ISSN: 0974-5823 Vol. 6 (Special Issue, Nov.-Dec. 2021)

International Journal of Mechanical Engineering

A study on glass fiber reinforced composite filled with polypropylene and nanoparticles :Anti-riot jackets

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Abstract

Today, a body protector is any protective covering worn to defend the body from physical assaults such as stones, blades, sticks, and other such objects. Body protectors are currently made in India with polycarbonate sheets and rubber/foam inserts stitched with flame-retardant cotton fabric. State police and the paramilitary often accept these body protectors. There is a need for improvement like body protectors foam used in body protectors which is not flame retardant. Attributable to this, there is a danger of fire in uproar conditions. The target of the current work is to deliver a material made of E-glass/S-glass/polypropylene epoxy composite with filler materials. The properties need to meet the necessary measures or much more than that of polycarbonate to guarantee the wellbeing of the wearer. The best combination which suits the desired application by indicating the optimum results for all the properties examined is chosen for the manufacturing of anti-riot jackets.

Keywords: Anti-riot jacket, Polypropylene, composite, nanoparticles

Introduction

The resin material is one of the two fundamental phases of composite material, while the reinforcing material is the other. In the matrix phase, the reinforcing material is incorporated. Reinforcement is a time-consuming procedure. The mechanical properties of composites are strengthened by material reinforcement. Composites are made up of two or more materials that are encased in resin. Polymer, metal, or ceramics will be used as the resin. Reinforcements can take the form of strands, particles, whiskers, or laminates, and they can be incorporated into an acceptable matrix to create a substance that integrates the constituent's best qualities. The composites' overall properties will be far superior to the compositions'. Glass fibre reinforced plastics with mechanical strength were first developed in the early 1940s, and reinforced polymer composites have grown in popularity since then. Thermal stability will be provided by the matrix or resin material, while mechanical strength will be provided by the embedded reinforcement [2].

Materials and methods

Materials

In this work, 7mil E-glass/S-glass fiber reinforcement with polypropylene material was used. The matrix system consists of epoxy resin (L-12) and room temperature curing hardener (K-6). The fillers materials used are Al_2O_3 and $Mg(OH)_2$.

Methodology

Glass fiber-epoxy composite fabrication by hand layup procedure. Preparation of the samples according to ASTM requirements and examination of mechanical properties such as tensile strength, bending strength, and hardness test. Evaluating the results obtained and testing for optimal results by adjusting the stacking process of glass fibers or changing the materials of the filler. The composites were developed from E-glass fiber, S-glass fiber polypropylene, and epoxy resin with filler materials, based on the ASTM standards. Composite processing was performed by hand layup techniques at room temperature and a composite was cured at room temperature. It is essential to monitor the sufficient volume fraction of fiber, epoxy, fillers, and fiber direction.

Table 1 Designation and detailed composition of the composite

SL.NO	Composite Material ID	E – Glass wt.%	S-Glass wt.%	Polypropylene wt.%	Epoxy wt.%	Al_2O_3 wt.%	$Mg(OH)_2$ wt.%
1	GFRP1(EPE)	40	-	10	50	-	-
2	GFRP2(SPE)	-	40	10	50	-	-
3	GFRP3(ESPE)	20	20	10	50	-	-
4	GFRP4(ESPE)	15	15	20	50	-	-
5	GFRP5(ESPE)	10	10	30	50	-	-
6	GFRP6(ESPEA$_1$)	20	20	10	40	10	-
7	GFRP7(ESPEA$_2$)	20	20	10	35	15	-
8	GFRP8(ESPEM$_1$)	20	20	10	40	-	10
9	GFRP9(ESPEM$_2$)	20	20	10	35	-	15
10	GFRP10(ESPEA$_1$M$_1$)	20	20	10	30	10	10

Composite laminate fabrication and specimen preparation

The composites filled with varying concentrations were driven by S-glass-E-glass-Polypropylene/Epoxy. By considering the density and mass, the volume fraction of fiber, epoxy, and filler materials are determined. In a basin, the necessary ingredients for resins, hardeners, and fillers are thoroughly mixed and the mixture is then continuously stirred. The glass fibers are manually placed. The mixture is evenly brushed over the glass plies and polypropylene plies, so made. To finish the laminate frame, captured air is eliminated physically with squeezes or rollers and the composite is cured at room temperature.

Experimentation

The tensile, impact and hardness tests were carried out using universal, impact and Brinell's hardness testing machines. Thermal conductivity, Thermal expansion of coefficient, flame propagation rate and fire resistance tests were conducted. The fracture morphology was done using scanning electron microscope and Energy dispersive spectrum was conducted to understand the distribution of the filler materials in the composites .The chi-square test for association was conducted to know the relationship between the variables and influence of the same on the overall properties of the composites.

Results and discussion

The outcomes of different property tests are depicted in this chapter. This chapter involves determining and discussing the tensile strength, impact strength, hardness, thermal conductivity, coefficient of thermal expansion, ignition time, and flame propagation rate of FRP laminates. The overview of the findings and the relationship between various FRP composite laminates are also discussed. All experiments were conducted at least three times (replicate) and all values were reported as the mean .GFRP10(ESPEA1M1) composite serial number ten is optimum combination of constituents which was obtained after experimentation and analysis of nine combinations ,which balances both mechanical and thermal properties of the composites .The results of first nine combinations and optimum tenth combination is depicted in the results and graph for better comparisons.

