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"An Experimental Study on the Influence of Cutting Parameters on Thrust Force" While Drilling on Different Materials

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Abstract:

in this thesis, the influence of cutting parameters in drilling of glass fiber reinforced composites mild steel and aluminum alloy. This paper presents a mathematical model for correlating the interactions of drilling parameters and their effects on thrust force and torque. The optimum value of cutting parameters is also determined to get minimum value of thrust force and torque. In this thesis, the diameter of drilling cutting tool is 12mm, 8mm.theoritical calculations are done to calculate thrust force and torque. The assembly of work piece and tool are modeled in Pro/Engineer. The input parameters considered are point angle 1180 and 1200, tool diameter, spindle speed, feed rate and materials. Different combinations of the above parameters are considered to get the minimum value of thrust force and torque. Structural analysis is done on the assembly to verify the stresses for different materials Mild Steel, Aluminum alloy and composite material E Glass Epoxy. Analysis is done in Ansys.

I.INTRODUCTION (HEADING 1):

The majority of the work pieces have holes, either through or blind holes. Drill holes serve all purposes, e.g. to take up rivets, screws, bolts, shafts, pistons and furthermore to pass through gases, fluids, etc. Besides by drilling and boring other methods can be used for making holes in work piece, e.g., by punching, perforating, enlarging with a drift, gas cutting, casting etc. However by none of this method the diameter of holes, centre to centre distances and the surface can be obtain as accurately as by drilling and boring. The drilling and boring, therefore, is very important operations in all kinds of metal working industries. Very often, drill holes are finish by refining procedures, such as reaming, grinding, and honing.

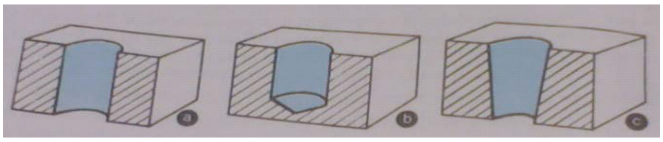

Figure 1
Fig.1 Various Holes
(a) Cylindrical through hole,
(b) Blind Hole,
(c) Tapered Hole

Movements while Drilling on the Drilling Machine:

The tool used for cutting holes in the solid materials is called Twist Drill. This is provided with two cutting edges in order that the cutting edge can cutoff chips, two movements required simultaneously. The rotary motion is called cutting motion. In special cases, this action is effected by rotating the work piece.The Drill is moved in a straight line towards the fixed work piece. This movement is called feed and it controls the thickness of the chips. The feed operations can also be effected by moving the fixed work piece towards the rotating drill, as it is done with some small bench types Drilling Machines where the table is raised. The feed is measured in mm/rev. as the drill is provided with two cutting edges, the thickness of the chip is half the feed. By the simultaneous double action to the cutting or main motion and the feed, each cutting edge of the drill describes a spiral and thereby produces a constant flow of chips.

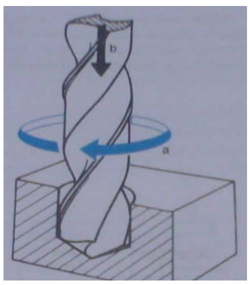

Figure 2 Drilling actions on drill machine

a) Cutting motion (b) feed motion

VARIOUS TYPES OF DRILLING MACHINES:

Drilling machines are made in many different types and sizes, each designed to handle a class of work or specific job to the best advantage. The different types of drilling machines are as follows.

PORTABLE DRILLING MACHINE :

As the name implies this type of drilling machine can be operated with ease anywhere in workshop and is used for drilling holes in work pieces in position which cannot be drilled in a standard drilling machine. Some of the portable machines are operated by hand power, but| most of the machines are driven by individual motor. The entire drilling mechanism including the motor is compact and small in size. The motor is, usually of universal type which may be driven by both A.C. and D.C. The maximum size of the drill that it can be used not more than 12 to 18 mm. The machine is operated at high speed as smaller size drills are only used. Some of the portable machines are driven by pneumatic power.

