and stiffness but is very brittle in nature with easy crack propagation through the interface. A weaker interface reduces the stress transmissibility and consequently decreased strength and stiffness. A crack here is more likely to deviate and grow at the weak interface. It results in deboning and/or fibre pull-out and contributes to improved fracture toughness. Complexities involve absorption of water and subsequent influence of freeze-thaw cycling on the changes of materials behaviour through microstructure modifications. The factors affecting the mechanical response of composites are fibre/matrix interfacial properties, volume ratios, load transfer mechanisms and fabrication techniques.

[10] Composites find huge applications in aerospace and other automobile sectors due to their high strength and stiffness. But, when these materials are loaded mechanically or thermally, cracks are developed in piles lies along the plies known as matrix cracks or transverse cracks, ply cracks. In presence of cracks these materials responds differently during loading and sometimes failure is caused. Mainly there are four fatigue failure mechanisms namely de-bonding, matrix cracks, delamination and fibre breakage.

[7] Durability of fibre reinforced polymer composites (FRP) are controlled by the durability of their constituents: reinforcement fibres, resin matrices, and the status of interfaces. It is at the interfacial area where stress concentration develops because of differences in the thermal expansion coefficients between the reinforcement and the matrix phase. A significant mismatch in the environmentally induced degradation of matrix and fibre leads to the evolution of localized stress and strain fields in the FRP composite. The present investigation aims to study the effects of changing hygrothermal conditioning cycles (either by changing relative humidity and temperature is kept constant, or by changing temperature but relative humidity is maintained same) on moisture gain/loss kinetics and on inter-laminar shear strength (ILSS) of varied weight fractions glass fiber reinforced epoxy and polyester matrices composites. This paper mainly focused on the assessment of mechanical properties of materials under influence of changing environment and loading speed.

Andras Izer and Tamas Barany [2] performed studies on various types of Polypropylene and fabrication of different types of PP composites and a comparative study on its various mechanical properties is made. The outcome from this work is, 1) by film-stacking method, a self-reinforced polypropylene composite exploiting the polymorphism of PP was developed. 2) Investigated the effect of processing temperature on the consolidation quality and the mechanical properties of the composite by static and dynamic mechanical, peel and microscopic studies. 3) Fracture and failure behaviour of the composites that were differently consolidated by microscopy and AE tests. 4) Creep behaviour of the differently consolidated composites is analysed. 5) Long-term behaviour from short-term tests is predicted. 6) Explored the reprocess-ability of SRPPCs and compared it to PP material. Thermo-formability of composites formed with different kinds of techniques is determined.

Kyoung Ju Kim, Ryoel and Philip Harrison [3] provides the information about the development of single-polymer or self-reinforced composites (SRCs), including the fundamental sciences such as design principles and mechanisms, as well as preparation techniques and potential application areas. The advantages of such SRC systems include the ability to achieve excellent interfaces between components, their pure chemical functionality, and their higher value as recyclable products due to their relative homogeneity compared to composites composed of different classes of components. Single-polymer composites are particularly important in biomaterials applications, since any additives composed of different chemicals could affect biocompatibility and biodegradation. Various techniques used to design and produce SRCs have been investigated and developed, such as hot compaction, overheating, solution, partial dissolving, cool drawing, physical treatment and chemical modification.

The concept of "overheating" as an established method for manufacturing SRCs is validated for two categories of semi-crystalline polymers-the draw able polar polymers, and the less drawable polar polymers. The interchange interactions in polar polymers are relatively weak and therefore a high degree of drawability can be obtained. Polar polymers, on the other hand, have relatively strong inter-chain interactions and are therefore less drawable. A shift in melting temperature of >20ºC can be achieved in the case of highly extended isotactic polypropylene (IPP) (draw ratios >14), while ultra-drawn PE can only achieve 10ºC overheating on constraining, and this is due mainly to a change in PE chain mobility during the hexagonal phase and also studied about the PP composite, its preparation by various techniques, processing and testing used about it.

"SRC" generally refers to a composite comprising polymeric oriented reinforcing elements (usually fibers or tapes) or rigid particles in a matrix of the same polymer. However, there are other kinds of SRCs based on molecular orientation through synthesizing or processing.