Mechanical, Thermal and fire resistance properties

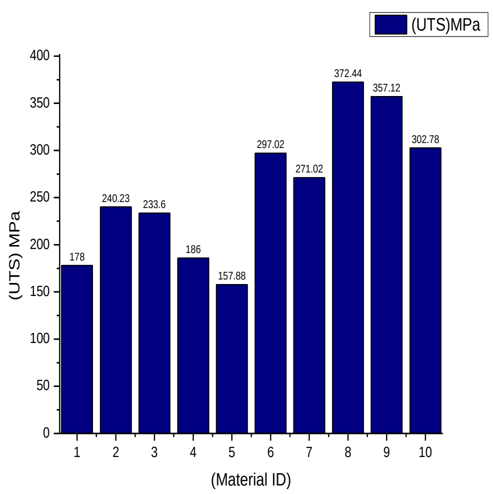
Mechanical, thermal and fire resistance properties properties of GFRP composites of varying concentration of fiber content were as shown in Table 2 and table 3 below.

Table 2 Mechanical properties for different laminates

Sl.No	Composite Material ID	Thermal conductivity (W/m^0C)	Thermal Expansion (/^{o}C)	Flame propagation rate(mm/sec)	Time to ignition (sec)
1	GFRP1(EPE)	2.49	$1.85x10^{-5}$	0.62	10
2	GFRP2(SPE)	2.38	$1.48x10^{-5}$	0.61	11
3	GFRP3(ESPE)	1.86	$1.86x10^{-5}$	0.61	11
4	GFRP4(ESPE)	1.98	$1.11x10^{-5}$	0.63	09
5	GFRP5(ESPE)	2.16	$1.92x10^{-5}$	0.64	08
6	GFRP6(ESPEA1)	1.79	$1.96x10^{-5}$	0.51	11
7	GFRP7(ESPEA2)	1.56	$1.86x10^{-5}$	0.56	13
8	GFRP8(ESPEM1)	1.42	$7.41x10^{-6}$	0.47	13
9	GFRP9(ESPEM2)	1.32	$3.63x10^{-6}$	0.44	14
10	GFRP10(ESPEA1M1)	1.44	$2.72x10^{-5}$	0.52	12

Table 3 Thermal and fire resistance properties for different laminate

Sl.No	Material ID	UTS (MPa)	Charpy(J/mm^2)	Hardness (BHN)
1	GFRP1(EPE)	178	0.365	79
2	GFRP2(SPE)	240.23	0.421	83
3	GFRP3(ESPE)	233.6	0.40	81
4	GFRP4(ESPE)	186	0.384	84
5	GFRP5(ESPE)	157.88	0.293	76
6	GFRP6(ESPEA1)	297.02	0.4871	90
7	GFRP7(ESPEA2)	271.02	0.4664	92
8	GFRP8(ESPEM1)	372.44	0.4378	87
9	GFRP9(ESPEM2)	357.12	0.4294	82
10	GFRP10(ESPEA1M1)	302.78	0.4159	94



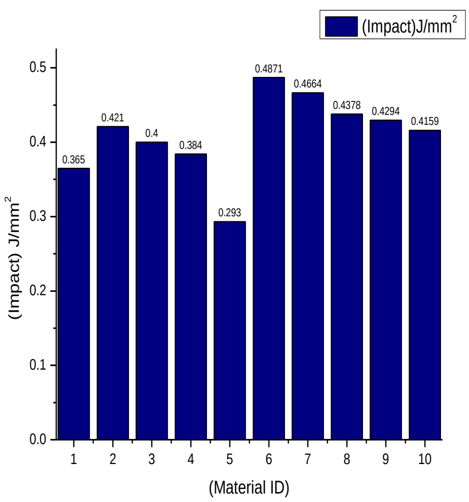
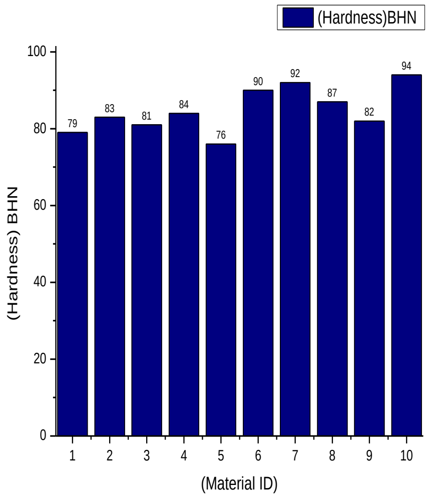
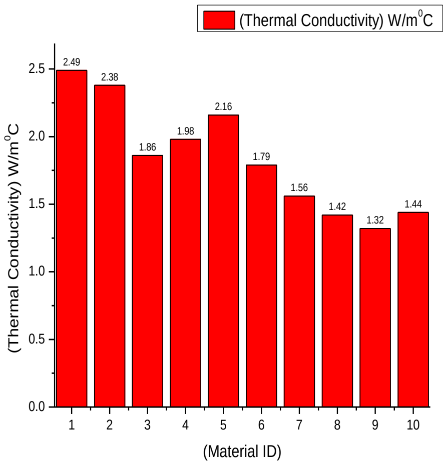
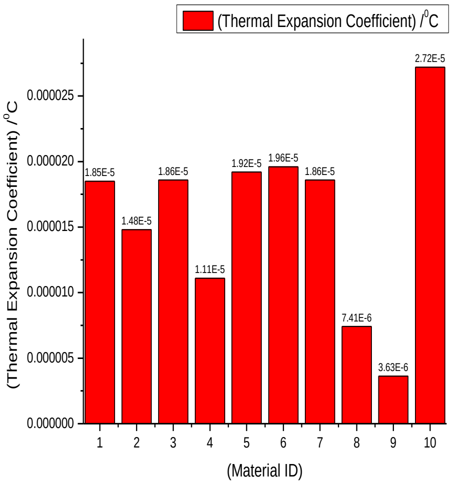