SENSITIVE DRILLING MACHINE :

The sensitive drilling machine is small machine designed for drilling small holes at high speed for light jobs; the base of the machine may be mounted on bench. It consists of vertical column, a horizontal table, a head supporting the motor and driving mechanism, and a vertical spindle for driving and rotating the drill. There is no arrangement for any automatic feed of the drill spindle. The drill is fed into the work by purely hand control by showing the figure3.

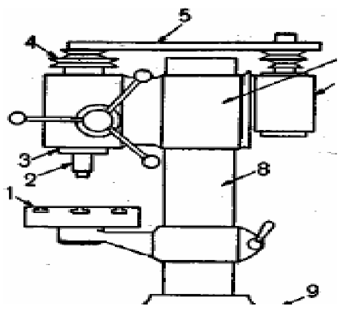

Figure 3

UPRIGHT DRILLING MACHINE :

The upright drilling machine used for handling medium sized work pieces. In construction the machine is very similar to a sensitive drilling machine for having a vertical column mounted upon the base. But this is larger and heavier than a sensitive drill and is supplied with power feed arrangement. In an upright drilling machine a large number of spindle speeds and feeds may be available for drilling different types of work.

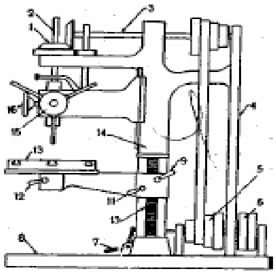

Figure 4.

Round column section or pillar drilling machine:

The arm and the table have three adjustments for locating work pieces under the spindle. The arm and the table may be moved up and down on the column for accommodating work pieces of different heights.This permits setting of the work below the spindle.

Moreover, heavy and odd size work may be supported directly on the base of the machine and drilled after the arm is swung out of the way. The table may be rotated 360°about its own centre independent of the position of the arm for locating work pieces under the spindle.

Box column section upright drilling machine:

The upright drilling machine with box column section has the square table fitted on the slides at the front face of the machine column. Heavy box column gives the machine strength and rigidity.

The table is raised or lowered by an elevating screw that gives additional support to the table. These special features permit the machine to work with heavier work pieces, and holes more than 50 mm in diameter can be drilled by it.

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RADIAL DRILLING MACHINE:

The radial drilling machine is intended for drilling medium to large and heavy work pieces. The machine consists of a heavy, round, vertical column mounted on a large base. The column supports a radial arm which can be raised and lowered to accommodate work pieces of different heights. The arm may be swung around to any position over the work bed. The drill head containing mechanism for rotating and feeding the drill is mounted on a radial arm and can be moved horizontally on the guide-ways and clamped at any desired position. These three movements in a radial drilling machine when combined together permit the drill to be located at any desired point on a large work piece for drilling the hole.

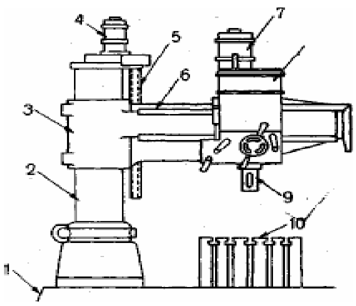

Fig. Radial drilling machine

Figure 6

GANG DRILLING MACHINE:

When a number of single spindle drilling machine columns are placed side by side on common base and worktable, the machine is known as the gang drilling machine. In a gang drilling machine four to six spindles may be mounted side by side. In some machines the drill spindles are permanently spaced on the work table, and in others the position of the columns may be adjusted so that the space between the spindles may be varied. The speed and feed of the spindles are controlled independently. This type of machine is specially adapted for production work.

MULTIPLE SPINDLES DRILLING MACHINE:

The function of a multiple spindle drilling machine is to drill a number of holes in a piece of work simultaneously and to reproduce the same pattern of holes in a number of identical pieces in a mass production work. Feeding motion is usually obtained by raising the work table.

AUTOMATIC DRILLING MACHINE:

Automatic machine can" perform a series of machining operations at successive units and transfer the work from one unit to the other automatically.Once the work is loaded at the first machine, the work will move from one machine to the other where different operations can be performed and the finished work comes out from the last unit without any manual handling. This type of machine is intended purely for production purposes and may be used for milling, honing and similar operations in addition to drilling and tapping.