One of the techniques suggested for developing SRCs is to increase the difference between the thermal processing temperatures. Research has shown that processing is very temperature sensitive, and that in most cases the optimum compaction temperature is about 1 ◦C below the point at which substantial crystalline melting occurs. At this optimum temperature, some of the original oriented phase is lost to bonding the structure together. The small difference in melting temperature between the reinforcing elements and the matrix poses a big challenge during fabrication, as both constituents have basically the same chemical structure and hence melting temperatures. As there are many polyolefin with different melting temperature available in the market, various PE- and PP-based SRCs have been developed based on the same polymer with different thermal properties.

[4] The creation of highly oriented, co-extruded polypropylene (PP) tapes with a large temperature processing window (>30ºC) and a high volume fraction of highly oriented PP (>90%). They also introduced all-polypropylene composites and reported the tensile and compressive properties of unidirectional composites. These composites show good retention of tape properties despite the relatively high temperatures used in composite manufacture and little deviation of mechanical properties with compaction temperature.

B. Alcock, N.O.Cabreraa, N.-M. Barkoula, J. Loos [4] discussed about the problem associated with the recyclability of the polymer composite currently used in the market. Numerous investigations were conducted to combine high modulus PE or PP fibres with a similar matrix. Most early studies concern PE since the ultimate modulus of a linear PE molecule (~250 GPa) is much greater than the crystal lattice modulus of the helical PP molecule (~40 GPa). However, the lower glass transition and melting temperatures of PE mean that creep at room temperature can be problematic and maximum usage temperature is lower than that of PP, which also benefits from a slightly lower price and density.

The high mechanical properties of the fiber are due to molecular orientation in the drawing direction. However, the main difficulty they found about combining fibers and matrices of similar polymers to create an all-polymer composite is to retain the properties of the oriented polymer molecules in the final composite, since molecular relaxation of highly oriented fibers readily occurs during heating. Initially, most studies focused on traditional routes to create thermoplastic composites, such as melt, powder or solution impregnation of multifilament yarns. The combination of similar polymer grades by exploitation of different melting temperatures opens up many routes for the production of single polymer composites. The creation of single polymer composites based on PE was first suggested by Porter and co-workers in the mid-1970s, by exploiting the difference in melting temperature of HDPE fibers and conventionally crystallized LDPE.

Similar works were continued in order to develop a route to produce single polymer composites based on PP, which can compete with glass fiber reinforced PP, by combining a high volume fraction of reinforcement together with a large temperature processing window.

A specimen was prepared with a tape which was a co-extruded three layer tape, with an A: B: A (copolymer: homo-polymer: copolymer) structure, that was manufactured at Lankhorst Indutech B.V., The Netherlands, using a co-extrusion and tape drawing line. Unidirectional all-PP composite laminates were created from this tape via a filament winding process, by winding tape from a bobbin onto a thin, flat steel plate using a custom built winding machine. This frame is then placed in a matching mould and the tapes are compacted into a unidirectional composite sheet by the application of heat and pressure. The composite is placed in a purposed built mould, which is positioned between the platens of a 500 KN hot press. After the desired compaction temperature has been achieved and held for consolidation, the press is rapidly cooled. Pressures maintained in the press throughout this process. The temperature inside the mould is monitored externally using thermometer probes, inserted in upper and lower halves of the mould.

Tensile test specimens were tested using an Instron 5584 tensile testing machine, equipped with 5KN load cell and data acquisition software. Specimens were placed in composite grips, which allow 108 free rotations to reduce the effect of moments in the off-axis specimens. Tensile tests were performed at 2 mm minK1 with a small preload (w1 N). To fully characterize the material, two types of tensile tests were performed: tensile deformation at low strain to determine moduli and Poisson's ratio, and deformation to failure to determine strength and strain to failure. To determine the Young's modulus (E-modulus) for each specimen, strain was measured using strain gauges placed in the direction of tensile loading at low strains (! 2.5%). The Young's modulus was calculated in all cases using a range of 0.05–0.2% strain; in all cases this proved to be a linear and reproducible region with very little deviation. To determine Poisson's ratio, an additional strain gauge was placed at 908 to the direction of loading. To determine the tensile strength and strain to failure of the specimens, high strain (O2.5%) data from the cross-head displacement was used to measure extension. Each test was performed 5 times to ensure reproducibility. Specimens, which failed within or very close to, the gripped region of the specimen, were discarded.

