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AN INVESTIGATION ON THE MECHANICAL PROPERTIES OF HYBRID POLYMER COMPOSITES FOR ENGINEERING APPLICATIONS

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Abstract:-There has been a tremendous advancement in the science and technology of the fiber reinforced polymer composites (FRP) in recent times. The low density, high strength to weight ratio, high stiffness to weight ratio, excellent durability, chemical resistant and corrosion resistant, good properties, high ultra-violet radiation stability, good electrical and thermal insulation , design flexibility of fiber reinforced polymers and cost effective manufacturing processes are the primary reasons for their use in many structural components in the aircrafts, automotive, marine, transportation, sports, medical science and more recently in the building and construction industries.

The FRP's presently used are reinforced by either carbon or glass or Kevlar fibers. As the field of application of these composites has widened, there is a demand for FRP composites with enhanced mechanical and tribological properties, besides corrosion resistance. This leads us to the idea of mixing two or more types of fibers in a epoxy resin to form a hybrid composite. In this work, carbon and glass fiber fabric reinforced epoxy laminates and the Kevlar and glass fiber fabric reinforced epoxy laminates were fabricated, by wet hand lay- up process and tested as per standard procedure.

The effect of post processing on the hybrid composite surfaces, namely Microwave radiation treatment has been investigated. The application of a simple microwave radiation and its effect on the densification of polymer composites and also their Mechanical properties were studied.

Key words: Carbon- Glass fibers fabric, Kevlar-Glass fibers fabric, Epoxy Matrix-Hybrid composites-Mechanical properties-flexural tests, drilling, delamination Post processing, Microwave radiation, densification.

1. INTRODUCTION

Enabled by the research of newer polymer matrix materials and high performance reinforcement fibers of Glass, Carbon and Kevlar, has witnessed a steady expansion in uses and volume of these advanced materials. The increased volume has resulted in an expected reduction in cost. High performance FRP composite can now be found in such diverse applications [1] as commercial aircrafts and space vehicles, the blades of the windmills, next generation of ships, for stealthier hull technologies, specifically those which create lower magnetic, lower acoustic, lower hydrodynamic, radar, and thermal signatures. Helmets for the Army, human body bone replacement, [2,3,4] armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, sports equipment's and even pressure vessels. For certain applications, the use of FRP composite rather than metals has in fact resulted in savings of both cost and weight. Careful selection of reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement. Armed witrh a wide range of advantages, FRP composites have a key role to play in the growing market in India. The most commonly used composite class for load-bearing structural applications is the continuous fiber-reinforced polymer-matrix composites. The most popular material systems have been the epoxy based resins reinforced with carbon, glass, or Kevlar fibers. As the demand for these reinforced polymer matrix composites with enhanced mechanical and tribological properties, corrosion resistance property has increased, mixing two or more types of fibers in a resin to form a hybrid composite was thought of. This leads to combining the advantages of the two individual fibers and nullifying their negative effects. One of the advantages of using hybrid composites is the flexibility in the choice, and the distribution of fibre reinforcements. The enormous potential of these hybrid composites and the infinite possibilities they offer of tailoring these composites for any desired application has generated the interest of researchers / materials engineers to investigate various combinations of hybrid composites so as to get the optimal combination for a particular application. This paper highlights the attempt at processing of few hybrid composites for different applications and presenting the results.

1.1 Automotive applications:

An important reason for use of composites in transportation applications is arguably to reduce weight in order to reduce fuel consumption or to increase payload. Composites also allow greater geometrical complexity than sheet metal, thus allowing a greater design freedom and more appealing aesthetics.

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1.2 Marine Applications:
Almost all leisure crafts, from the smallest dinghy to power boats and sailing yacht's have been manufactured from composites. The main reason for this is that composite boats are relatively inexpensive, fewer craftsmen skills are required than to work wood or metal. Start-up costs are generally very low. Even maintenance is required is less.

1.3 Aerospace Application:
Although aerospace applications are insignificant in terms of production volume, the field has been and still is vital to the development of composites because weight saved in a flying craft directly translates into increased load carrying capability or performance enhancement. In aerospace applications, composites may actually lower manufacturing cost due to the possibility of parts integration. Common aircraft composites include rudders, flaps, wing skins and substructures, leading edges, complete vertical and horizontal stabilizers, landing gear doors, access doors and large parts of cabin interior and cargo compartments etc.

