GLASSFIBRE REINFORCED POLYMER WITH EMBEDDED ADDITIVES

Mr. Manigandan A ME., Jaya Karan R BE., Gopinath R BE., Akash A BE.,

(Department of mechanical engineering)

Loyola institute of technology, palanchur, Chennai:6000123

Abstract:

This study investigates the synergistic effects of incorporating additives within glass reinforced polymer (GRP) composites to enhance their mechanical, thermal, and durability properties. The research focuses on optimizing the dispersion and interaction of additives within the polymer matrix to achieve improved structural performance. Through a systematic experimental approach, the study aims to establish the influence of various additives on the tensile strength, impact resistance, and thermal stability of GRP composites. The findings contribute to advancing the understanding of composite materials and offer insights into tailoring their properties for specific engineering applications, such as aerospace, automotive, and construction.

Key Words: Structural Performance, Mechanical Properties, Thermal Stability, Durability, Polymer Matrix, Tensile Strength, Impact Resistance

1.INTRODUCTION

Glass Reinforced Polymer (GRP) composites have emerged as vital materials in various engineering applications due to their lightweight, high strength, and corrosion-resistant properties. To further enhance the performance of GRP, the integration of additives into the polymer matrix has garnered significant attention. This research develops into the intricate interplay between GRP and embedded additives, aiming to unlock synergistic effects that can elevate the material's mechanical strength, thermal stability, and overall durability. The study explores the optimization of additive dispersion within the polymer matrix to tailor the properties of GRP composites, providing valuable insights for advancing composite material science and meeting the evolving demands of modern industries.

Glass Reinforced Polymers (GRPs), also known as fiberglass composites, represent a class of materials that have garnered widespread use across diverse engineering sectors owing to their remarkable combination of high strength, low weight, and resistance to corrosion. These composites, composed of a polymer matrix reinforced with glass fibers, have proven instrumental in applications ranging from aerospace components to automotive parts and structural elements in construction.

In the pursuit of enhancing the already impressive properties of GRPs, researchers have turned their attention to the strategic incorporation of additives within the polymer matrix. These additives, diverse in nature and function, hold the promise of imparting additional beneficial characteristics to the composite material, addressing specific performance limitations or tailoring it for specialized applications. The synergy between GRP and embedded additives offers a nuanced avenue for exploring advanced material engineering and pushing the boundaries of composite technology.

The motivation for this research stems from the growing demand for composite materials with improved mechanical strength, thermal stability, and overall durability. While GRPs have demonstrated exceptional properties, there exists a continual need to optimize and fine-tune these materials to meet the evolving challenges of modern industries. The integration of additives into GRPs serves as a strategic approach to achieve this optimization, opening up possibilities for tailoring composite characteristics to specific performance requirements.

This study aims to develop into the intricate dynamics between GRPs and embedded additives, exploring the effects of different types and concentrations of additives on the mechanical, thermal, and durability aspects of the composite. By systematically investigating the dispersion and interaction of additives within the polymer matrix, we seek to unravel the synergies that can be harnessed to enhance the overall performance of GRPs. The findings of this research are expected to contribute significantly to the understanding of composite materials, providing valuable insights for engineers, material scientists, and industries seeking to leverage the full potential of glass reinforced polymers with embedded additives.

2.LITERATURE REVIEW

Shrikant M. Harle. Natural polymer composites are more environmental friendly. Ongoing researchers found varieties of natural fibers, which improved the mechanical strength of polymer composite, Natural fibers resulted in lighter composite materials. Also, due to the low density

of the natural fibers used in the composites can be regarded as a useful light weight 'engineering material. From the above discussions it is quite evident that newer' composites using abundantly available natural fibers are on the horizon, this brought new trends in composite materials.

M.S. EL Wazerya*, M. I. EL Elamya, and S. H. Zoalfakar. This experimental investigation of mechanical behavior of glass fiber reinforced polyester resin composites leads to the following conclusions. This work shows that successful fabrication of glass fiber with random oriented reinforced polyester composites with different fiber contents is possible and very cost effective by simple hand lay-up technique. It was found that the tensile strength varies from 28.25 MPa to 78.83 MPa, flexural strength varies from 44,65 MPa to 119.23 MPa and impact energy at room temperature varies from 3.5 Joules to 6.50 Joules with the variation in glass fiber percentage from 15wt.% to 60 wt.%. The hardness value will greatly increase from 31.5 BHN to 47 BHN when the resin reinforced by glass fibers from 15 wt.% to 60 wt.%. The mechanical property such as tensile strength and flexural bending strength of polyester resin has been improved by a great extent due to the presence of glass fiber reinforcement.

