EFFECT OF CURING CYCLE AND EVALUATION OF MECHANICAL STRENGTH OF GLASS/POLYESTER POLYMER COMPOSITE

[1]Mahantesh M,[2]Madusoodhan Reddy,[3] Ambadas,[4] Babu Reddy
[1] M.Tech student,[2] M.Tech student,[3]Assistant professor,[4]Assistant professor
[1] Department of Machine Design,
[1]VTU CPGS,Kalaburgi,Karanataka-585105

Abstract— Composite of Glass fiber reinforced with Polyester resin is manufactured by conventional hand layup method, to study effect of curing temperature(100 ^{0}C,120 ^{0}C and 130 ^{0}C) with curing time period(30,60 and 90mins) on composite material and also optimization of curing temperature and curing time period. Grey relation analysis has been carried out to optimize different mechanical strength such as tensile strength, flexural strength, and inter laminar shear strength.

Keywords- Glass/polyester,Curing,Fabrication,Hand layup,Grey relation analysis.

1. Introduction

Composites or composite materials are available in nature or engineered fusing two or more materials with significantly different chemical and physical properties which linger distinct at microscopic or macroscopic level within the finished structure. The constituent material is basically of two categories: reinforcement and matrix, the matrix supports the reinforcement against mechanical and environmental damage by surrounding and maintaining their relative position, while the reinforcement bestow physical properties and special mechanical such as dielectric, strength, stiffness etc.

Metallic oxides and metals in epoxy and other resins prove to be quite effective in providing those characteristics as they (the composites) have good thermal conductivity of the fillers thus increasing their applications in the field of electronics.

Curing is an irreversible reaction where chemical covalent cross-links are formed which are thermally and mechanically stable.The curing process plays a major role in achieving the final mechanical properties and chemical resistance of the material. State of polymer resin is liquid (soft) before the fabrication of composite,which then changes to solid matrix (hard) after curing.For the fabrication of composite, two types of resins are used i) primary resin (matrix) ii) secondary resin (hardener). Most commonly used primary resins are epoxy, unsaturated polyester and polyurethane. Secondary resin i.e. hardener is added for curing purpose. Most commonly used secondary resin includes amines or peroxides. During cross linking, the state of matrix changes from liquid to gel and then transforms into solid. Curing can be done at room temperature as well as at elevated temperature.This depends on composition of resin and hardener. Optimum curing results in a perfectly cross-linked polymer network which leads to increased Tg (glass transition temperature) and mechanical properties. The Tg depends on different factors, including composition of the resin molecule, curing agent, curing time, cross-linking density and temperature. Generally, during post curing the Tg increases with increasing post curing temperature but it will not exceed the cure temperature. There are several parameters that define the post-cure process.When the temperature increased than Tg, the material looses their mechanical properties. Two biggest variables are temperature and time, but also the time between initial curing and post curing and temperature profile gradient play a role. So, post curing process can play crucial role in obtaining optimum mechanical and thermal properties of polymer matrix composites.Present investigation includes the effect of two most primary post curing parameters, post curing temperature and time on tensile strength, flexural strength and ILSS strength. These obtained mechanical strengths are optimized by using grey relation analysis.

2 Literature review

D S Kumar et al, have studied outcome of cure factors for mechanical parametes of epoxy resin reinforced with GFRP. Curing was done at elevated temperature range (80,110 and 140°C) for varying time (2hours, 4hours, 6hours, 8hours and12hours). ILSS test was done for every post cured specimens. The results revealed that the ILSS affects with post cured parameters.No majoralter in ILSS was observed for 80°C upon the whole curing period. In the case of 110 °C a flat growth in ILSS is found for time upto 12hrs, but in samples which are cured at 140 °C it is observed a hasty growth in ILSS with increase in curing period.[1]

Luca Sorrentino et al,have Studied Polymeric composite made by 2/2 twill carbon fabric reinforced with epoxy resin for varying thickness from 6mm-60mm laminates with different curing temperature of 91.3 °C, 138.4 °C and 159.4 °C corresponding to curing time of 10mins and 20mins. A decline of the interlaminar shear strength for increase in temperature for thicker laminate was found . For 6 mm thin laminate at91.5 °C specimen resists maximum shear strength, while the time period of temperature don't manipulate the structural potency of epoxy resin. [2]

Joao R. Correia , Marco M. Gomes et al In this research paper, it has explained about experimental and systematic study for mechanical reaction at increased temperature for GFRP reinforced with polyester resin and also explains broad study of the tensile strength, shear strength and compressive strength of the GFRP polymers at varying temperatures from 20-250°C. Tensile strength is significantly decreased when this material is expose to higher temperature around 230°C, and for 220°Cmaterial still having strength of 54% of their atmospheric/room temperature. Shear strength and compressive strength is decreased at high temperatures, exhibiting 11% and 5% of compressive and shear strength with ambient temperature.[3]

3. Materials and experimental methods

3.1 Materials

The materials used in this paper are tabulated below along with their material properties.