It was concluded that all polypropylene composites can be successfully created with high fibre volume fractions (>90%) possessing high tensile moduli and strengths. By using a combination of constraining and co-extrusion, the temperature window for creating these composites can be greater than 30 8C. Despite the high temperatures involved during the compaction process, the excellent mechanical properties of the oriented tapes are retained in the resulting unidirectional composites. Furthermore, the composite is not sensitive to deviations in the process temperature since mechanical properties proved approximately constant within the processing temperature window.

B. Machining methods

a) Conventional machining

[15] Difficulty in machining composite materials is discussed in this article. Composite materials being anisotropic, non-homogenous and consisting very abrasive reinforcing fibres it is more difficult to machine when compared to metals. Due to this, even the tools wear rapidly. Different machining operations result in different problems.

Traditional machining processes causes several damages like matrix catering, thermal alterations, fibre pull-out, fuzzing, delamination, fibre-matrix de-bonding, etc. From the discussion they have concluded that in order to minimize the heat generated and avoid thermal damage proper tool geometry and operating conditions must be adopted. Special tool designs are required to avoid fuzz. Even the health effects of the dust produced was studied and known that if proper precautions are not taken respirable dust levels can exceed tolerable levels. For some of the processes liquid coolant helps a lot.

b) Non-conventional machining

[20] Because of the heterogeneity, anisotropy, low thermal conductivity, heat sensitivity of the material and the high abrasiveness of the reinforcing fibres it is difficult to machine composite materials. Hence non-conventional techniques can be used where the objective is increasing cutting rates, improving surface quality, or in cases where conventional machining methods are non-effective.

Lasers are a very good alternative to machining composites, this is because there will be no contact between the tool and work-piece. This will eliminate problems associated with chatter and vibration and allowing for machining of small or thin components. The important parameters for a laser cutting are energy absorption, thermal diffusivity and reaction temperature.

Water jet cutting is another advanced non-conventional method used for drilling, cutting, milling and turning of advanced composites with organic, metal and ceramic matrices. The principle is to produce a thin water-jet with very high pressures and high velocities, and, upon impact, material is removed by localized shearing. Some of its advantages are high cutting speeds and the absence of heat affected zone compared to conventional or laser machining techniques. At high cutting speeds, delamination are introduced into the work-piece and in some cases, moisture absorption during water-jet cutting can lead to delamination under load.

EDM is another non-conventional method which is versatile process and can be used for machining intricate and complex shapes in conducting materials. Electro-chemical spark machining is one more process which is similar to the EDM but can handle electrically non-conducting materials. Of the different types of non-conventional machining methods laser and water-jet machining are extensively used in industries. They produce high quality cut and are highly flexible. The major concern with water-jet is delamination, but this can be eliminated by choosing proper operation parameters.

Abrasive water jet machining

[5] Machining of any Fiber Reinforced Plastic which is basically a Polymer Matrix Composite without causing any damage is quite challenging when machined with conventional processes viz. drilling, milling, grinding, sawing etc. due to its inherent anisotropy, heterogeneity and thermal sensitivity, even if proper care may have been taken. Abrasive waterjet machining technology have proven its capability to cut almost any material and being successfully applied to machine numerous materials including composites owing to its certain advantageous characteristics like 'cool' cutting, self-cleaning, no special or additional tooling, extremely fast set-up, minimal fixturing, etc.

The details inferred are as follows:

The Material removal Mechanism, factors affecting the AWJ cutting performance. Performance evaluation for AWJ cutting of Fiber Reinforced Plastics.

