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Experimental Investigation of Polymer Matrix for Heat Distortion Temperature Test

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Abstract: In this research, the investigation aimed to develop polymer matrix composite with polyester and vinyl ester better heat resistance. The glass fiber with polyester preferred with different composition of composite with addition of different fillers in different weight fractions was fabricated. fabricated using vacuum bag molding technique. The mechanical properties were evaluated using Universal testing machine and The heat distortion temperature is the temperature at which a polymer or plastic sample deforms under a specified load. This property of a given plastic material is applied in many aspects of apparatus with different loads. Better mechanical properties and wear properties were obtained with increase in weight percentage of secondary reinforcement content. The Heat Distortion Temperature is determined by the test procedure outlined in ASTM D648.Further it was found that The proportion 40:60 and 20:80 does not formed as perfect IPN hence it is found that 80% vinyl ester and 20%poyurethane have good elasticity and toughness in comparison with other propoportions.
Keywords : Polymer matrix composite, polyester, vinyl ester flexural test, Heat distortion.

I. Introduction

The fiber reinforced polymer composites are the most rapidly growing class of materials, due to their good combination of high specific strength and modulus. They are widely used in variety of engineering and automobile applications. In recent years, there have been rapid growth in the development and application of fiber reinforced thermosetting polymer composites such as epoxy, polyester and vinyl ester. This is due to the realization of their good strength, low density and high performance to cost ratio with rapid clean processing. In recent times, there has been a remarkable growth in the large-scale production of fiber and/or filler reinforced epoxy matrix composites. Because of their high strength-to- weight and stiffness-to-weight ratios, they are extensively used for a wide variety of structural applications as in aerospace, automotive and chemical industries. On account of their good combination of properties, fiber reinforced polymer composites (FRPCs) are used for producing a number of mechanical components such as gears, cams, wheels, brakes, clutches, bearings and seals [1]. Most of these are subjected to tribiological loading conditions. Various researchers have studied the tribiological behavior of FRPCs. Studies have been conducted with various shapes, sizes, types and compositions of fibers in a number of matrices. Many investigations have been done on wear properties on polymer composites. B. Suresha et al (2010) studied the tribiological properties of vinyl ester based composites with two different fibers such as carbon and glass fibers. They conclude that friction and wear characteristics of bidirectional fabric reinforced vinyl ester composites depends on the fabric materials. Carbon-vinyl ester composites showed lower friction under different loads /sliding velocities and hence may be suitable for bearing applications. The wear resistance is improved with addition of carbon fiber in vinyl ester than glass fiber.In recent years, many researches have been devoted to explore the potential advantage of thermoset matrix for composites applications [2]. G. Chandramohan et al (2008) studied the wear behavior of vinyl ester based composite with the addition of different fillers such as SiC, graphite and glass fiber. Wear volume increases with increase in abrading distance/loads for all samples. They conclude that SiC filled glass-vinyl ester composites showed better wear resistance and wear rate is higher in unfilled glass fiber reinforced vinyl ester