Patil Deogondal, Vijaykumar N Chalwa. Tensile, Bending and Impact strength increases with addition of filler material. ZnS filled composite shows significantly good results than TiO2 filled composites. ZnS_ filled composite shows more tensile load in comparison with unfilled and TiO2 filled composites. Impact toughness notch across the laminates is higher than that of along the notch. Impact toughness value for unfilled glass composite is more than filled composite. TiO2 and ZnS filler material makes material harder and brittle which is the reason for reduction in impact toughness value. ZnS filled composite shows significantly higher values than TiO2 filled composites.

Muthu Kumaraswamy, V.K. Sandeep, B.Derick Nithin R.Manual Livingston2, J.G.Jigbert Jimsin The composite materials are suitable for the application where medium load is experienced it can be effectively interchanged to the conventional materials due to their advantages such as Less weight, Good load bearing capacity, thus it can act as a replacement for many materials. In future Composite materials will find the broad applications in many fields the characteristics like high load capacity to the weight ratio, easy production methods, cheap availability of raw materials will make it suitable for various applications.

TESTING METHODOLOGY

GLASS TRANSITION TESTING (TG TESTING)

Different operational definitions of the glass transition temperature Tg are in use, and several of them are endorsed as accepted scientific standards. Nevertheless, all definitions are arbitrary, and all yield different numeric results: at best, values of Tg for a given substance agree within a few kelvins. One definition refers to the viscosity, fixing Tg at a value of 1013 poise (or 1012 Pa-s). As evidenced experimentally, this value is close to the annealing point of many glasses. In contrast to viscosity, the thermal expansion, heat capacity, shear modulus, and many other properties of inorganic glasses show a relatively sudden change at the glass transition temperature. Any such step or kink can be used to define Tg. To make this definition reproducible, the cooling or heating rate must be specified. The most frequently used definition of Tg uses the energy release on heating in differential scanning calorimetry (DSC, see figure).

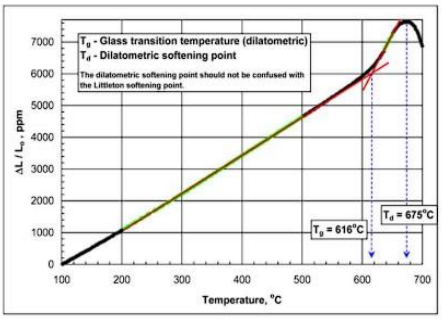

Figure 7 Determination of T_g by dilatometry.

. The linear sections below and above Tg are colored green. Tg is the temperature at the intersection of the red regression lines. Summarized below are Tg values characteristic of certain classes of material. The glass transition temperature (Tg) is a phenomenon of amorphous polymers. At this temperature, polymers undergo a transition from glassy to rubbery state. Tg is an important feature of polymer behaviors. It marks a region of dramatic changes in the physical and mechanical properties. Polymers are made up of long chains of molecules. Tg depends on the chemical structure of the polymer defined by its crystallinity. They may be amorphous, crystalline or semi-crystalline.

DIFFERENTIAL SCANNING CALORIMETRY (DSC)

Differential Scanning Calorimetry (DSC)is a thermo-analytical technique using differential scanning calorimeter. It monitors the difference in heat flow between the sample and reference against time or temperature. It also programs the temperature change of the sample in a specified atmosphere. DSC determines the thermal properties of the polymer. It applies to amorphous sections of polymers that are stable. These materials do not undergo decomposition or sublimation in the glass transition region

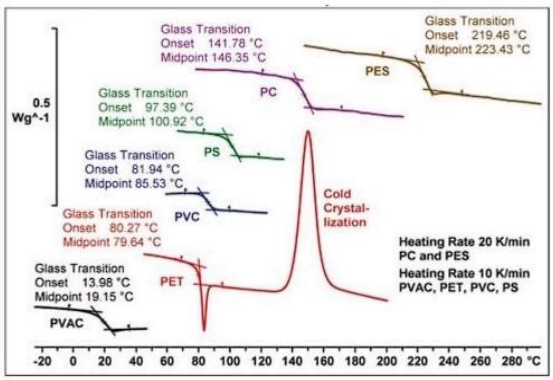

Figure Glass Transition Temperature Measurements of Different Polymers Using DSC

The test standards used to find Glass Transition Temperature of resins via DSC include