DEEP HOLE DRILLING MACHINE:

Special machines and drills are required for drilling deep holes in rifle barrels, crank shafts, long shafts, etc. The machine is operated at high speed and low feed. Sufficient quantity of lubricant is pumped to the cutting points for removal of chips and cooling the cutting edges of the drill. A long job is usually supported at several points to prevent any deflection. In some machines step feed is applied

DRILLING MACHINE OPERATIONS:

- Drilling
- Reaming
- Boring
- Counter boring
- Counter sinking.
- Spot facing.
- Tapping.
- Lapping.
- Grinding.
- Trepanning

DRILLING:

Drilling is the operation of producing cylindrical hole by removing metal by the rotating edge of a cutting tool called the drill. The drilling is the method for producing a hole. Before drilling the centre of the hole is located on the work piece by drawing two lines at right angles

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to each other and then a centre punch is used to produce an indentation at the centre. A 12 mm drill may produce a hole as much as 0.125 mm oversize and a 22 mm drill may produce one as much as 0.5 mm oversize as shown in figure 7.

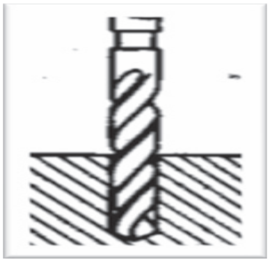

Figure 7

REAMING:

Reaming shown in Fig.8 is an accurate way of sizing and finishing a hole which has been previously drilled. In order to finish a hole and to, bring it to the accurate size, the hole is drilled slightly undersize. The speed of the spindle is made half that of drilling and automatic feed may be employed. The tool used for reaming is known as the reamer which has multiple cutting edges. Reamer cannot originate a hole.

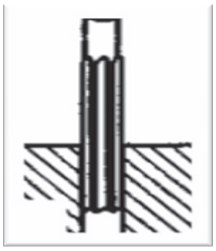

Figure 8

BORING:

Boring illustrated in Fig.9 is performed in a drilling machine for reasons stated below:

1. To finish a hole accurately and to bring it to the required size.

2. To machine the internal surface of a hole already produced in casting.

3. to correct out of roundness of the hole.

4. To correct the location of the hole as the boring tool follows an independent path with respect to the hole.

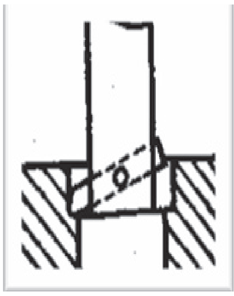

Figure 9

The cutter is held in a boring bar with taper shank to fit into the spindle socket. For perfect finishing a hole, the job is drilled slightly undersize. In precision machines, the accuracy is as high as ± 0.00125 mm. It is a slow process than reaming and requires several passes of the tool.

COUNTER BORING:

Counter boring shown in Fig.10 is the operation of enlarging the end of a hole cylindrically. The enlarged hole forms a square shoulder with the original hole. This is necessary in some cases to accommodate the heads of bolts, studs and pins. The cutting edges may have straight or spiral teeth. The pilot fits into the small diameter hole having running clearance and maintains the alignment of the tool. These pilots may be interchanged for enlarging different size of holes.

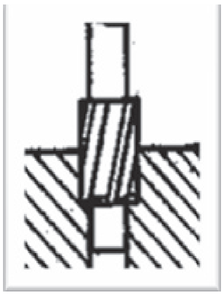

Figure 10

COUNTERSINKING:

Countersinking is the operation of making a cone-shaped enlargement of the end of a hole to provide a recess for a flat head screw or countersunk rivet fitted into the hole. The tool used for countersinking is called a countersink. Standard countersinks have 60°, 82° or 90° included angle and the cutting edges of the tool are formed at the conical surface is shown in figure 11.

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Figure 11

SPOT FACING:

Spot facing shown in Fig.12 is the operation of smoothing and squaring the surface around a hole for the seat for a nut or the head of a screw. A counter bore or a special spot facing tool may be employed for this purpose.