composites and graphite fillers are not very beneficial to the wear performance [3]. R. Prehn et al (2005) studied wear performances of polymer composites with different fillers. Epoxy resin with addition of fillers such as silicon carbide exhibits good wear properties which can be used for bearing applications [4]. Y.Z.Wan et al (2006) wear performances increased with addition of more percentage of fiber content in polymer composites. Carbon fiber has good tribiological and mechanical properties which increases the wear properties of the composites with specific wear rate and coefficient of friction gradually increases with increase in fiber volume content in composites [5]. B. Suresha et al (2009) investigated the dry sliding wear of carbon-epoxy with the addition of graphite fillers from 5 to 10%. They conclude that wear properties is improved with increase in graphite powder content in carbon-epoxy composites and further they conclude that 10% graphite carbon-epoxy exhibits high wear resistance compared to 5% and unfilled composites [6]. K.Gopala Krishna et al (2009) studied the friction and wear characteristics of polymer based composites with addition of steel powder and alumina powder. They conclude that addition of steel powder exhibits high wear rate compared to ceramic particles. Alumina is suitable for increasing wear performances. Polymer exhibits low friction coefficient compared to metals to their low interfacial adhesion energy. By reinforcing fillers such as metals, ceramics and fillers increase the strength and stiffness of the matrix [7]. H. Unal et al (2004) studied wear performances on PTFE composites with different fillers such as glass, carbon and bronze with different volume fractions. They conclude that addition of glass fiber, bronze and carbon fillers to PTFE were found effective in reducing the wear rate of the PTFE composites. Wear rates are little sensitive to test speed and large sensitivity to the applied loads particularly at high values [8]. Siddhartha et al (2012) studied the mechanical and tribiological properties of epoxy based composites with two different fiber forms bidirectional and chopped glass fiber. They conclude that bidirectional glass fiber exhibits good mechanical and tribiological properties compared to chopped fibers, because of bonding between the fibers and matrix [9]. Hui Zhang et al (2007) studied the influence of fiber length on tribiological properties and carbon fiber reinforced epoxy composites. They conclude that long carbon fibers exhibits better wear resistance than these with short carbon fibers in epoxy composites [10]. Osman Asi (2010) investigated the bearing strength of glass-epoxy composites with addition of $Al_2O_3$with different volume fractions. The increase of Al_2O_3particle loading in the matrix improved bearing strength of the composites. Further it is concluded that increase in Al_2O_3 more than 10% decreases the strength but remains above that of the unfilled glass reinforced epoxy composites [11]. B. Suresha et al (2006) investigated glass-epoxy with SiC as fillers. They conclude that silicon carbide filled glass-epoxy composites shows higher resistance to slide wear compared to plain glass-epoxy composites [12]. BekirSadik et al studied tribiological properties of polymer based journal bearing with different polymers such as PE, PA, POM, PTFE and Bakelite bearing. They conclude that higher wear resistance has been obtained in PA and POM bearings [13]. L. Wang et al (2000) compared conventional steel, silicon nitride material shown significant benefits in terms of rolling contact fatigue life and the lower density of the material greatly reduces the dynamic loading which can be used in high speed applications such as machine tool spindles and gas turbine engines.As a result of their sustained development and testing. It is expected that silicon nitride baking will be used in all types of applications [14]. Guang Shi et al (2003) investigated friction and wear of low nanometer silicon nitride filled epoxy composites. They conclude that incorporation of nano-Si_3N_4 particle into epoxy can significantly reduce frictional coefficient and wear rate of the latter under dry sliding wear conditions [15]. Siddhartha et al (2011) conclude that the addition of Titania in epoxy composites exhibits high wear resistance and better mechanical properties and Zhenyu et al (2008) carbon fiber reinforced polyphenlylene with TiO_2 as fillers .Sandhyatani Biswas et al (2009) investigated the wear performances on red mud filled glass-epoxy composites. They conclude that hardness is improved with increase in red mud content and mechanical properties such as tensile; shear impact strength is decreased with increase in red mud particle content in glass-epoxy composites [16.17,18,]. Fibers reinforced polymer composites are used for producing number of mechanical components such as gears, cams, wheels, brakes, clutches, bush bearing and seals. Considerable efforts are being made to extend the range of applications. In aircraft and space vehicles high reliability and relatively long life are required of all assemblies and elements, including bearings. With the advent of the space era very demanding bearing operating conditions such as high vacuum, extreme temperatures, large temperature differentials, long life (both wear and fatigue life, usually 10–15 years without maintenance) and low frictional power are quite common. Use of inorganic fillers dispersed in polymeric composites is increasing. Fillers not only reduce the cost of the composites, but also meet performance requirements, which could not have been achieved by using reinforcement and resin ingredients alone. Pushkar Venkatesh Kulkarni et al (2012) fabricated and testing PTFE based composite bearing material for turbine pump with addition of different fillers in PTFE composites. They conclude that bronze filled with PTFE composite bearing exhibits good wear resistance [19].