1. ASTM E1356-08(2014)— Standard Test Method for Assignment of the Glass Transition Temperatures by Differential Scanning Calorimetry
2. ASTM D3418-15— Standard Test Method for Transition Temperatures, Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
3. ASTM D6604-00(2017)— Standard Practice for Glass Transition Temperatures of Hydrocarbon Resins by Differential Scanning Calorimetry
4. ISO 11357-1:2016 — Plastics — Differential scanning calorimetry (DSC)
5. Part 1: General principles
6. Part 2: Determination of glass transition temperature and step height

TEMPERATURE TESTING

E-glass/epoxy laminates were prepared using ASTM D 3039/D 3039M, ASTM D 695 and ASTM D 5023 standards [21]. Four-ply glass fiber with a common epoxy matrix was used to prepare GFRP laminates for tensile and compressive strength testing. Twelve-ply glass fiber laminates were prepared for dynamical mechanical analysis (DMA) testing. All laminates were produced using the resin transfer molding (RTM) process. After RTM processes, laminates were cured on a glass table at 25 °C for 24 h, After these processes, laminates were post-cured in an oven at 65 °C for 16 h. Laminates were then cooled at room temperature and tabs were produced with plain weave glass fibers, using hand lay-up production techniques. Laminates were cut using a computer numerical control (CNC) machine, with a tolerance of 0.02 mm. They were then cleaned and flashes were removed using sandpaper, before testing. Test specimens were
measured, inspected for defects and placed into the composite testing Matrix digestion using the burn-off method was used to determine the volume fractions according to ASTM 3171. For the present study, the volume fraction of E-glass fibers was obtained at 55%. Tensile and compressive strength tests were carried out using a Lloyd LR testing machine. The testing machine was equipped with a 30 KN load cell and measurements were taken at a rate of 2 mm/min. Average tensile and compressive strength results, standard deviations, coefficients of variation and two-parameter Weibull distributions were recorded and shown in Table 2 and Table 3. Laminates were preserved in deep freezers at — 80 °C, -20
°C, and 0 °C, for 60 days, to investigate and characterize the stiffness, tensile and compressive response of materials. Tensile and compressive tests were carried out at heating and testing temperatures of -80 °C, -20 °C, and 0 °C. Long-term effects of moistures were studied to investigate their effect on tensile strength, elastic modulus, failure strain and compressive strength of a material. Additional tests were carried out to determine the laminates response at25 °C, 50 °C, 75 °C, and 100 °C. Laminates were preheated for 2 h in a binder oven, before testing to ensure that temperature was uniform along with the thickness of laminates. A heat-con thermocouple was mounted in the oven to measure temperatures during a test. An epsilon digital extensometer of 25 mm gauge length was used to measure DMA tests were carried out as per ASTM: DS023 using DMA Q 800 TA Instrument. Three-point bending modes were used. The heating rate was the stra increased at 2 °C/min and frequencies were set at | Hz, 10 Hz and 100 Hz. Glass transition temperature (T,) of epoxy resin was measured using a DMA tool. Liquid nitrogen was used as a coat a height of 4.57 + 0.03 mm, width 13 + 0.02 mm and length 64 + 0.02 mm. In 1g agent. Dimensions of test samples were set
DMA experiments, sensors measured the testing temperature and loading,

$$\varepsilon = \varepsilon 0 \sin(o.t)\ a \quad (1)$$

where $\varepsilon 0$ was strain amplitude, ω was the circular frequency and t denotes time. Corresponding stress σ was expressed as,

$\sigma = \sigma 0 \sin(\omega.t+\delta)$ 2 (2)

where σ o0 was stress amplitude and δ represented phase angle between stress and strain, Storage modulus (E'), loss modulus (E") and damping factor (Tan was expressed as,

$E'=(\sigma 0/ \varepsilon e0)\cos\delta$ (3)

$E''=(\sigma 0/ \varepsilon e0)\sin\delta$ (4)

$\text{Tan}\ \delta=E''/ E'$ (5)

Table -1:

TABLE 1 Compressive properties of laminates at various temperature

Designation of GFRP Laminates	σa(MPa)	m Values	R Values	Compressive Strength (MPa)	Standard Deviation and Coefficient of Variation
−80/G	451.93	38.37	97.91%	443.19	(24.15, 5.45%)
−20/G	453.74	39.50	97.78%	445.68	(23.07, 5.18%)
0/G	547.78	29.69	97.85%	536.77	(24.36, 4.54%)
25/G	458.36	14.65	98.16%	444.04	(48.08, 10.83%)
50/G	352.83	19.36	98.04%	342.52	(18.92, 5.52%)
75/G	161.82	27.40	97.78%	159.77	(9.24, 5.78%)
100/G	30.12	17.85	98.14%	29.10	(2.02, 6.94%)

RESULT

The use of Glass Fiber Reinforced Polymer (GFRP) composites has shown significant potential and numerous advantages in various industries and applications. GFRP materials possess high strength-to-weight ratio, corrosion resistance, excellent durability, and design flexibility. These characteristics make GFRP composites a suitable alternative to traditional materials like steel and concrete in many structural and non-structural application.