1.4 Microwave Treatment:
A microwave oven works by passing non-ionizing microwave radiation, usually at a frequency of 2.45 gigahertz (GHz)—a wavelength of 122 millimeters (4.80 in)—through the material. Microwave radiation is between common radio and infrared frequencies. The material absorbs energy from the microwaves in a process called dielectric heating. Many molecules that may act as electric dipoles, i.e., they have a partial positive charge at one end and a partial negative charge at the other, and therefore rotate as they try to align themselves with the alternating electric field of the microwaves. This molecular movement represents heat which is then dispersed as the rotating molecules hit other molecules and put them into motion.
Microwave heating can cause localized thermal runaways in material with low thermal conductivity, where dielectric constant increases with temperature. Under certain conditions, glass can exhibit thermal runaway in a microwave to the point of melting.

1.5 Machinability:
Drilling is arguably the most common post-processing operation performed on FRP composites. The effect of various machining parameters i.e. cutting speed, the feed rate, and the drill diameter on the quality of the drilled holes produced after drilling of fiber reinforced plastic sheet have also been studied.

2. EXPERIMENTAL PROCEDURE FABRICATION OF COMPOSITE LAMINATES(FOR AUTOMOBILE & AEROSPACE)
Hybrid fibre reinforced materials can be made in two separate ways either by intimately mingling them in a common matrix, or by laminating alternate layers of each type of composite. In this work the latter technique has been used. The following considerations apply to this type of hybrid material. In principle several different types of fibbers can be incorporated into a hybrid system but in practice it is likely that a combination of only two types of fibres would be of most use [7].
Hand Lay-up. This is a manual approach in which layers of fabric and resin are successively applied onto a mold sheet. The fiber layers are oriented in such a way as to develop the desired strength and stiffness. The test materials were plain woven (0^0 - 90^0) carbon-glass fabric in epoxy resin matrix LY556 mixed with 10% hardener HY951. In the second case and plain woven (0^0 - 90^0) kevlar-glass fabric in epoxy resin matrix LY556 mixed with 10% hardener HY951. Each layer of fabric is placed, a roller is used on the composite so that a strong bond results and excess resin is squeezed out. The stacking of fabric materials and resin is done until the required thickness is achieved. 12 and 17 layers of alternate resin and reinforcement fabric were used to build up the thickness of 2.5mm and 3mm respectively. The composite panels were then allowed for polymerization to take place for 30 to 35 minutes. Then they were cured at room temperature for 24hrs. under a pressure of one atmosphere. The post curing was carried out at 100^0 C in a oven for 4hrs and then cooled to room temperature. Prior to testing, the composite plates were cut into specimens of appropriate dimensions as per ASTM standards.

2.1 Tensile test method:
The tensile tests were carried out in accordance with ASTM D30392, using a minimum of one specimen (dimensions: 250 mm of length x 25 mm of width x 2.5 - 3 mm of thickness) for each laminate. The specimens were prepared by bonding end-tabs of glass fibers/epoxy laminate [5]. The tensile tests were performed in an universal testing machine at constant cross-speed of approximately 2 mm/min at room temperature and results were obtained. The maximum tensile strength was calculated using the maximum load prior to failure and average cross sectional area.
Tensile Tests carried out for Automobile & Aerospace Applications

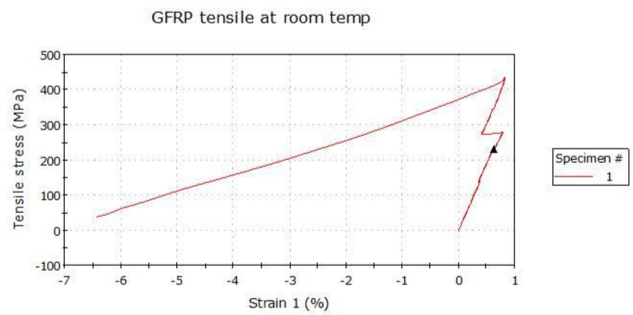

Fig.1:Kevlar-glass (Orientation, Kevlar fiber at 0o & glass fiber at 90o)