The below mentioned things were concluded: The versatility of AWJ technology for cutting almost any material has been well established in terms of narrow kerf width and faster rate of cutting when compared to other conventional and unconventional machining processes used for similar operation. In addition this machining process does not call for extra tooling and fixturing yet has surplus advantages of intrinsically cool cutting and self-cleaning

Delamination may be caused during AWJ cutting of FRP. It is the degradation of material properties adjacent to the kerf and very much of concern because it will seriously affect the capacity of the component to bear designed loads for expected life. Contaminations in form of moisture absorption or embedment of abrasive particles in to the parent material are also considered as undesirable machining effect. Therefore compatibility among the FRP to be cut and AWJ parameters has to be decided by preliminary experimentation to check against the described damages

Laser machining

Venkatesh Kannan M, Kuppan P, Senthil KumarA, Ramesh Kumar K, [13] studied about the impact of laser scan speed on surface temperature, tool wear and cutting forces during machining of alumina using laser assisted machining. Alumina, being a ceramic material, can be machined using advanced machining process like USM, ECM, diamond grinding, cryogenic machining etc. but these are limited due to its disadvantages like low material removal rate, high tool cost and wear, low surface finish leads to the restriction in using them. Preheating the material can reduce the hardness tensile strength and strain hardening of work material which helps in easy removal of material i.e., preheating results in increased material removal rate. Pre heating can be done by using heat sources like induction coil, ox acetylene torches, plasma and laser are the various techniques used, among them plasma and laser are the well suited for thermal assisted machining (TAM). However using this for the industrial applications is rather difficult, the main advantage in using this method is ability to control the temperature field of machining zone during operation.

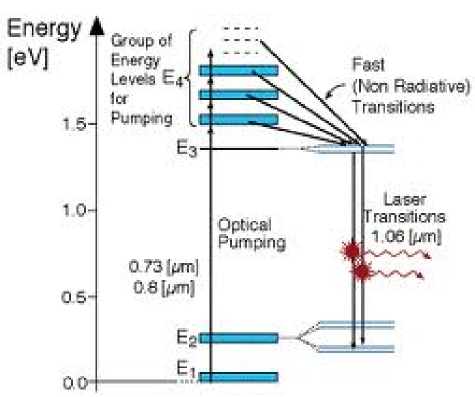

Figure-1. Energy-wavelength plot.

The glass phase transition temperature for alumina is 850ºc and material is preheated to the temperature. The laser power was varied from 0W (conventional) to 700W and the corresponding average surface temperature are recorded shown in Figure-1 and the impact the impact of laser scan speed on surface temperature is observed and a bar graph is shown in Figure-2., and also gave the details regarding tri axial cutting forces (f_x, f_y, f_z) and specific cutting energy varying and tool wear with changing laser cutting speeds.

Finally, it was concluded that, surface temperatures of the ceramic material are proportional with laser scan speed and the optimal temperature (around 1250ºc) at a laser power of 350W and laser speed between 50mm/min. laser speed has a significant effect on tool wear and surface temperature plays a vital role on cutting forces and tool wear in LAM.

[6] Laser machining of polymer matrix composites: scope, limitations and application of laser machining in the field of machining of composites especially polymer matrix composites. Due to its properties like non-homogeneous and anisotropy composite are difficult to machine using traditional methods and facing the problems like damage of work piece through chipping, delamination and high wear on the cutting tools. Therefore researchers are looking for non-traditional machining methods to overcome these problems of machining. Among the various non-conventional machining methods available, Electro Discharge Machining can be used for electrical conductive materials, Abrasive Jet Machining and Water Jet Machining can be used for brittle materials and Ultrasonic Machining can be used for harder materials but Laser Machining (CO2andND: YAG) offers an attractive alternative to all of above because it is a non-contact, abrasion less technique eliminates tool wear, machine-tool deflections, vibrations and cutting forces, moreover it can be used for almost all type of materials. It gives details about the laser components and properties of laser that make efficient in working, parameters of laser and advantages of using this process.

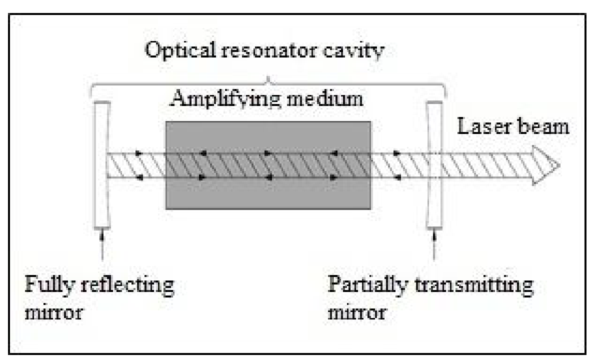

Figure-2. Laser components.