Reinforcement Material	**Matrix material**	**Hardner**	**Accelerator**
E-glass of 360 GSM bidirectional woven roving	Polyester resin (Mouldcraft Isophathalic IS9)	methyl ethyl ketone peroxides	Cobalt octate
Density of fiber $\dot{\rho}_f$ =2.54 g/cc	Density of resin $\dot{\rho}_r$ =1.37-1.40g/cc		
Young' modulus of fiber = 70-74 N/mm^2		Young' modulus of resin = 27800N/ mm^2	

Table no 1 Materials used and their properties

3.2 Fabrication of GFRP Composite

Woven fabric E- glass fibre were cut into the size of 15 cm X 15 cm to form 5 layer sheets and weighed by using electronic weighing machine. Polyester resin was weighed to be 40% of the total weight of the fibre. Then hardener and accelerator is added which is equal to 10% and 2% of the weight of epoxy resin respectively. Glass fibre/polyester laminate have been prepared by hand lay-up method and cured in a microwave oven.

Figure no 1: a) cured laminate b) ASTM standard size specimen for tensile and flexural test c) ASTM standard size specimen for ILSS test

3.3 Tensile test

Tensile test was done on 10kn capacity computer controlled UTM, ASTM D3039 standard is used for the tensile testing. The length of the specimen is 125 mm, width of specimen is 12.5 mm and thickness of specimen is 2 mm.The tensile test set up is shown in figure number 2

Figure no 2 Tensile test set up

3.4 Flexural test

Flexural test was done on 10kn capacity computer controlled UTM, ASTM D7264 standard is used for the flexural testing of laminate structure. The spam length for flexural test is 90 cm. The length of the specimen is 125 mm width of specimen is 12.5 mm and thickness of specimen is 2mm. Theflexural test set up is shown in figure number 3.

Figure no 3 Flexural test set up

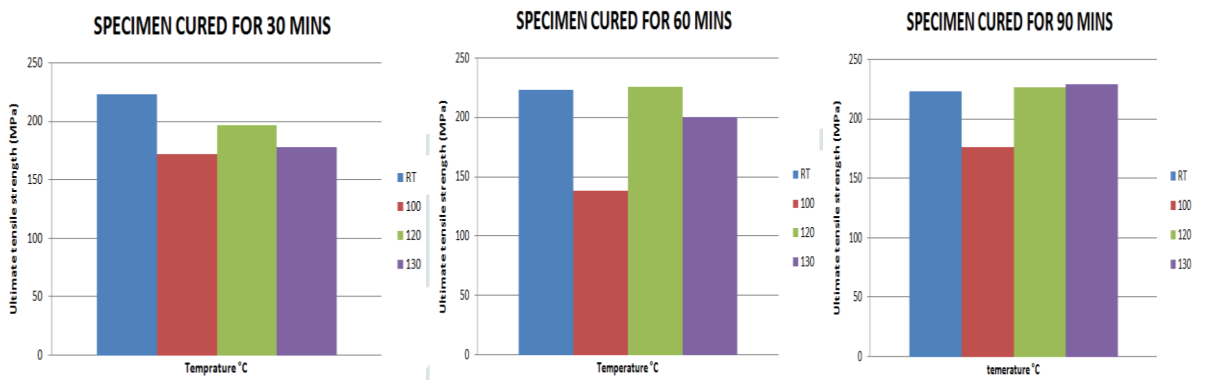
3.5 ILSS test

ILSS test was done on 10kn capacity computer controlled UTM, ASTM D2344 standard is used for the Inter laminar shear strength testing of laminate structure.The spam length for this set up is 90 mm. The length of the specimen is 50 mm width of specimen is 10 mm and thickness of specimen is 2mm.