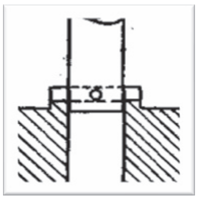

Figure 12

TAPPING:

Tapping shown in Fig.13 is the operation of cutting internal threads by means of a cutting tool called a tap. A tap may be considered as a bolt with accurate threads cut on it. The threads act as cutting edges which are hardened and ground. When the tap is screwed into the hole it removes metal and cuts internal threads which will fit into external threads of the same size.

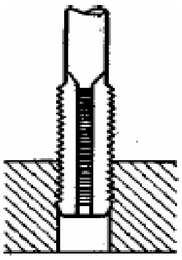

Figure 13

LAPPING:

Lapping is the operation of sizing and finishing a small diameter hole already hardened by removing a very small amount of material by using a lap. There are many kinds of lapping tools. The copper head laps are commonly used. The lap fits in the hole and is moved up and down while it revolves.

GRINDING:

Grinding operation may be performed in a drilling machine to finish a hardened hole. The grinding wheel is made to revolve with the spindle and is fed up and down. A suitable grinding wheel may be selected for surface grinding operation. Grinding can also be done to correct out of roundness of the hole. The accuracy in grinding operation is quite high about ±0.0025 mm.

TREPANNING:

Trepanning is the operation of producing a hole by removing of metal along the circumference of a hollow cutting tool. Fewer chips are removed and much of the material is saved while the hole is produced. The tool may be operated at higher speeds as the variation in diameter of the tool is limited by the narrow cutting edge. The tool resembles a hollow tube having cutting edges at one end and a solid shank at the other to fit into the drill spindle. This is one of the efficient methods of producing a hole is shown in figure 14.

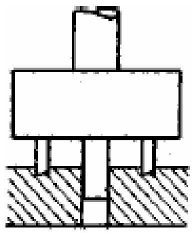

Figure 14

INTRODUCTION TO COMPOSITES:

A COMPOSITE MATERIAL is described in this chapter as a material composed of two or more distinct phases and the interfaces between them. At a macroscopic scale, the phases are indistinguishable, but at some microscopic scales, the phases are clearly separate, and each phase exhibits the characteristics of the pure material.

This special class of composites always consists of are in forcing phase and a matrix phase. There in forcing phase is typically a graphite, glass, ceramic, or polymer fiber, and the matrix is typically a polymer, but may also be ceramic or metal.

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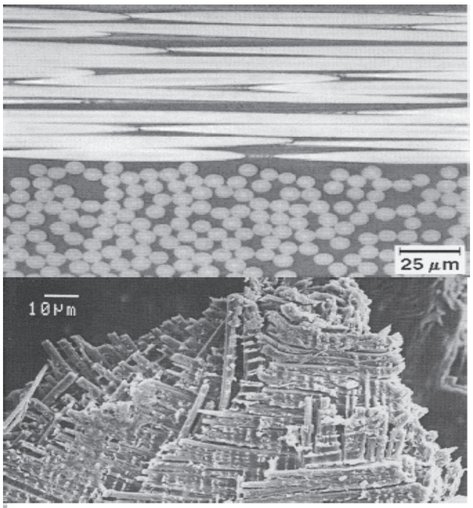

FIGURE 15 :Cross section of a graphite fiber–reinforced epoxy polymer.

CHARACTERISTICS:

Many materials can be classified as composites. They are composed of several distinctly different and microscopically identify substances. Composites are widely used in many industries and applications today, driven by the need for strong, lightweight materials. The composites reduce weight and allow for designs that tailor the mechanical properties of the material to meet the loading requirements of the structure. In addition, composites are replacing traditional engineering materials in many industrial, recreational, architectural, transportation, and infrastructure applications.Composites occur very commonly in nature. Some of the best examples are wood, bone, various minerals, mollusk shells, and insect exoskeletons. In wood, the cellulose fibers of the cell wall are “glued” together by the lignin matrix