σy= 407.914 MPa

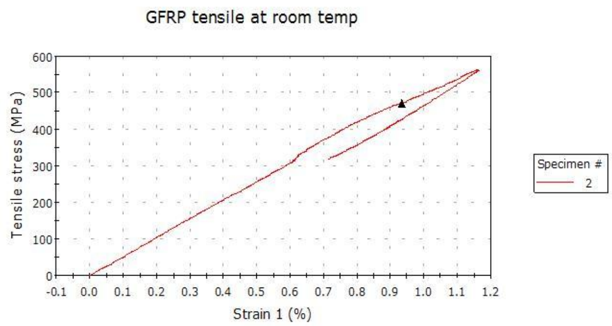

Fig.2: Carbn-glass (Orientation, Carbon fiber at 0o & glass fiber at 90o)

σy= 556.722 MPa

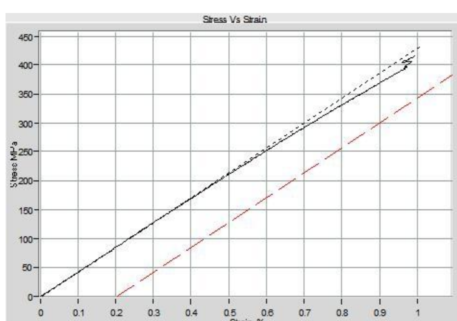

Fig. 3: Kevlar-glass (Orientation, Kevlar fiber at 90o & glass fiber at 0o)

σy= 415.86 MPa

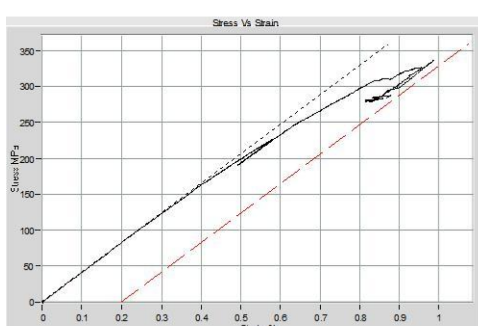

Fig.4: Carbn-glass (Orientation,Carbon fiber at 90o & glass fiber at 0o)

σy= 332.506 MPa

2.1.1. Results & Discusion:

From the graphs above it can be seen that the Carbon-glass-epoxy hybrid composite (2.5mm-3mm thick) has maximum strength when the carbon fibers are oriented in longitudinal direction where as Kevlar-glass-epoxy hybrid composite(2.5mm-

3mm thick) exhibit almost same strength when the Kevlar fibers are oriented in longitudinal as well as in transverse direction. Further it is also observed that as the thickness of the composites increases to 4mm and above, the tensile strength actually decreases.

2.2 Compression test method:

Compressive testing was carried out in accordance with procedure of the ASTM D16216 test standard using a minimum of one specimen (30mm x 20mm) on a universal testing machine. All specimens were loaded until failure using a constant crosshead speed of 0.5 mm/.min[6]. In addition to compressive stress, strain data was also collected for each composite configuration. Compression Tests carried out for Automobile & Aerospace Applications

Carbon-Glass-Epoxy

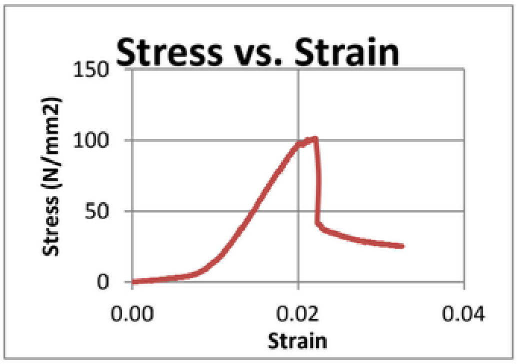

Fig.6

Maximum Load = 21.1345 kN
Compressive Strength = 105.6723 N/mm2
Thickness = 2.5mm