Figure no 4 ILSS test set up

4 Results and discussion

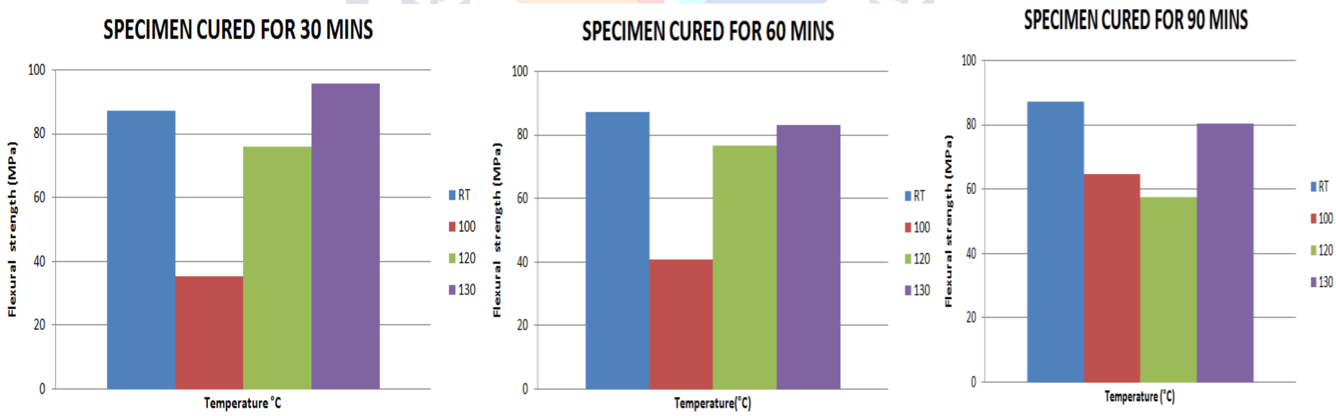
4.1 Tensile strength



(a) (b) (c)

Figure no 5 Ultimate tensile strength for 100^{0}C,120^{0}C and 130^{0}C compared to room temperature

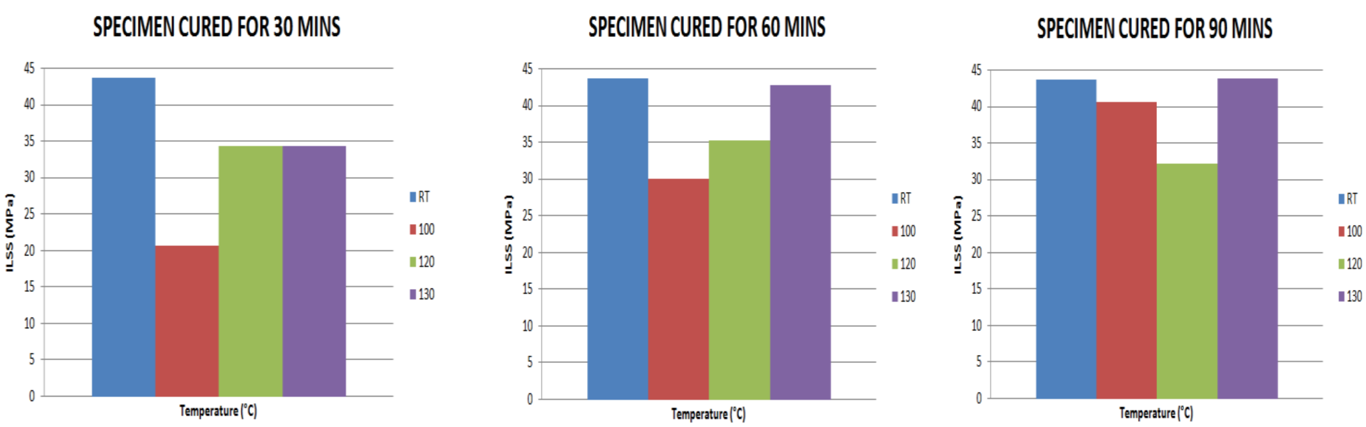
4.2 Flexural strength



(a) (b) (c)

Figure no 6 Flexural strength for 100^{0}C,120^{0}C and 130^{0}C compared to room temperature

4.3 ILSS strength



(a) (b) (c)

Figure no 7 ILSS strength for 100^{0}C,120^{0}C and 130^{0}C compared to room temperature

4.4 Grey relation analysis

In Grey relational analysis experimental data i.e. measured features of quality characteristics are first normalized to range between zero & one. This process is known as Grey relational generation.Based on normalized experimental data, Grey relational coefficient is calculated to represent the correlation between the desired and actual experimental data. Overall Grey relational grade is determined by averaging the Grey relational coefficient corresponding to selected responses. The overall performance characteristic of the multiple response process depends on the calculated Grey relational grade. This approach converts a multiple response process optimization problem into a single response optimization situation with the objective function which is the overall Grey relational grade.The following table gives Grey relational coefficient,grey grade and rank.