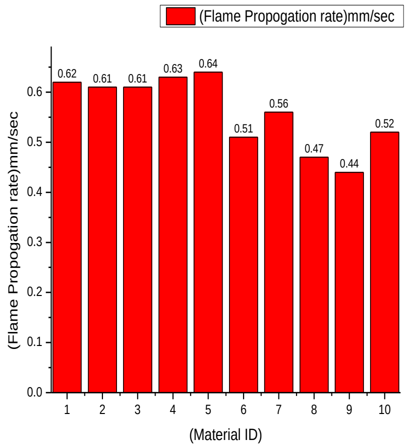
Figure 1.(a)UTS **(b) Charpy test**



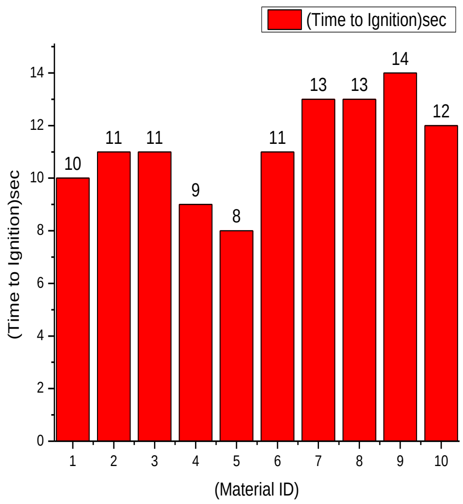


(c)BHN **(d)Thermal conductivity**





(e)TEC **(f)Flame propagation rate**



(g)Ignition Time

Concluding remarks and scope of future work

The performance of the composite material for the specific application is judged by its mechanical behaviour under various loading conditions. The present work is based on the application of the anti-riot jacket where the mechanical properties should be optimum and reduced thermal properties. The tensile and impact properties should be the forefront property of the composite used for such a purpose. The research done shows that the increase in the percentage of polypropylene decreases the mechanical properties. The ideal weight percentage of polypropylene which showed good results is 10 wt.% The Pure S-glass with polypropylene and epoxy also gives a better result but the cost of S-glass is high compared to E-glass. Hence, a new class of composite with a combination of E-glass and S-glass with polypropylene fiber lamina and some added fillers gives the best mechanical properties as such for the use of anti-riot jackets. The experimentation concludes with the following points

Mechanical properties

- 15 wt. % Magnesium hydroxide increases the tensile strength of the material as it mixes properly with the matrix and provides good adhesion.
- 10 wt. % of aluminum oxide increases the impact strength of the materials proving good to interlaminate strength to the composite.
- The hardness of the materials seen to notably increase by adding aluminum oxide.

Thermal properties

The impact of Al_2O_3 and $Mg(OH)_2$ on the thermal properties of glass fiber reinforced epoxy-based composites was studied and the following conclusions were made.

- Compared to Al_2O_3, $Mg(OH)_2$ provides better thermal stability to the composite when used as a filler material.
- When the $Mg(OH)_2$ filler material weight fraction increased the thermal expansion coefficient decreased which is evident from the results.

Fire Resistance Properties

- Fire results show that the increase in wt% of filler material especially $Mg(OH)_2$ improved the flame propagation property.
- $Mg(OH)_2$ acts as flame retardant filler material from the experimentation results.
- All the specimens having flame extinguish time more than 30 Sec failed to come under UL-94V rating.

Table 4 Optimum composition composite

Composite Material ID	Tensile strength (MPa)	Impact strength (J/mm^2)	Brinell hardness (BHN)	Thermal conductivity (W/m^0c)	Thermal expansion coefficient ($/^0c$)	Flame propagation rate (mm/sec)	Time to ignition (sec)
GRFP10 (ESPEA1M1)	302.78	0.4159	94	1.44	2.72×10^{-5}	0.52	12

E-glass 20wt.%,S-glass 20wt.%, Polypropylene 10wt.%, Epoxy 30wt.%,Al_2O_3 10wt.%, $Mg(OH)_2$ 10wt.%

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