Effect of Sodium bicarbonate on Fire behaviour of filled E-Glass Reinforced Epoxy Composites

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Abstract- Composites such as fibre reinforced polymers give us the good mechanical properties, but their fire behaviour is not appreciable and needs to be improved. In this work, E-glass fiber is used as a reinforcement material and Epoxy resin is used as a matrix with particulate sodium bi-carbonate (NaHCO3) is used as additive. The hand lay-up technique is adopted for the development of composites by varying percentage of additive. All the tests were conducted according to ASTM standards to study the Fire behaviour of the developed composites. The different fire properties like Ignition time, mass loss rate and flame propagation rate of Fiber Reinforced Polymers (FRP) with NaHCO3 are compared with neat FRPs. It is found that the ignition time increases as the percentage of additive is increased.

1. Introduction

A composite is a combination of two or more materials with different properties and the resulting composite will have properties that differ from those of the combining ones. Fibre reinforced polymer (FRP) composites consists of Glass fibre as reinforcement and polymer as matrix. FRPs offer great advantage as they are light weight, exhibit good mechanical properties like high tensile strength, high impact strength, high fatigue strength and possess good corrosion resistance. The area of applications of FRP's include Aerospace, marine, ballistic armour as they give high strength to weight ratio.

Although the FRPs give great structural and mechanical properties they have poor fire properties. A.P Mouritz in his ASTB report [1] suggested that adding filler materials to polymer will help improving their fire behaviour. Also the use of low cost easily available fillers may be useful to bring the cost of component down. The fire behaviour of FRP's also influenced by area accessible to oxygen, heating rate and pressure [2]. Study of effect of such filler addition is necessary to ensure that the mechanical properties are not affected adversely by such an addition. There is a need for the design of aircraft cabins, boats with fire resistance polymers [3, 4] as there is a more chance of people getting injured by fire in case of any fire hazards. The purpose of use of fillers can be divided into two basic categories,

first, to improve the properties of the material and second, to reduce the cost of component. Now a variety of inorganic fillers have been used to change the properties of composites. In this work E-glass/epoxy based composites filled with varying concentrations of sodium bicarbonate ($NaHCO_3$) were prepared by hand lay-up technique [1]. The other techniques available are bladder moulding, compression moulding, vacuum bagging, filament welding. The objective of this work is to investigate the effect of $NaHCO_3$ on fire behaviour of E-glass fiber reinforced epoxy composites and comparison of results.

The effect of additives such as pentabromobenzylacrylate (PBBMA) and magnesium hydroxide on mechanical and flame retardant properties of polypropylene composites containing glass fibers. This work was done on the basis that addition of PBBMA and Mg (OH)2 has a positive effect on flame retardant properties and with minimal negative effect on mechanical properties [5]. Flame retardant epoxy resin based on novel reactive phosphorous-containing monomer (DODPP). They have investigated thermal properties and burning behaviors of cured epoxy resins by differential scanning calorimeter (DSC), Thermogravimetry (TG), LOI, UL-94 and cone calorimetry [6].

2. Materials and methods

2.1 Materials selection

In this work, E-Glass fiber of size 7-mill is chosen as the reinforcement material and Epoxy resin L-12 as the matrix material, as they fulfil majority of the requirements which are desired in this work. The properties of E-Glass fiber and Epoxy resin are as detailed below:

TABLE 1: Properties of E-Glass fibre and Epoxy resin

Properties	E-glass	Epoxy
Specific gravity	2.54 gm/cm^3	1.16 gm/cm^3
Young's modulus	70 GPa	3.792 GPa
Ultimate tensile strength	3447 MPa	82.74 MPa

E-Glass is electrical resistant glass providing good overall strength at low cost. It accounts for about 90% of all glass fiber reinforcements. It has good electrical resistance, and it is used in antennas because of its radio frequency transparency. It is also used in computer circuit boards to provide stiffness and electrical resistance.

Epoxy resin is polymers have higher mechanical properties, particularly dynamic and fatigue resistant properties and water resistance than polyesters. They exhibit low shrinkage during cure. They also have excellent adhesion characteristics. They have good heat and chemical resistance, good electrical properties. Epoxies generally have a slower cure. Epoxy resins should be considered where higher shear strength than is available with polyesters and the application requires good mechanical properties at elevated temperatures or durability.

Fillers are ingredients added to enhance the properties such as strength, surface texture, and ultraviolet absorption of a polymer and to enhance the flame retardant $NaHCO_3$ is used as filler materials. Hardener is a substance which is added to polymers for aiding in curing of composites. Approximately 10% of hardener is added while fabricating the composite materials. In this work K-6 (Epoxy hardener) is used as hardener.

2.2 Fabrication of composites

Fabrication of composites was done at room temperature by hand layup technique and the composites were cured at room temperature. The proper volume fraction of fibre, epoxy, fillers and orientation of fibres were controlled.