Carbon-Glass-Epoxy

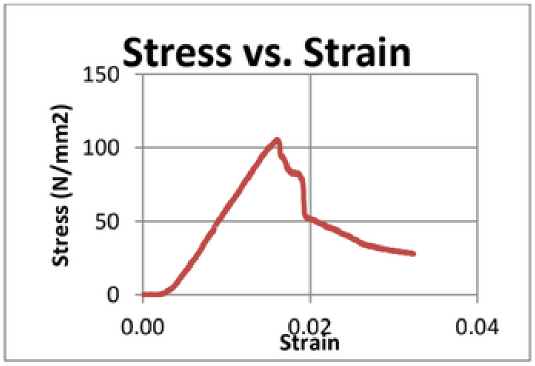

Fig. 7

Maximum Load = 22.5035 kN
Compressive Strength = 112.5173 N/mm2
Thickness = 3mm

Kevlar-Glass-Epoxy

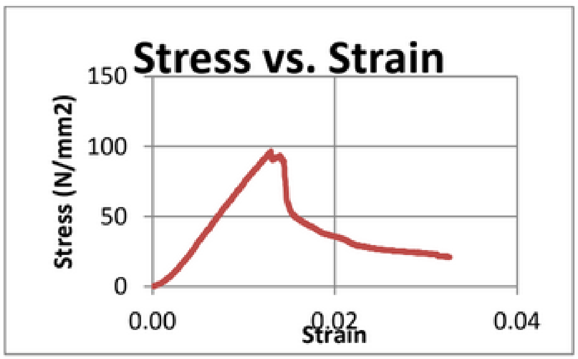

Fig.8

Maximum Load = 17.8870 kN
Compressive Strength = 96.6867 N/mm2
Thickness = 2.5mm

Kevlar-Glass-Epoxy

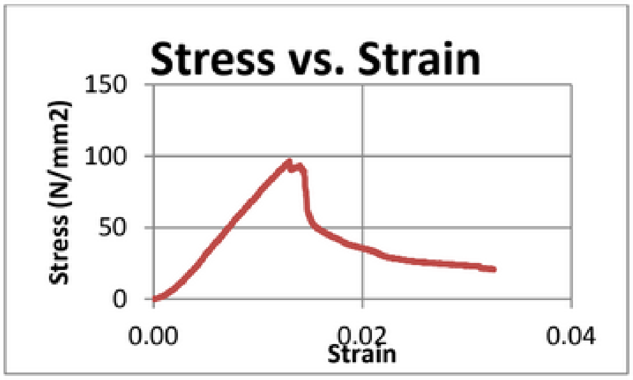

Fig.9

Maximum Load = 17.9264 kN
Compressive Strength = 96.8995 N/mm2
Thickness = 3mm

2.2.1 Results & Discusion:
In both Carbon-glass-epoxy and Kevlar-glass-epoxy hybrid composites, it was found from the compression test conducted as per ASTM D1621 standard that the compressive stress increased with increase in thickness of the specimen.

2.3 Flexural test method:
Flexural Strength specimens were fabricated according to (ASTM-D790) standard which has a rectangular shape(10mm×135mm) [4]. Three-point flexural tests were performed to measure the flexural strength of the composites[14,15]. A span of 100 mm was used maintaining a cross head speed of 2 mm/min.

Flexural Tests carried out for Automobile & Aerospace Applications

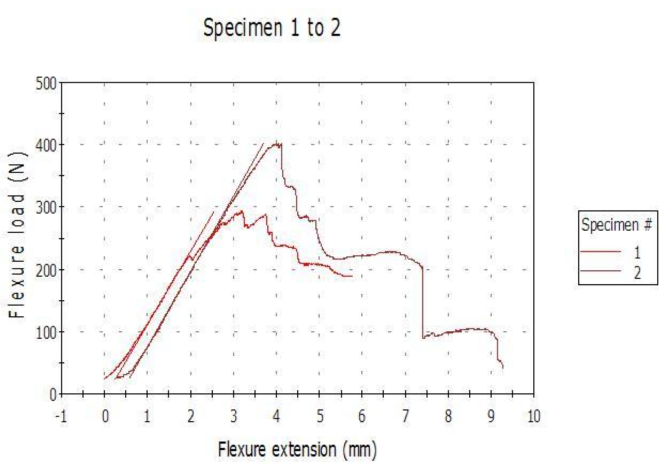

Fig.10 Carbon-glass-epoxy(carbon fiber longitudinal orientation 2.5mm & 3mm thick)