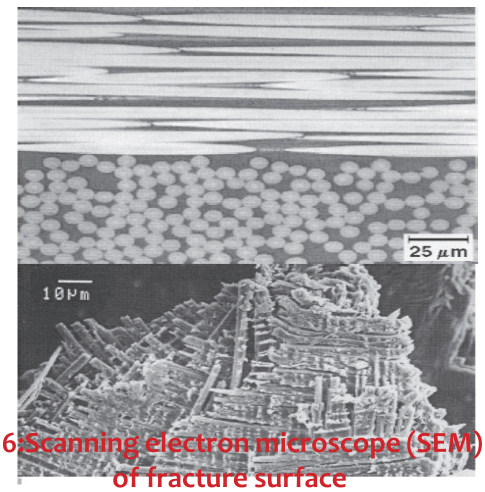

FIGURE 16:Scanning electron microscope (SEM) image of fracture surface

E-glass offers excellent strength, compatibility with common matrix polymers, and is very low in cost. Various types of graphite fibers are commonly used in aerospace and the recreational products industry, where light weight and maximum material performance are very important to the designer. The matrix binds the reinforcement together and enhances the distribution of the applied load within the composite. Polymeric materials are widely used as matrix materials. Two general classes of polymers are used: thermosets and thermoplastics. Thermosets are initially low molecular weight molecules that are often viscous liquids at room temperature, what we commonly think of as “resins.” Their low viscosity and fluid behavior make them very suitable to low-cost processing. The thermo set resins undergo chemical reactions when heated (or initiated by some other energy source such as UV light, electron beam, or microwave) and form a high molecular weight cross-linked polymer is shown in the figure 16.

CONSTITUENT MATERIALS:

A composite can contain several chemical substances. There are additives, for example, to improve process ability and serviceability. However, the two principal constituents that are always present in advanced composites are the matrix and the reinforcement. Generally, they are combined without chemical reaction and form separate and distinct phases. Ideally, the reinforcement is uniformly distributed throughout the matrix phase. The combination of the properties of the reinforcement, the form of the reinforcement, the amount of reinforcement, and matrix properties gives the composite its characteristic properties. Table I shows typical values of selected properties of common matrix materials. The properties are tensile strength, F, Young’s modulus, Et, total strain (or strain-to-failure), εt , coefficient of thermal expansion, α, and specific gravity.

TABLE I Matrix Materials

Property	Epoxy	Polyimide	Polyester	Polysulfone	Polyether ether ketone	Al 2024	Ti 6-4
E^{tu} (MPa)	6.2–103	90	21–69	69	69	414	924
E^{t} (GPa)	2.8–3.4	2.8	3.4–5.6	2.8	3.6	72	110
ε^{t} (%)	4.5	7–9	0.5–5.0	50–100	2.0	10	8
α (10^{-6} m m^{-1} K^{-1})	0.56	0.51	0.4–0.7	0.56	0.5	24	9.6
Specific gravity	1.20	1.43	1.1–1.4	1.24	1.2	2.77	4.43

After fabrication, fibers are processed with surface treatments for protection during handling and weaving and also for chemical compatibility with the matrix systems.

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After forming and treating, the filaments are typically wound on spools for use by manufacturers in fabricating composites, producing unidirectional preforms, or weaving into various geometries of textile preforms. Table II lists the properties of some of the fibers, measured in the longitudinal direction (along the axis of the fiber), used in composite materials: tensile strength Ftu, ,Young 's modulus Et, coefficient of expansion α, strain-to-failure εt , diameter, and density ρ. Mechanical properties transverse to the longitudinal axis are not shown. Because of the small diameter of the fibers, transverse properties are not measured directly. Variations in the fiber properties can be caused by several factors. There can be variations in the composition of the starting material such as in E-, S-, and C-glass fibers. There can be variations in processing such as in the way the processing temperature is changed to vary the strength and modulus of graphite fibers. Also, the difficulty of performing mechanical testing on fibers contributes to uncertainty and scatter in the measured properties of fibers.