Hand lay-up technique is a low volume, labor intensive method suited especially for larger components, E-Glass is positioned manually in the open mould and resin is brushed over and into the glass pieces. Entrapped air is removed manually with rollers to complete the laminates structure. Room temperature curing epoxies and polyester are the most commonly used matrix resins [7]. Curing is initiated by a catalyst in the resin system, which hardens the fiber reinforced resin composite without external heat for a high quality part surface and release gel coat is first applied to the mould surface. Specimens each were prepared for different test from the below composites materials based on ASTM standards.

Figure 1: Representation of Hand Lay-Up Technique

Table 2: Nomenclatures of composite materials fabricated

Material Designation	% of glass fiber (Volume)	% of epoxy (Volume)	% of NaHCO$_3$(Volume)
GE	50	50	Nil
GESB$_1$	50	45	5
GESB$_2$	50	40	10
GESB$_3$	50	35	15
GESB$_4$	50	30	20

GE-Glass Fiber reinforced epoxy
GESB-Glass Fiber reinforced epoxy resin with sodium bi-carbonate

3. Experimentation

3.1 Fire behaviour Test: The fire properties of composite materials depend on several factors such as the type of material, fire conditions, and test method used to measure the property [8].

a.   Vertical UL94 Test:

Rectangular shaped samples with dimensions of 127x12.7x3.2mm are exposed vertically to a methane gas burner flame as required by UL94V [7]. The samples ignited at the bottom and burns upward. The time required for the flame to self-extinguish after the burner removal is measured and the occurrence

of dripping on to a piece of cotton placed underneath the sample is recorded. Test is repeated for different samples. This test also classifies the materials as V-0, V-1 and V-2.

V-0 = specimens not burn more than 10 Sec and the drip do not ignite the cotton.

V-1= specimens not burn more than 30 Sec and the drip do not ignite the cotton.

V-2= specimens not burn more than 30 Sec and the drip ignite the cotton.

If the entire sample is consumed the material is classified as non-rated (NR).

b. Time to ignition:

Time to ignition is the period of time that a combustible material can with stand exposure to a constant heat flux before igniting and undergoing sustained flaming combustion, more simply, it is the time taken for a material to start burning. The ignition time can be used as a rough measure of the flammability resistance of material. Obviously it is desirable to use material with long ignition times in high fire risk applications. Extending the time- to- ignition value reduces the fire hazard of composite material used in an aircraft. The unit of time-to-ignition is seconds (Sec) [9].

The **Mass loss rate** is calculated as,

$$\frac{\text{Initialweight} - \text{finalweight}}{\text{Total flame time} - \text{Ignition time}} \text{ , gm/sec}$$

The **Flame Propagation rate** is calculated as,

$$\frac{\text{Initial length} - \text{final length}}{\text{Total flame time} - \text{Ignition time}} \text{ , mm/sec}$$

4. Result and discussions

The addition of sodium bicarbonate improved the fire properties like time to ignition, flame propagation rate, mass loss rate are shown and compared with the graph below.
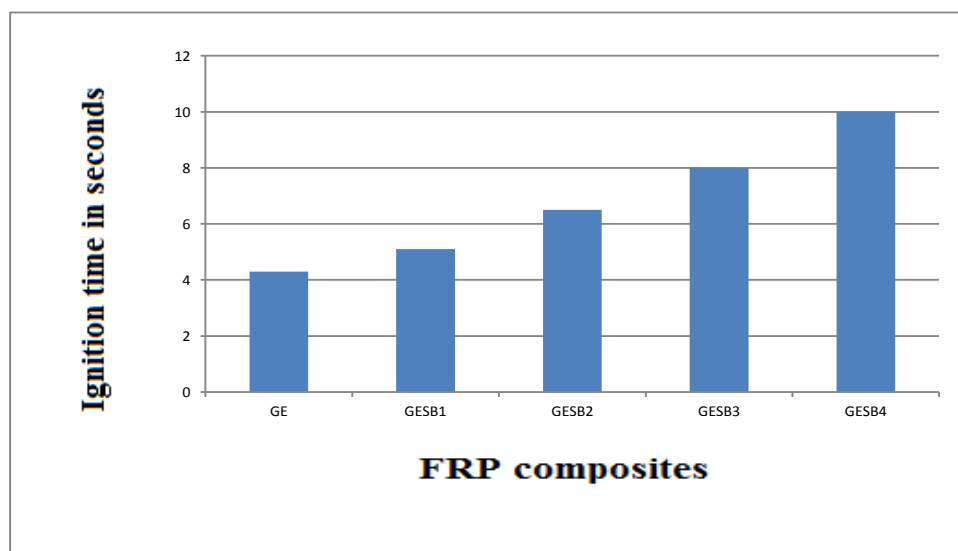