2. **Experimental Details**

2.1Resin preparation:

2.1.1Polyurethane resin:

To prepare polyurethane resin take ploy & isocyanine in equal ratio, Add ethanol to ploy in which ethanol must be 60% of polyol weight and stir. Add ethanol to isocyanate in which ethanol must be 60% of isocyanate weight and stir until the exothermic reaction is felt Now mix both in paper cup until the foam gets reduced to resin

Apply the resin for the surface before 10mintues

2.2 Vinyl ester resin:

- The vinyl ester resin is taken in a cup for required proportion
- Add promoter of 1.5% of vinyl ester weight
- Stir the mixture well

2.3 IPN Formation:

- The vinyl ester resin which is already taken by adding promoter is now mixed with polyurethane resin in required proportion
- Add accelerator of about 2% of total weight of resin and stir it well
- Add hardener of about 2% of total weight of resin and stir it well until it forms as a dense liquid
- This formed mixture is called as interpenetrating polymer network

2.4 Catalysts:

MEKP catalyst is standard methyl ethyl ketone peroxide used for the cure of unsaturated polyester resin at room temperature in combination with cobalt accelerator

Typical concentrations for MEKP catalyst run from 1to 3% by weight based on resin and for cobalt accelerator from 0.25% to 4% based on 1% metal content solution. MEKP is recommended for the curing of ortho and isophthalic, Bisphenol-A or vinyl ester resin at temperatures between 15 and 50^0C.

A faster reaction and shorter demold times can be obtained by the action of promoter such as dimethyl aniline to the resin.cobalt accelerator chemical present in some polyester resin systems that reacts with mekp catalyst to begin the hardening process. adding extra cobalt to pre accelerated systems can result in very quick gel cure times, caution is advised. not for epoxy resins.

2.5 Various proportion:

We have tried five different proportions of vinyl ester and polyurethane which are listed below,

1. Specimen1:100%vinyl ester
2. Specimen2:80% vinyl ester&20%polyurethane
3. Specimen3:60% vinyl ester&40%polyurethane
4. Specimen4:40% vinyl ester&60%polyurethane
5. Specimen5:20% vinyl ester&80%polyurethane

3. Fabrication Process

3.1. Sheet molding process:

Apply PVA (Poly vinyl alcohol) release wax on carrier film and leave to dry for an hour.
Then apply the resin on the carrier film with the help of brush evenly on the surface
Now place the glass fiber which we had cut for our required size on the carrier film
Smoosh it by rollers until the resin ooze out in to the glass fiber
Now apply the resin gently on the glass fiber

Since we need three millimeter thickness we have to put six layers of glass fibers.
Repeat the same procedure for the six layers of fibers
Now carefully place another carrier film on the top layer and make sure there is no air voids.
Now we have to cure the material.
Curing is nothing but drying the material at room temperature for allowing the material to set
Curing is done for about 24 hours.
After curing remove the carrier film on both sides of the specimen
Now wash the material with cold water in order to remove the releasing agent

3.2 Post curing

- The process of forming an uncured thermo set resins, then completing the curing after the article has been removed from its forming mold or mandrel.
- Additional elevated temperature cure usually without pressure to improve final properties or complete the cure.
- In certain resins, complete cure and ultimate mechanical properties are attained only by exposure of the cured resin to higher temperatures than those of curing.
- Post curing is done by keeping the material in hot air oven at 80^0C for two hours.
- Remove the material from the hot air oven with the help of gloves and allow it to cool in room temperature.
- Then cut the material according to required standard size.