TABLE II Fiber Materials

Property	Boron	Carbon	Graphite	Aramid	Alumina	Silicon carbide	E-glass	S-glass
E^{tu} (MPa)	2.8–3.4	0.4–2.1	0.81–3.6	2.8	1.4	3.3	3.4	4.6
E^{t} (GPa)	379–414	241–517	34–552	124	345–379	427	69	83
α (10^{-6} m m^{-1} K^{-1})	4.9	−0.09	−0.09	−4.0	3.4	.40	5.1	3.4
ρ (g cm^{-3})	2.5–3.3	1.55	1.55	1.60	3.90	3.07	2.55	2.5
Diameter (10^{-3} m)	0.05–0.2	0.008	0.008	0.013	0.38–0.64	0.14	0.005–0.013	0.009–0.010
ε^{t} (%)	0.67	1.0–2.0	0.4–2.0	2.5	0.4	0.6	4.8	5.4

The reinforcement is the main load-bearing phase of the composite. It provides strength and stiffness. There is a direct relationship between an increase in volume fraction of reinforcement and an increase in strength and stiffness of the composite material. This relationship depends on the assumption of compatibility with the matrix and on the existence of good bonding to the fibers. The reinforcement and matrix are combined either be-fore or at the time of fabrication of the composite. This depends on the fabrication process. A common practice in making continuous-fiber-reinforced laminates is to combine the constituents before fabrication into a continuous "tape like" preform that is used much like broad goods in that shapes are cut out of the preform and fabricated into parts. To produce this preform product, fibers are combined with resin, typically by drawing the fiber bundle through a resin or resin solution bath. Several bundles of resin-impregnated fibers are then aligned and spread in to very thin layers (0.127 mm thick) on a release ply backing.

The resin is usually partially cured during production of the preform to reduce its "tackiness" and improve the handle ability of the preform. This tape like preform is known as prepreg, or unidirectional tape. It is an expensive method for producing a preform, but the preform is a continuous, well-characterized, well-controlled method to combine the matrix resin and the reinforcing fiber.

III. PROPERTIES OF COMPOSITES:

In many of the applications in which composite materials are used, they can be considered to be constructed of several layers stacked on top of one another. These layers or laminate typically exhibit properties similar to those of orthotropic materials. Orthotropic materials have three mutually perpendicular planes of material property symmetry. A lamina with its coordinate system and two of the planes of symmetry.is shown in the figure17. The lamina is made of one thickness of reinforcement embedded in the matrix. The elastic and strength properties of the reinforcement and the elastic and strength properties of the matrix combine to give the lamina its properties. The reinforcement provides the strength and stiffness of the composite. Increasing the amount of reinforcement increases the strength and stiffness of the composite in the direction parallel to the reinforcement.

The effect of the form of the reinforcement is not as simple. However, some general observations can be made. Lamina reinforced by long, continuous parallel fibers has greater strength and stiffness than lamina reinforced by short, randomly oriented fibers. Woven fiber reinforced lamina usually have greater strength perpendicular to the principal fiber direction than do unwoven fiber reinforced lamina. The strength and stiffness of lamina reinforced by unwoven continuous fibers decrease as the angle of loading changes from parallel to the fibers to perpendicular to the fibers. values for some properties of composite materials made of unwoven continuous fiber reinforcements. The table shows the strength and elastic properties of a laminate made of several lamina stacked on top of one another with all the fibers aligned in the same direction. The properties in the direction parallel to the fibers are much greater than the properties in the direction perpendicular to the fibers. This variation of properties with the orientation of the lamina axis is called anisotropy.

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The single lamina serves as a building block. The engineer can select the orientation and number of each of the lamina in a laminate and design the laminate such that it has the required response. This designing of a laminate has some interesting implications that the engineer should understand. Balance in a laminate means that for each lamina with a positive angle of orientation there must be a lamina with an equal negative angle of orientation. Both lamina must have the same mechanical and physical characteristics is shown in figure 18.