In-spite of all these, there are some disadvantages too, they are, composite material contains two or more chemically distinct phases that are not in

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thermodynamic equilibrium. The properties of the phases used are vary and makes difficulty in machining. The energy require to melt the fibre or to vaporize them is higher to that require to melt or vaporize polymer matrix and also thermal conductivity of fibre is very much higher than polymer matrix. Processing in pulse mode of laser is appreciable as it can able to provide accurate amount of energy that is enough to completely cut the work piece. So, one has to find the optimum parameters so that the above mentioned problems can be overcome and to ease of machining.

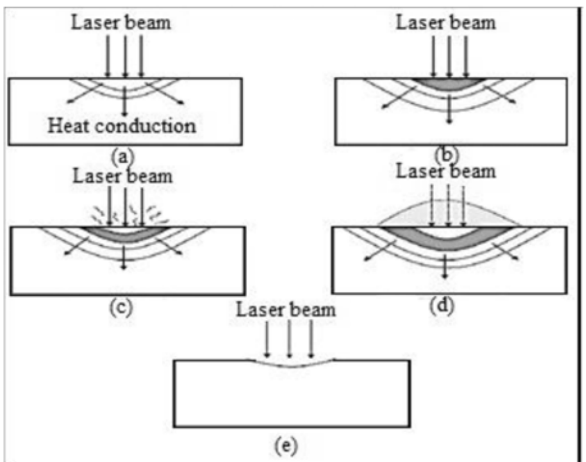

Figure-3. Various effects of laser–material interaction: (a) heating, (b) surface melting, (c) surface vaporization, (d) plasma formation, (e) ablation.

[14] The temperature distribution across the depth of the work-piece that is machined using Laser assisted machining (LAM) is studied. Ti-6Al-4V alloy is the material considered for this, because Titanium alloys has a wide range of applications in automotive as well as aerospace industries. They have high strength to weight ratio and can withstand heavy temperatures. Due to its high strength, conventional machining is low productivity process. Thus LAM is preferred. Finite element model of transient temperature distribution problem is developed. The effect of various input parameters is studied and observed that the temperature of the work-piece increases with laser power and decreases with increase in spot radius and scanning speed as shown in Figure-4.

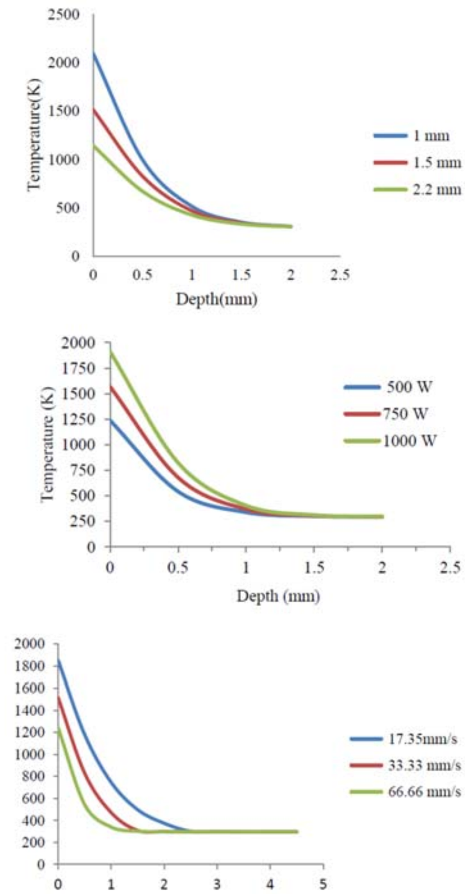

Figure-4. Graphs showing temperature change across the depth of work piece with respect to laser power, spot radius and scanning speed.