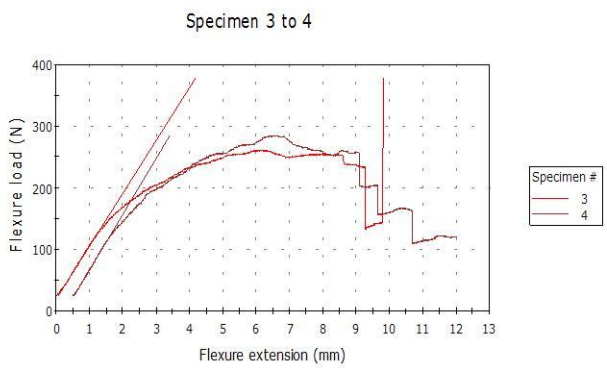

Fig.11 Kevlar -glass-epoxy(Kevlar fiber longitudinal orientation 2.5mm & 3mm thick)

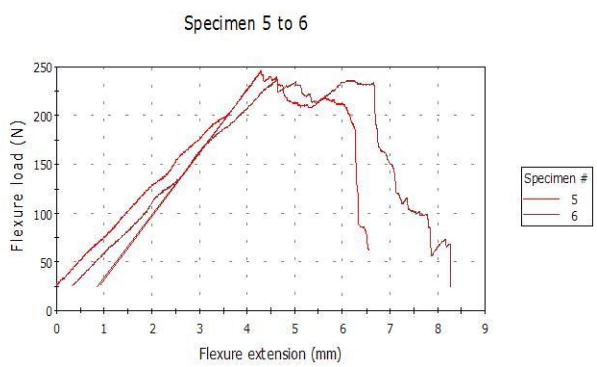

Fig.12 Kavlar-glass-epoxy(Kevlar fiber transverse orientation, 2.5mm & 3mm thick)

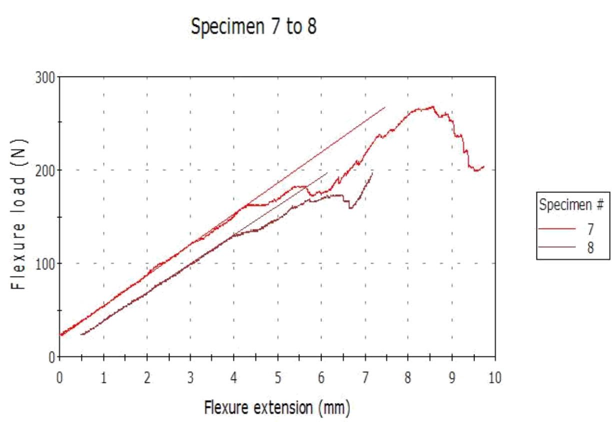

Fig.13 Carbon-glass-epoxy(carbon fiber transverse orientation, 2.5mm & 3mm thick)

2.31 Results & Discusion:

The above results show that the hybrid composites are stronger in flexural strength when the Carbon and Kevlar fibers are oriented longitudinally. Also their strength decreases with the thickness.

2.4 Impact test method:

Impact specimens fabricated according to the (ASTM-E23) standard suitable to Charpy Impact Instrument . A minimum of one specimen for each orientation of the reinforced fabric composite ,was tested[22].

Impact Test Results for Automobile & Aerospace Application:

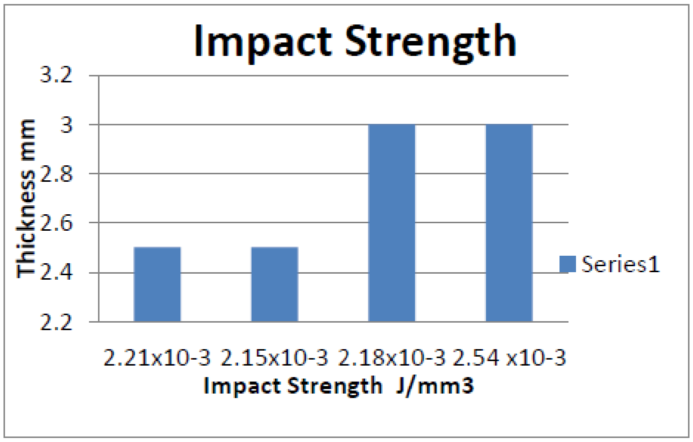

Fig.15

2.41 Results & Discusion:

It was observed that the impact strength is greater when the carbon and Kevlar fibers are oriented at 0^0 in the hybrid composites, also the impact strength increases with thickness.