Figure 17

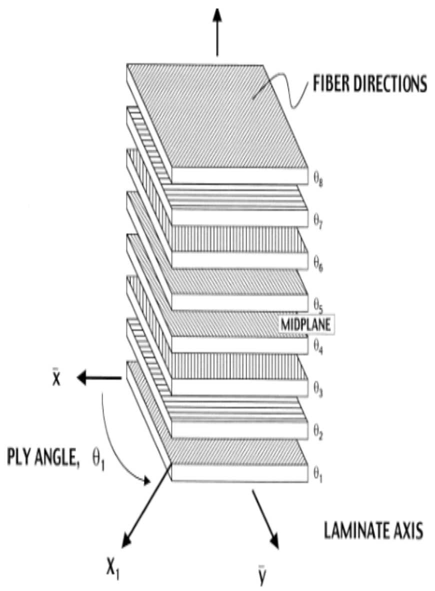

FIGURE 4 Orientation and location of laminae in a laminate.

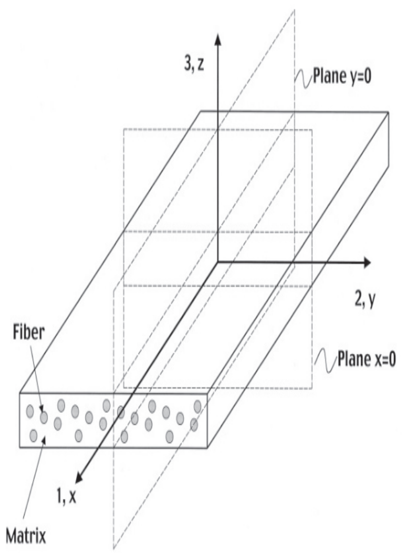

Figure 18

INTRODUCTION TO E – GLASS EPOXY:

E-glass is a popular fiber made primarily of silica oxide, along with oxides of aluminum, boron, calcium and other compounds. Named for its good electrical resistance, E-glass is strong yet low in cost, and accounts for over 90% of all glass fiber reinforcements, especially in aircraft radomes, antennae and applications where radio-signal transparency is desired. E-glass is also used extensively in computer circuit boards where stiffness and electrical resistance are requiredis shown in figure 19.

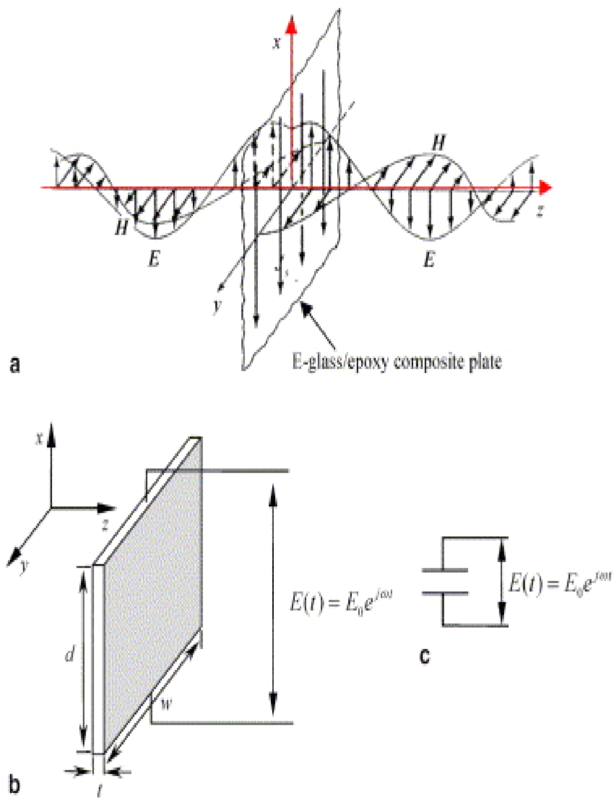

FIGURE 19

BACKGROUND:

E-Glass or electrical grade glass was originally developed for standoff insulators for electrical wiring. It was later found to have excellent fiber forming capabilities and is now used almost exclusively as the reinforcing phase in the material commonly known as fiberglass.

FIBRE MANUFACTURE:

Glass fibers are generally produced using melt spinning techniques.

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These involve melting the glass composition into a platinum crown which has small holes for the molten glass to flow. Continuous fibers can be drawn out through the holes and wound onto spindles, while short fibers may be produced by spinning the crown, which forces molten glass out through the holes centrifugally. Fibres are cut to length using mechanical means or air jets.