At particular values of laser power, scanning speed and spot size the alloy will reach its melting point; hence those values are not desirable for LAM. Thus the results help in selecting the optimum laser parameters for LAM.

[21]The application of the CO_2 laser cutting process to polymers, polyethylene (PE), polypropylene (PP), polycarbonate (PC) in different thicknesses ranging from 2 to 10 mm are investigated. Laser power, cutting speed, type of focussing lens, pressure and flow of the covering gas, thickness of the samples are the process parameters examined. Kerf widths, melted transverse area, the melted volume with time and the surface roughness on the cutting edges were measured further. It was found that not always high cutting speeds are synonymous with good process efficiency. It was also concluded that the employment of powerful CO_2 laser is not necessary; sometimes a 100 watts power is enough. The Figure-5 shown below is the result for PE sheets.

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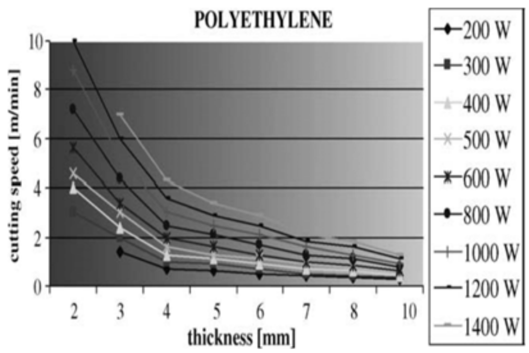

Figure-5. Cutting speed vs. thickness for different laser power levels.

C. Tool wear

Rajesh kumar Verma [8] mainly focused on the problems faced during machining of glass fibre reinforced polymers, the machining problems are mainly due to its isotropic nature and non-homogeneity of the material. It also highlights the glass fibre materials and reinforced polymers that can be used effectively. Fibre orientation with respect to cutting tool orientation and the forces developed during the cutting operation as shown in Figure-6 were analysed.

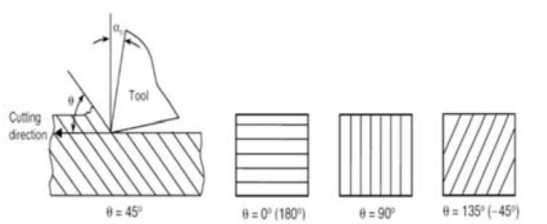

Figure-6. Fibre orientation angle w.r.t cutting direction.

As they are very hard, cutting can't be done with conventional tools, they require high strength tools such as PCD, diamond coated or carbide tools and also analysed the machining characteristic of GF/PP and GF/Polyester composites by comparing the thrust force on the thermo set composite and the thermoplastic composite. A conclusion has been arrived that thermoplastic composite experience lower order thrust force and temperatures prevailing over the cutting zone favours the formation of lubricating layer thereby minimizing the tool wear.

[16] Various research activities carried out in LBM process are provided. It includes the introduction to laser, its development, different LBM configurations and applications of LBM for different category of materials. Advanced machining processes (AMPs) are very important nowadays as the present day engineering materials require stringent design, intricate shape and are of unusual size. Laser have come into existence because of its properties like coherence, high power density and better focussing characteristics. CO2 and Nd: YAG lasers (as shown in fig.7) are most established lasers among various type of lasers used for machining in industries.

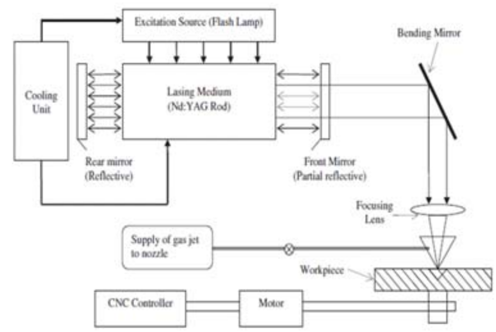

Figure-7. Schematic of Nd: YAG laser beam cutting system.

LBM is the most powerful machining method for cutting complex profiles and drilling holes in a wide range of work-piece materials. Apart from this LBM is also suitable for precise machining of micro-parts. The performance of LBM mainly depends on the laser parameters, material parameters and process parameters. Machining of thick materials and machining of micro-parts need considerable research work.