Figure 2: Comparison of Ignition time for different FRP composites

From the above graph, it can be seen that as the percentage of $NaHCO_3$ is increased, the ignition time is also increased. So $NaHCO_3$ added FRPs give better ignition time.
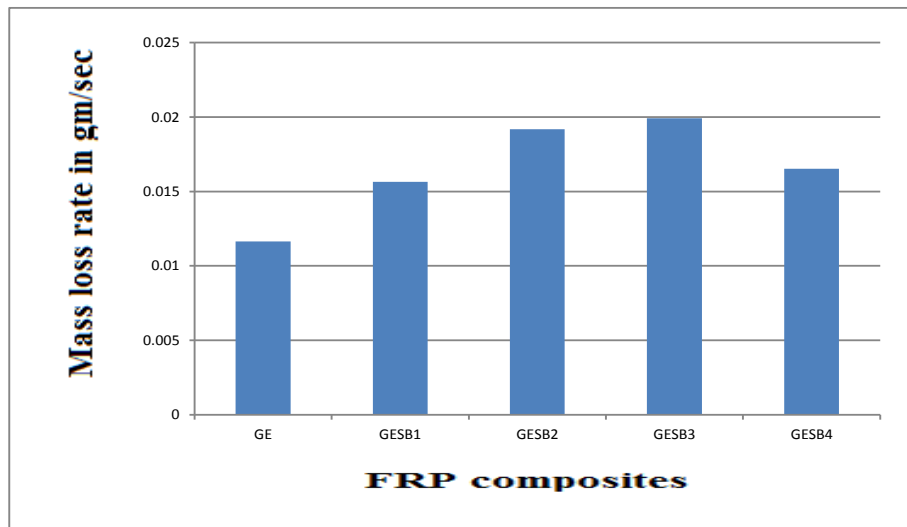
Figure 3: Comparison of mass loss rate of different FRP composites

From the above graph, the mass loss rate is increasing for 5% to 15% of NaHCO$_3$ but found to be decreasing on further addition of NaHCO$_3$. It is due to the reaction of hydrogen with atmospheric oxygen which leads to the formation of water molecules that retards the fire propagation and hence the mass loss rate [10].
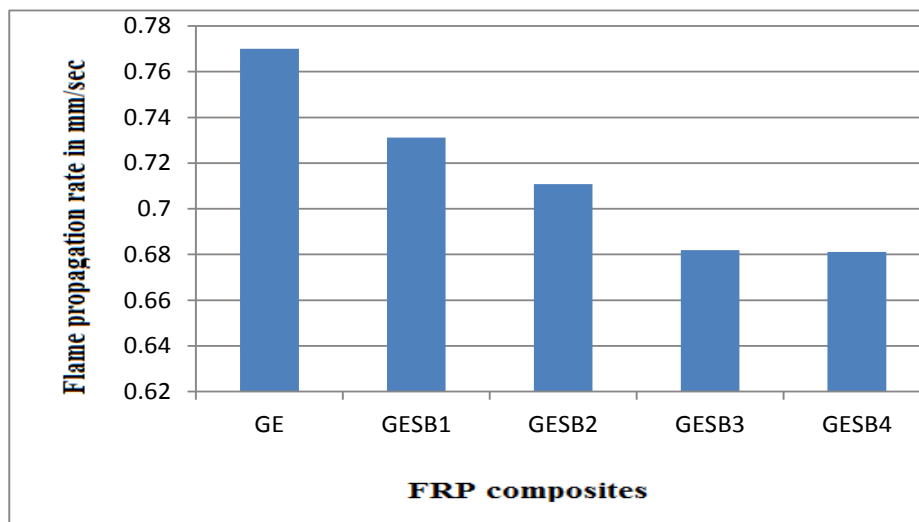

Figure 4: Comparison of flame propagation rates of different percentage of NaHCO3 filled FRPs

The flame propagation rate for FRPs with NaHCO3 filler particles is lower than the neat FRP as shown in the above graph. The flame propagation rate decreases proportionately with the percentage increase in NaHCO3 since the water molecule formation takes place when these specimens subjected to fire. But this behaviour is not likely to be continued after 15% addition of NaHCO3, because of the decreasing bonding strength which leads to lower total time of burning [11].

Flame retardant ternary composites of polymer/cross-linked rubber/Nano-magnesium hydroxide (MH), by blending thermoplastic polymer with a special compound powder of cross-linked

rubber/Nano-MH. The cone testing results showed that the new flame –retardant ternary composite had better flame retardancy than the composite obtained by conventional process, such as longer time to ignition and lower mean heat release rate in initial time, this is due to more uniform dispersion of Nano-MH in the ternary composite than in conventional one [12]. Fire resistance properties of bio-composite sandwich plates were manufactured by combining an inorganic potassium alumino silicate binder with waste sawdust and several plates were strengthened with carbon and glass fiber reinforcements to create more durable sandwich structure. Based the test results obtained from the fire testing, increasing the inorganic binder content reduces the heat release rate of the bio-composite. The addition of fiber reinforcement facings decreases the amount of smoke released by the bio-composite sandwich plate. Bio-composites with all carbon reinforcement produced 5 times less smoke than facings [13].

6. Conclusions

From the work it can concluded that, as the percentage of volume of $NaHCO_3$ increases ignition time also increases. In this case the maximum ignition time was found for $GESB_4$. In mass loss rate it was found to be increasing up to 15% volume of $NaHCO_3$ later reduces due to poor interfacial bonding. The flame propagation rate was minimum for 15% and 20% of $NaHCO_3$ compared with other compositions. Finally, addition of $NaHCO_3$ will improve the fire behaviour of FRP composites.

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