2.5 Drilling:

Drilling is most commonly used machining processes in various industries such as automotive, aircraft and aerospace, dies/molds, home appliance Sports equipment, Medical and Electronic equipment industries. The quality of the drilled hole can be critical to the life of the joints for which the holes are used. In order to drill holes efficiently with the least waste and defects, it is essential to understand the machining behavior of FRPs. [7,8,9,10,11,12,17]. There is a huge effect of the machining parameters and tool conditions on the damage caused to the fiber reinforced composites, even the finish and mechanical properties are effected. The effects of variation of these machining parameters on drilling were analyzed.

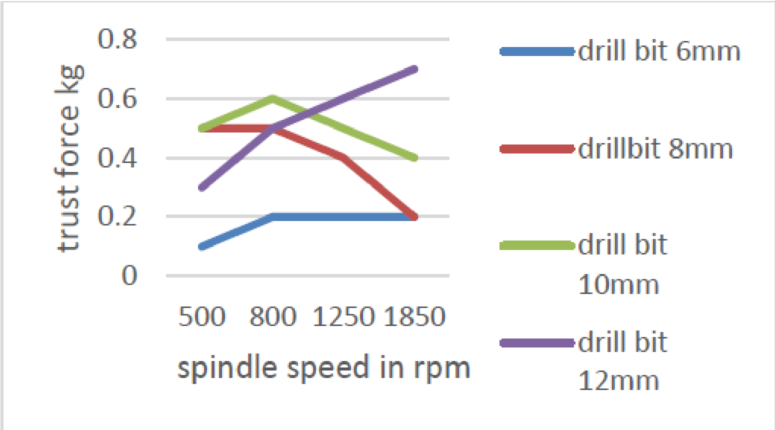

Fig.18:THRUST VS SPINDLE SPEED

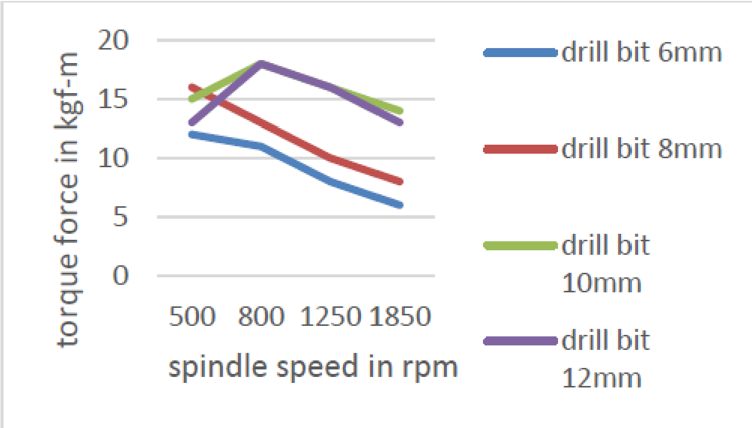

Fig.19:TORQUE VS SPINDLE SPEED

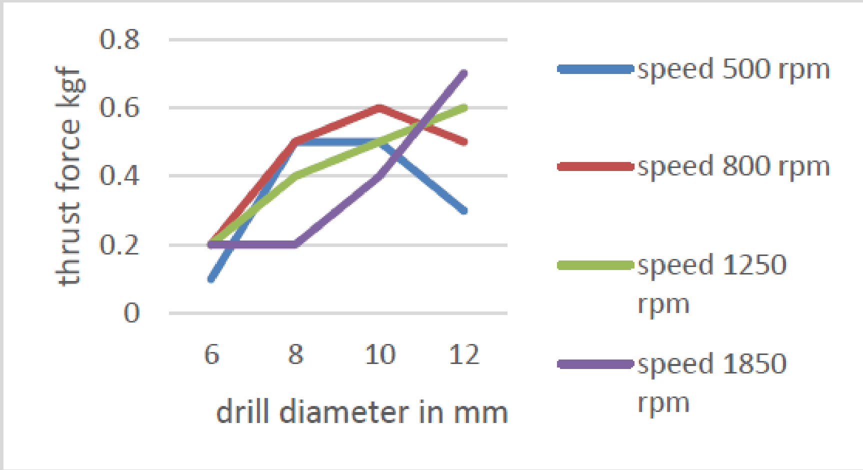

Fig.20: THRUST VS DRILL DIAMETER

2.51 Results & Discusion:

HSS drill bits of different diameter were used to drill hole in the specimens It is found that increasing drilling thrust force causes greater delamination and thus, greater edge defects and that the resultant hole is elliptical and not circular as intended.. It was also seen that the defects are minimum for low thrust force and slow speed of 500 rpm.

2.6 Microwave treatment :

Microwave heating is fundamentally different from the conventional one. [13,16,21]. In microwave, energy is delivered directly to the material through molecular interaction with the electromagnetic field. Microwave heating is the transfer of electromagnetic energy to thermal energy. This is energy conversion rather than heat transfer. Since microwaves can penetrate the material and supply energy, heat can be generated throughout the volume of the material resulting in volumetric heating. Hence, it is possible to achieve rapid and uniform heating of thick materials. Microwaves are electromagnetic waves with wavelengths varying from 1 mm to 1 m and corresponding frequencies between 300 MHz and GHz. frequencies of 0· 915 GHz and 2· 45 GHz. 2· 45 GHz is mostly used for household microwave ovens and 0· 915 GHz is preferred for industrial/commercial microwave ovens. Water is driven away from the interior section due to volumetric heating. Hence, this technology is commercially utilized for post processing of hybrid polymer matrix composites. This kind of heating permits efficient and faster drying of the hybrid polymer matrix composites.