Characterization techniques

[17] Abrasive water-jet machining is a non-traditional machining process that offers a productive alternative to conventional techniques. An experimental study was conducted by them to know the influence of material properties on surface integrity and texture of the metal machined by abrasive water-jet. A power jet model 20-35 abrasive water jet was used for this study. The pressure pump and controlling unit are capable of generating water pressures up to 240MPa and a flow rate of2.50I min^{-1}. Profilometry, microscopy and hardness testing were used to inspect the quality of the machined surfaces. They have concluded that the extent of deformation depend on metals' strain hardening behaviour and the attack angle.

Paulo Davim *et al*. [18] presented a preliminary study to evaluate the effect of the processing parameters of CO_2 laser, which is widely used in the industrial applications, on the quality of the cut for several polymeric materials by evaluation of presence of burr and dimension of heat affected zone (HAZ). In all plastics, the HAZ increased with the laser power and decreased with the cutting velocity. Finally it was concluded that the laser cutting workability of PMMA is very high, followed by PC, PP and thermosetting plastics respectively.

George A. Gogotsi [19] studied the fracture toughness of zirconia, alumina, and silicon nitride ceramics, zirconia and alumina single crystals, silicon carbide as well as silicon nitride ceramic particulate composites, silicon nitride laminated composites, and other ceramics materials by a single edge V-notched beam (SEVNB) method. Later, SENB (single edge notched beam) and SEPB (single edge pre-cracked beam) as well as micro-Raman spectroscopy data were used to analyze the SEVPB results which showed that the ratio between

SEVNB and SENB results is about 0.6 for elastic materials, over 0.9 for inelastic ones, and about 1.0 for laminated ceramic composite. The test data confirm that the SEVNB method can be easily applied in practice and can be used for majority of advanced ceramics and ceramic particulate composites at different temperatures and even in the oxidation environment. Also it was proven that the SEVNB data for ceramics and ceramic particulate composites are independent of the flexure type and exhibit small scatter.

Structural integrity

Y. kong, J.N Hay [21] studies about the procedures adopted in the measurement of crystallinity of polymers and the degree of crystallinity of metallocene polyethylene (m-PE) and poly ethylene terephthalate (PET) are measured using DSC (Differential scanning calorimetry). The degree of crystallinity of a polymer is temperature dependent and it is determined and compared at certain fixed temperature and all readings that need to compare for different materials are done at same temperature. Various methods are available to determine the crystallinity of a polymer =namely wide angle X-ray diffraction (WAXD), density, differential scanning calorimetry (DSC), infrared (IR), Nuclear Raman spectroscopy (NMR) are used among all these, DSC is probably the widely used methods. DSC analysis is done on the basis of First Law method which is based on the application of first law of Thermodynamics. The crystallisation and melting of a polymer sample on heating in a calorimetry involves two steps, one determines the overall enthalpy changes on heating from T1 (temperature just above the glass transition temperature) to T2 (the temperature at which last trace of crystallinity is observed). The second is the virtual experiment of measuring enthalpy change on cooling from T2 to T1 without crystallisation. For a closed system the difference between these two steps is enthalpy fusion of the sample, enthalpy values are used at all stages for various paths. The first law method is valid and it measures the fractional crystallinity which compares favourably with that determined by other methods.

CONCLUSIONS

Mechanical properties of composites like toughness, strength and resistance to corrosion etc. made the composites to use in all fields effectively and almost can be used in all places at which metals are using now, but machining is necessary in order to turn them in to required shape. While machining problems like delamination etc. arises while machining using conventional methods like drilling, turning etc. Unconventional methods like laser cutting, WJM etc. can be used and those machining problems can be reduced to some extent and a lot study has to be done in the area of machining in order to use them effectively.

The interest for self-reinforcing composites has increased worldwide for a few years. The methods of hot compaction and co-extrusion are particularly investigated. The effects of processing parameters (processing temperature, pressure) are studied. The machining type and parameter were not discussed. The influence of machining and their comparative study on the mechanical properties were not studied using tensile test and flexural test. The influence of different range of temperatures on the polymer structure at molecular level was not studied. DSC and XRD were done but FTIR was not done.

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