EXP NO	NORMALIZED VALUES			GREY RELATIONAL COEFFICIENT			GREY GRADE	RANK
	TENSILE	FLEXURAL	ILSS	TENSILE	FLEXURAL	ILSS		
1	0.6275	0	0	0.5730	0.3333	0.3333	0.4132	9
2	1	0.0903	0.4036	1	0.3546	0.4560	0.6035	5
3	0.5879	0.4835	0.8587	0.5481	0.4918	0.7796	0.6065	4
4	0.3582	0.6746	0.5867	0.4379	0.6057	0.5474	0.5303	6
5	0.42	0.6845	0.6267	0.3429	0.6131	0.5725	0.5095	7
6	0.281	0.3696	0.5002	0.3396	0.4423	0.5001	0.4273	8
7	0.565	1	0.5894	0.5347	1	0.5490	0.6945	1
8	0.3205	0.7943	0.9521	0.4239	0.7085	0.9125	0.6816	2
9	0	0.7494	1	0.3333	0.661	1	0.6664	3

Table no 2 Grey relational coefficient, grey grade and rank

5 Conclusions

- The maximum ultimate tensile strength is obtained at 130°C for 90 minutes cured specimen i,e 228.95MPa and minimum at 100°C for 60 minutes.
- The maximum flexural strength is obtained at 130°C for 30 minutes cured specimens i,e 95.496MPa and minimum at 100°C for 30 minutes.
- The maximum ILSS is obtained for 130°C at 90 minutes cured specimens i,e 43.83MPa and minimum at 100°C for 30 minutes.
- Optimized results from grey relation analysis is obtained at 100°C for 90 minutes which gives grey rank of one and gives better optimized mechanical results.
- The maximum young's modulus is obtained at 130°C for 60 minutes and minimum at 120°C for 30 minutes.
- The maximum flexural modulus is obtained at130°C for 90 minutes and minimum at 100°C for 30 minutes.

5.1 Scope for future work

- The mechanical strengths can be evaluated for fracture strength,compression strength and fatigue strength.
- The failed surfaces can be studied by scanning electron microscope (SEM).
- The heat absorption of laminates in microwave oven can be evaluated by differential scanning calorimeter (DSC).
- The mechanical strengths can be evaluated at below room temperature.
- The mechanical strengths are also can be evaluated for different volume fraction of materials.

Acknowledgement

I wish to express my sincere thanks & gratitude to thank my parents, teachers & all people who have helped me directly or indirectly for the completion of this project work. I hereby acknowledge with deep sense of gratitude the valuable guidance, encouragement and suggestions given by my M. Tech project guide Mr. Ambadas. Assistant Professor Dept. of Machine Design VTU CPGS, kalaburagi, Karnataka

REFERENCES

[1] Effect of post-curing on thermal and mechanical behavior of GFRP composites by D S Kumar*, M J Shukla, K K Mahato, D K Rathore, R K Prusty and B C Ray.

[2] A new methodology to evaluate the influence of curing overheating on the mechanical properties of thick FRP laminates by Luca Sorrentino, Luca Esposito, Costanzo Bellini.

[3] Effect of microwave curing process on the flexural strength and interlaminar shear strength of carbon fiber/bismaleimide composites by Xuehong Xu, Xiaoqun Wang, Ran Wei, Shanyi Du.

[4] Microwave Curing of Carbon-Epoxy Composites: Penetration Depth and Material Characterization by M. Kwak, R. Wise, P. Robinson, A. Bismarck.

[5] Effects of various temperatures on the mechanical strength of GFRP box profiles by Ferhat Aydin.

[6] Mechanical properties and bond characteristics of different fiber reinforced polymer rebars at elevated temperatures by Rami J.A. Hamad , M.A. Megat Johari , Rami H. Haddad.

[7] Mechanical behavior of pultruded glass fibre reinforced polymer composites at elevated temperature: Experiments and model assessment João R. Correia , Marco M. Gomes, José M. Pires, Fernando A. Branco.

[8] Use of grey based taguchi method in ball Burnishing process for the optimization of Surface roughness and micro hardness of AA 7075 aluminum alloy by Ugur Esme**.**