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ANALYSIS OF THE EFFECT OF QUANTITY OF CATALYST AND LAMINATE THICKNESS ON CURING TIME IN PRODUCTION OF GLASS REINFORCED POLYESTER COMPOSITE

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Abstract:

Production process of reinforced plastic composite materials involves the curing of a thermosetting resin through an exothermic chemical reaction. Research studies have shown that the exothermic heat released during curing process and whose degree varies with laminate thickness has an effect on curing time. The curing time for the resin dictates the rate of production and quality of product. This study aimed at investigating the effect of laminate thickness and quantity of catalyst on the curing time during the production of glass reinforced polyester composite. This research utilized unsaturated polyester resin, Methyl Ethyl Ketone Peroxide catalyst and E-glass fiber reinforcement for sample preparation. Different amount of catalyst ranging from 0.5% to 5% were dispensed on the polyester resin used in making laminate samples of thicknesses ranging from 1mm to 3mm and hand lay-up technique was used to produce sample panels. Curing time of the samples was determined according to the ASTM standards while data analysis was done using the statistical analysis software. Results showed that curing time reduced with increase in both laminate thickness and quantity of catalyst which could be attributed to heat evolved during polymer cross linking heat that was more pronounced in thicker laminate and higher catalyst levels. Statistical analysis showed that the catalyst level had a significant effect on curing of glass reinforced polyester composites compared with laminate thickness or an interaction between the two. It was concluded that the curing time of glass- reinforced polyester composites depended on the laminate thickness and quantity of catalyst.

Keywords: Polyester Composite; Glass Fiber; Curing Time; Laminate Thickness and Hand Lay-*Up Technique.*

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1. Introduction

Currently, composite materials are considered as a new and important class of engineering materials. Composite is defined as a material that consists of one or more discontinuous phases which are usually hard and strong embedded in a continuous phase. The continuous phase is called the matrix while the discontinuous phase is termed as the reinforcement material (Kokta et al., 2005). Reinforcement provides strength and rigidity, helping to support structural loads whereas the matrix or binder (organic or inorganic) maintains the position and orientations of the reinforcement. Significantly, constituents of composites retain their individual chemical, physical and mechanical properties, yet together, they produce a combination of the properties which individual constituents would not be capable of producing alone (Bledzki and Gassan, 2008, Maleque et al. 2007)). Composites tend to have characteristics such as high strength, high modulus, low density and excellent resistance to fatigue, creep, creep rupture, corrosion and wear (Mokhtar et al., 2007 and Yin et al., 2007).

According to Shankar et al, (2017), glass-reinforced plastic is a type of composite material made up of a plastic matrix reinforced by fine fibers made of glass. These engineering materials have found applications in automobiles, boats, aircrafts, furniture and as construction materials. This is because unlike the conventional materials such as steel, wood, aluminum and concrete, fiber reinforced composites have excellent specific mechanical properties (high strength to weight ratio), corrosion resistance and are low cost (Garkhail et al., 2000 and Sheikh and Channiwalla, 2010).

Several studies that have been done showed that, generally, the properties of fiber reinforced composites are governed by the factors such as the type, amount and composition of the resin and reinforcement material s, processing conditions, laminate thickness and additives used. If the proper curing conditions of resins in particular are provided and the right quantities of additives are used then, the anticipated properties dictated by the resin and fiber type selected would be attained (Visco et al.,2007). This indicates that the selection of the material type and quantities and the processing conditions should be carefully selected for quality and economically feasible product to be produced.

As reported by El-Wazery et al., (2017), a satisfactory cure of the resins is influenced by the overall thickness of the layer to be cured, the gel time required, and the working temperatures. Laminate thickness and quantity of catalyst as an additive, plays a significant role in the cure time of the laminate since it affects the exothermic temperature and hence properties of the composite (Ling et al., 2004). However, there is limited information on how these factors relate to the properties of the particular composite product. The focus of this research was to study the effect of laminate thickness and the quantity of catalyst on the curing of glass reinforced polyester composite laminates that could be used in the manufacture of furniture.

2. Materials and Methods

2.1. Production of Laminate Samples

The samples were made from pre-accelerated unsaturated polyester resin impregnated on E- glass fiber. Various samples sizes thicknesses were produced by combining different fiberglass m at

sizes using hand lay-up processing technique. Dimension of the mould used to prepare the samples was 0.45 m long by 0.15 m wide by 0.004 m thick and was made from flat glass plates. Quantity of catalyst was varied from 0.5% to 5% by volume of the resin for each selected laminate thickness which ranged from 0.5 mm to 3 mm. The selection of thickness range was based on the thickness to which most of the furniture manufactured from fiber reinforced plastic fall under. The following procedure was followed in production the samples:

1) The mould was cleaned with warm soapy water then wiped to dry.
2) Mirror wax polish was applied and then wiped with cotton waste to remove any impurities on the mould.
3) To facilitate the removal of the sample from the mould, releasing agent was applied on the polished mould surface.
4) The gel coat was then applied on the mould and left to dry.
5) Glass-fiber mat was spread over the gel coat and a layer of catalyzed resin brushed on the mat surface before rolling using a squeegee to remove the air bubbles.
6) The sample was then left to cure and the curing time was taken once the laminate is hardened.

2.2. Data Analysis

The Statistical Analysis Software (SAS) was used in data analysis. Analysis of variance (ANOVA) was performed on the treatment means for each parameter. Least Significance Difference (LSD) was performed at 5% level of significance to examine whether there was significance difference in the means.

3. Results and Discussion

The results on the effect of laminate thickness and quantity of catalyst on the curing time of the composite are shown in Table 1 and the graphical presentation is shown in Figure 1 where as analysis of variance results from Statistical Analysis System (SAS) are shown in Table 2.