Figure 1

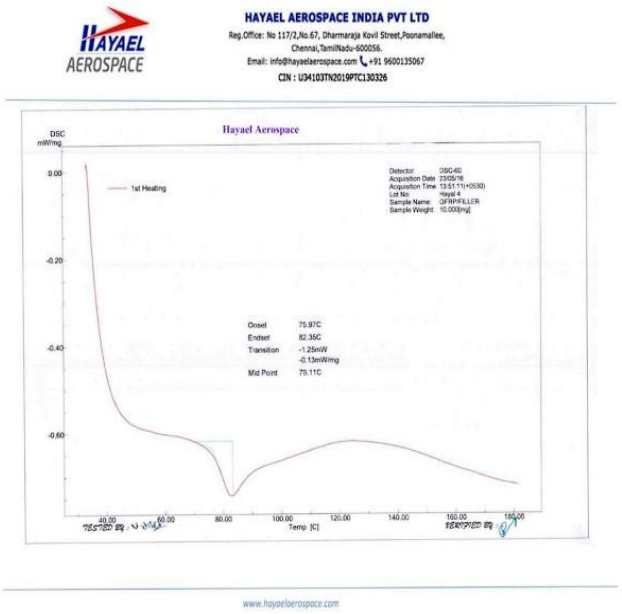

Figure 8 Glass reinforced polymer sample result

The glass transition temperature, Tg, is the temperature at which polymer chains can slide past each other without breaking. When a polymer is cooled below its Tg, it gets very hard and brittle; when it is heated above its Tg, it becomes very soft and liable. Glass transition temperature (Tg) testing is an essential characterization technique for assessing the thermal behavior and stability of materials, including glass fiber reinforced polymers (GFRP). By determining the Tg, researchers and engineers can understand the temperature range at which the material transitions from a glassy, rigid state to a rubbery, flexible state, During Tg testing, a sample of the GFRP material is subjected to controlled temperature changes, typically using techniques such as differential scanning calorimetry (DSC) or dynamic mechanical analysis (DMA). As the temperature increases, the material undergoes molecular rearrangement, resulting in a noticeable change in its physical properties. The Tg is defined as the midpoint of this transition and provides insights into the material's performance at different temperature ranges.

DISCUSSION

Glass Reinforced Polymer (GRP), a composite material blending a polymer matrix with glass fibers, gains enhanced functionality through embedded additives. The polymer matrix, often comprising polyester, epoxy, or vinyl ester resins, synergizes with E-glass or S-glass

fibers to yield a lightweight yet robust material. Incorporating additives further refines its properties, with fillers improving dimensional stability, flame retardants enhancing fire resistance, UV stabilizers guarding against sunlight-induced degradation, and colorants allowing for aesthetic customization. The manufacturing processes, including lay-up techniques, pultrusion, and injection molding, contribute to the versatility of GRP. Exhibiting remarkable strength-to-weight and stiffness-to-weight ratios, GRP finds applications in automotive components, construction materials, aerospace structures, and marine environments, owing to its resistance to corrosion and minimal maintenance requirements. Despite initial higher costs and limited recycling options, the long service life, durability, and diverse applications position GRP as a compelling solution in various industries, emphasizing its pivotal role in modern engineering and design.

CONCLUSION

In conclusion, Glass Reinforced Polymer (GRP) with embedded additives stands as a transformative material in the realm of composite engineering, offering a compelling fusion of strength, versatility, and tailored functionality. The combination of a polymer matrix, typically composed of resins like polyester or epoxy, with strategically embedded additives such as fillers, flame retardants, UV stabilizers, and colorants, significantly amplifies its properties. This composite exhibits exceptional strength-to-weight and stiffness-to-weight ratios, making it an ideal choice for applications demanding structural integrity without the burden of excessive weight. Its resistance to corrosion, durability, and minimal maintenance requirements position GRP as a stalwart contender in industries ranging from automotive and construction to aerospace and marine. The diverse manufacturing techniques, including lay-up methods, pultrusion, and injection molding, underscore the adaptability of GRP to various design requirements. Despite challenges such as initial costs and limited recycling options, the longevity and resilience of GRP underscore its pivotal role in modern engineering and design, emphasizing a future where lightweight, durable, and customizable materials play a central role in shaping innovative solutions across industries.

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