COMPOSITION:

E-Glass is a low alkali glass with a typical nominal composition of SiO2 54wt%, Al2O3 14wt%, CaO+MgO 22wt%, B2O3 10wt% and Na2O+K2O less then 2wt%. Some other materials may also be present at impurity levels.

KEY PROPERTIES:

Properties that have made E-glass so popular in fiberglass and other glass fiber reinforced composite include:

- Low cost
- High production rates
- High strength, (see table 1)
- High stiffness
- Relatively low density
- Non-flammable
- Resistant to heat
- Good chemical resistance
- Relatively insensitive to moisture

PROPERTIES OF E GLASS EPOXY:

Physical Properties Metric

Density 1.90 g/cc

Mechanical Properties Metric

Tensile Strength at Break 490 MPa
Compressive Strength 300 MPa

Thermal Properties Metric

Linear 11.0 µm/m-°C
Maximum Service Temperature, Air 130 - 150 °C

THE ADVANTAGEOUS PROPERTIES OF E-GLASS GENERALLY OUTWEIGH THE DISADVANTAGES WHICH INCLUDE:

- Low modulus
- Self abrasiveness if not treated appropriately leading to reduced strength
- Relatively low fatigue resistance
- Higher density compared to carbon and organic fibers.

APPLICATIONS:

The use of E-Glass as the reinforcement material in polymer matrix composites is extremely common. Optimal strength properties are gained when straight, continuous fibres are aligned parallel in a single direction. To promote strength in other directions, laminate structures can be constructed, with continuous fibers aligned in other directions. Such structures are used in storage tanks and the like.Random direction mats and woven fabrics are also commonly used for the production of composite panels, surfboards and other similar devices.

RESULTS TABLE:

ALUMINUM WITH TIP ANGLE 1180

	SPEED 1500 RPM		SPEED 3200 RPM	
	8 mm	12 mm	8 mm	12 mm
DISPLACEMENT (mm)	0.192e-6	0.384e-7	0.611e-7	0.224e-7
STRESS (N/mm²)	0.006993	0.007287	0.002232	0.004192

E-GLASS WITH TIP ANGLE 1180

	SPEED 1500 RPM		SPEED 3000 RPM	
	8 mm	12 mm	8 mm	12 mm
DISPLACEMENT (mm)	0.319e-6	0.428e-7	0.117e-6	0.245e-7
STRESS (N/mm²)	0.007418	0.008016	0.002715	0.004583

MILD STEEL WITH TIP ANGLE 1200

	SPEED 1000 RPM		SPEED 2500 RPM	
	8 mm	12 mm	8 mm	12 mm
DISPLACEMENT (mm)	0.242e-7	0.543e-7	0.139e-7	0.310e-7
STRESS (N/mm²)	0.007502	0.010249	0.004289	0.005859

ALUMINUM WITH TIP ANGLE 1200

	SPEED 1500 RPM		SPEED 3000 RPM	
	8 mm	12 mm	8 mm	12 mm
DISPLACEMENT (mm)	0.181e-7	0.407e-7	0.104e-7	0.232e-7
STRESS (N/mm²)	0.005616	0.007672	0.003209	0.004383

E-GLASS WITH TIP ANGLE 1200

	SPEED 1500 RPM		SPEED 3000 RPM	
	8 mm	12 mm	8 mm	12 mm
DISPLACEMENT (mm)	0.198e-6	0.444e-7	0.113e-6	0.254e-7
STRESS (N/mm²)	0.006139	0.008388	0.003508	0.004793

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CONCLUSION:

In this thesis the influence of cutting parameters, speed, point angle and feed rate on thrust force and torque for three materials E – Glass Epoxy, Mild steel and Aluminum alloy are done theoretically, analytically and experimentally. Two drill bits of different diameters 8mm and 12mm are considered.The thrust force depends on the speed, drill point angle and feed rate and decreases with the increase of point angle, speed but increases with the increase of diameter of drill bit. The torque also depends on the speed, drill point angle and feed rate and decreases with the increase of point angle, speed but increases with the increase of diameter of drill bit. From the analysis results, we can conclude that stress values are less for speed of 3000rpm, angle 1200 and drill bit diameter of 8mm.

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