Table 1: Mean Curing Time (min) for varying Laminate Thickness and Catalyst Levels
Thickness

Thickness (mm)	Catalyst (%)						Overall (Lsd=5.152)
	0.5	1	2	3	4	5	
1	300	284	115	110	94	71	162.3^a
1.5	280	230	105	80	75	50	136.7^b
2	215	200	94	72	43	35	109.8^c
2.5	185	172	84	70	33	30	95.7^d
3	150	143	80	60	28	25	81.0^e
Overall (Lsd=5.64)	226.0^u	205.8^v	95.6^w	78.4^x	54.6^y	42.2^z	

Note: Means followed by the same letter(s)(a,b,c,d,e) in same column; (u,v,w,x,y,z) in same row are not significantly different at 5% level of significance using LSD.
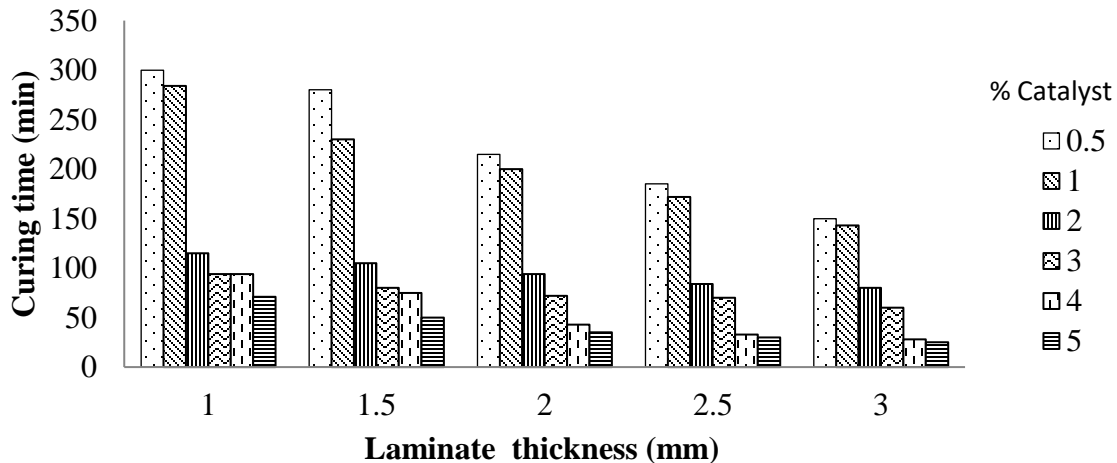
Figure 1: Curing time verses laminate thickness

Table 2: Statistical Analysis System Results for Analysis of Variance of the Effect of Laminate Thickness and Quantity of Catalyst on Curing time

Source	DF	Sum of squares	Mean of squares	F value	Pr>F
Model	29	572300.11	9734.4862	330.56	<0.0001
Laminate Thickness	4	76397.61	9099.4000	319.92	<0.0001
Quantity of Catalyst	5	468046.59	3609.3000	1567.99	<0.0001
Laminate Thickness * Quantity of Catalyst	20	27856.0	1392.8000	23.33	<0.0001
Error	60	3582.0	59.7000		
Corrected Total	89	575882.1			

Dependent Variable: Curing Time
R-Square = 0.993780; C.V = 6.598273; Curing Time Mean = 117.1000

From Table 1, and Figure 1, it is observed generally that curing time increased with laminate thickness. When laminate thickness was 1mm the mean curing time was 162.3 minutes, whereas at 3mm, it reduced to 81.0 minutes. Statistical analysis shown in Table 2 also depicts that curing time was significantly influenced by the thickness of the laminate at 5% level of confidence. This could be attributed to the fact that during polymer cross linking, heat is evolved which could have caused increase in temperature (exotherm) of the polymer catalyst mix. Thicker parts tend to have higher exotherms than thinner parts because heat is retained in the polymer thus causing the reaction to occur faster and consequently, even more heat to be evolved. Also thicker parts contain higher fiber content and therefore absorb the exothermic heat which increases the rate of reaction.

On the hand, the curing time was observed to be reducing with increasing quantity of catalyst. The mean curing time was 226.0 minutes at 0.5% catalysts. It reduced to 78.4 and 42.2 minutes at 3% and 5% catalyst respectively. From Figure 1, it is also observed that the mean curing time for 0.5% and 1% catalyst was relatively higher as compared to other percent catalyst level. Generally, at 5% level of confidence, the quantity of the catalyst had a significant effect on the curing time as indicated by the overall row in the Table 1. The significant decrease in curing time for a given level of catalyst concentration is primarily because of an increase in free radicals generated due to

decomposition of the catalyst. These free radicals initiate an exothermic co-polymerization reaction. In the course of co-polymerization, heat evolved resulted in temperature rise within the laminate consequently increasing the resin reaction rate. Kuang and Richardson, (2006) and Waigaonkar et al., (2011) reported the same trend in their studies.

Statistical analysis results shown in Table 2, shows that the effect of laminate thickness on the curing had an Fcal, α=0.05 value of 319.92 while that of quantity of catalyst was 1567.99. This suggests that both laminate thickness and quantity of catalyst had had significant effect on the curing time. However, the interaction between the two variables had minimal effect (Fcal, α=0.05 value of 23.33).

4. Conclusion

The curing time significantly reduced with increase in laminate thickness and quantity of catalyst of the glass reinforced composite which was attributed to increased exothermic process due to enhanced cross linking. It can be deduced that more heat evolved was at thicker parts of the composite which accelerated the polymerization process.

Acknowledgement

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