This results in the densification of the composite as can be seen from fig.21.

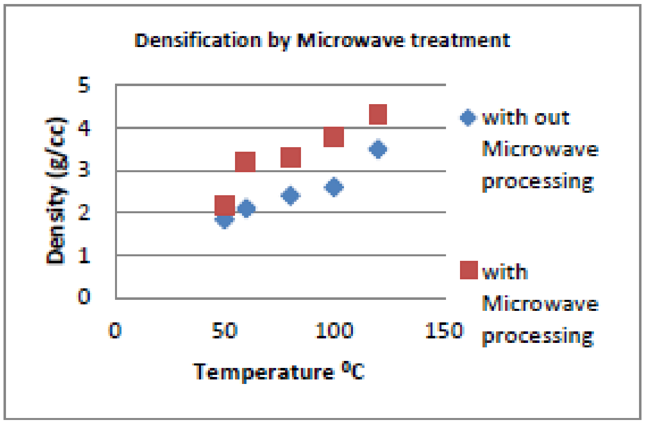

Fig.21

3. CONCLUSIONS:

The following conclusions are made based on the test results conducted on the hybrid polymer matrix composites. The test results found on the combination of hybrid fibers (glass & carbon, glass & Kevlar with matrix epoxy) with different orientation showed better results of mechanical and other properties in general. Based on the results obtained, an inference is also made that the given combination of fibers exhibit enhanced mechanical properties not only in the longitudinal direction but also in transverse direction too. This opens up the field of choice of material and application for the designer, particularly while designing components subjected to both longitudinal and transverse loading, namely pressure vessels.

1. The test results found on the combination of hybrid fibers (glass & carbon, glass & Kevlar with matrix epoxy) with different orientation showed better results of mechanical and other properties in general.

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3.The effect of post processing by microwave radiation treatment on the hybrid composite surfaces has also been , investigated. A significant increase in densification and increased adhesion in hybrid composite was noticed.

4. As drilling operation which is frequently performed on composite materials, the effect of various machining parameters on the quality of the holes drilled was also studied. The relative imperfections around the hole increases with the thrust force, relative imperfections also increases with decreasing hole radii, implying that the absolute imperfections will increase even more rapidly with increasing hole radii. It is seen that at critical delaminating thrust force, no defects will occur.

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