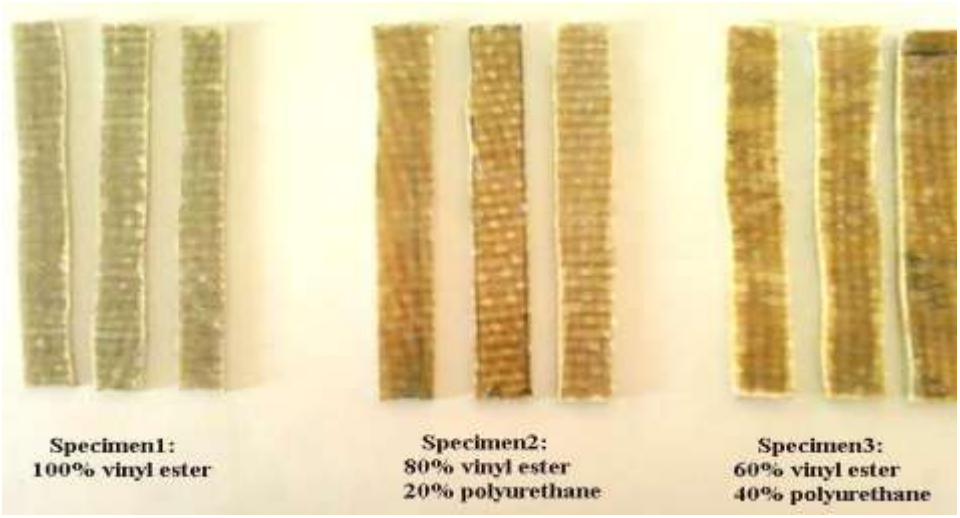


Figure 1 Standard Specimen modals

Heat Distortion Test on a Composite Material

3.3 Definition:

- The heat distortion temperature is the temperature at which a polymer or plastic sample deforms under a specified load.
- This property of a given plastic material is applied in many aspects of product design, engineering, and manufacture of products using components.

Figure 2.HDT

Methodology:

- The Heat Distortion Temperature is determined by the test procedure outlined in ASTM D648.
- The test specimen is loaded in three-point bending in the edgewise direction.
- The outer fiber stress used for testing is either 0.455 MPa and the temperature are increased at 2 °C/min until the specimen deflects 0.25 mm.

3.4 Need for HDT test:

- To analyse the hygrothermic effect **(**ie) change in properties due to moisture absorption and temperature change.
- Thermal simulations of a system will show temperatures that will be encountered by a specific component of that system. Knowing what temperature that a specific component will have to endure during use will allow the determination of the best material for that application.
- Example: One of two materials may be used for *Component A* of a system, ***acrylic or polycarbonate***. *Component A* will have to endure temperatures of 120 °C during use. Polycarbonate (HDT=140 °C) will not deform at 120 °C but acrylic (HDT=90 °C) would deform. Polycarbonate would be used for *Component A* in this case.

4. Experimental Setup:

4.1HDT Kit details:

The heat distortion kit consists of the following parts,

- Water bath
- Heating coil
- Gas Thermometer
- Digital temperature controller
- Dial indicator
- Load setup
- Lid

4.1.1 Water bath:

Water bath is a device which is used to maintain a constant temperature and also increase the temperature at uniform rate. **WE USE WATER BATH** because water retains heat so well, using water baths was one of the very first means of incubation.

Specification

Power	1200watts
Dimension	310* 250*150 in mm
Accuracy	$\pm 1^0$C
Range	2^0Cto 100^0C

4.1.2Heating coil:

A heating element converts electricity into heat through the process of Joule heating. Electric current through the element encounters resistance, resulting in heating of the element.

Most heating elements use Nichrome 80/20 (80% nickel, 20% chromium) wire, ribbon, or strip. Nichrome 80/20 is an ideal material, because it has relatively high resistance and forms an adherent layer of chromium oxide when it is heated for the first time. Material beneath the wire will not oxidize, preventing the wire from breaking or burning out.

4.1.3 Gas thermometer:

Gas thermometers simply work on the principle of volumetric thermal expansion of a gas or liquid. The fluid is constrained in 2 dimensions, and therefore all the expansion occurs in one dimension. The thermal expansion hopefully is linear over the temperature range of application, and one has to calibrate at a minimum of two temperatures to obtain a valid range. A gas thermometer measures temperature with the variation in pressure or volume of a gas. When volume is kept constant, the thermometer measures the temperature by the variation in pressure alone. This is called a constant volume gas thermometer.

4.1.4 Load setup:

The main objective of the load setup is to apply pressure on the specimen by three point bending method. According to the ASTM D648 standard pressure of about 0.455 Mpa must be applied to the specimen.

A constant load has been machined according to the specified standard. A knife edge is designed and fabricated in order to hold the specimen according to the standard.

4.1.5 Load calculation:

Pressure according to ASTM std =0.455Mpa.

Surface area in contact with specimen= $(\pi/4)*D^2$

Diameter of the rod =0.01m.

Surface area in contact with specimen= $(\pi/4)*.01^2$

$=7.85*10^{-5}m^2$

Load =Pressure*Area.

$= (0.455*10^6)* (7.85*10^{-5})$

=35.72N

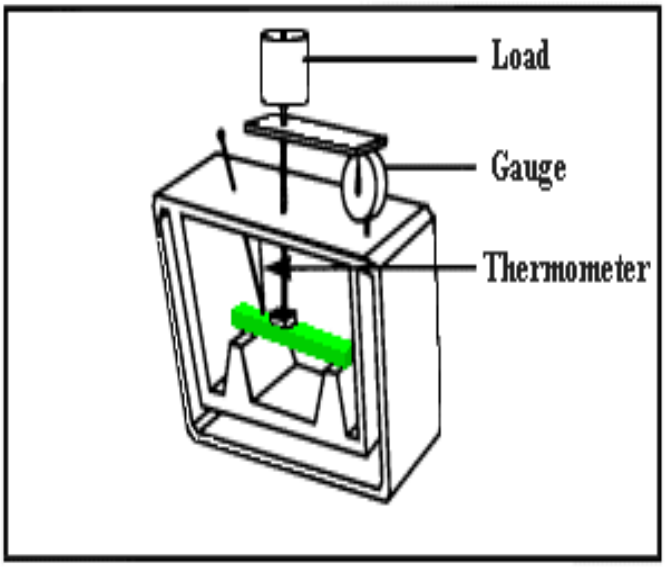
Now load in terms of kg

Load=35.72/9.811 kg

Load=3.5kg

4.1.6 Test procedure:

- The test involves inserting molded plastic test pieces into a closed oil bath.
- Then the oil is heated and the heat is controlled to maintain a uniform rate of rise of heat.
- The test sample is supported at both ends and a uniform pressure is applied between the supports.
- With the heating of the oil in the oil bath, the molded plastic test piece is also heated up.
- As a result the sample becomes more flexible and applied pressure causes it to bend.
- The temperature at which the plastic test sample is distorted at a pre-defined distance is known as the heat distortion temperature.



Temperature	Deflection
60	0.02
62	0.02
64	0.04
66	0.09
68	0.19
70	0.25

9. Tabulations:

The temperature and deflection of each specimen is noted and the readings are tabulated as given below:

Temperature	Deflection
50	0.01
52	0.04
54	0.07
56	0.11
58	0.16
60	0.20
62	0.25

Temperature	Deflection
40	0.02
42	0.08
44	0.13
46	0.18
48	0.25

Graph:

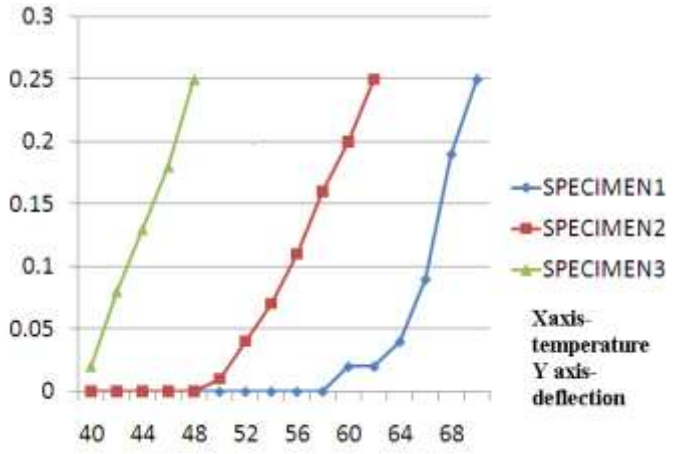


Figure 10. Graph

Conclusion:

Thus we manufactured polmer matrix composites of different combinations of vinylester and polyurethane successfully.And also the heat distortion kit is fabricated and test is done.The heat distortion temperature for each specimen is found by using the heat diastortion kit and the readings are tabulated and compared by graph.The proportion 40:60 and 20:80 does not formed as perfect IPN hence it is found that 80% vinyl ester and 20%poyurethane have good elasticity and toughness in comparison with other propoportions.

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