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Use of non-traditional fillers to reduce flammability of polyester resin composites

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Abstract

This work reports the use of non-traditional fillers as flame retardants in polyester resin composites. Studies have been carried out to evaluate the fire-retardant properties of non-traditional fillers viz. hydroxyapatite, zinc borate and fly ash in combination with traditional fire retardant filler antimony trioxide, in prepolymer polyester resin composite system. Polyester resin was synthesized using phthalic anhydride (PA), maleic anhydride (MAN) and propylene glycol (PG). Flammability properties studied using limiting oxygen index suggests that incorporation of non-traditional fillers increases fire retardancy with considerable improvement in mechanical properties. However, the effectiveness of fillers as flame retardants depends on several factors including the type of fillers and incorporation level of the fillers. The use of antimony trioxide and fly ash increases the fire resistance behavior but there is decrease in mechanical properties and thermal stability. The results reveal that good improvement in fire resistance with considerable increase in mechanical properties and thermal stability was obtained with 30% zinc borate as filler.

KEY WORDS:
composites
flammability
non-traditional fillers
polyester resin

KLJUČNE RIJEČI:
kompoziti
gorivost
netradicionalna punila
poliesterska smola

Uporaba netradicionalnih punila za smanjivanje gorivosti poliesterskih kompozita

Sažetak

Prikazane su mogućnosti primjene netradicionalnih punila kao usporavala gorenja za kompozite na osnovi poliesterskih smola. Provedena su ispitivanja radi procjene svojstava usporavanja gorenja netradicionalnih punila, odnosno hidroksiapatita, cinkova borata i lebdećeg pepela u kombinaciji s tradicionalnim punilom antimonovim trioksidom u pretpolimernome kompozitnom sustavu. Poliesterska smola sintetizirana je reakcijom ftalnog anhidrida (PA), maleinskog anhidrida (MAN) i propilenglikola (PG). Ispitivanje svojstva gorivosti određivanjem graničnog indeksa kisika pokazuje da dodavanje netradicionalnih punila smanjuje gorivost uz znatno poboljšanje mehaničkih svojstava. Međutim, učinkovitost punila kao usporavala gorenja ovisi o nekoliko čimbenika, uključujući vrstu punila i razinu uključivanja punila. Uporaba antimonova trioksida i lebdećeg pepela povećava otpornost na gorenje, ali dovodi do sniženja mehaničkih svojstava i toplinske postojanosti. Rezultati pokazuju da se dobro poboljšanje otpornosti na gorenje uz znatno poboljšanje mehaničkih svojstava i toplinske postojanosti postiže s 30 % cinkova borata kao punila.

Introduction

Polyester resins are one of the most important matrix materials for commodity glass fiber reinforced composites.[1] For many years, polyester resin composites have been used in very varied technologies, like naval constructions, off-shore applications, water pipes, building construction, automotive applications etc.[2-8] Polyester resins exhibit several useful characteristics due to the high degree of cross-linking between individual polymer chains.[9] Typical qualities include a high glass transition temperature, high modulus and specific strength, creep resistance and good solvent resistance. Superior properties, coupled with ease of processing have led to numerous applications of these polymers, perhaps most important as matrix materials for fiber-reinforced composites.

Actually, these materials have a number of benefits as compared with traditionally used metal-based materials as they are light in weight, non-magnetic, corrosion-proof etc. However, the use of these materials is limited due to their poor fire performance.[10]

Flame retardation is a process by which the normal combustion processes of polymers are altered by the addition of certain chemicals. Some polymeric materials are fire-retardant or smoke-retardant and their fire performance is acceptable for certain applications. However, for many polymeric materials, it is necessary to improve their fire performance by incorporating commercially available flame retardants. Fire retardants are expected to be effective in improving fire performance without excessive loss of other important performance characteristics. Increase in environmental awareness has directly or indirectly affected polymers and flammability in various ways. Concern about the atmospheric ozone layer has reduced the use of chlorofluorocarbons and increased their replacement by alternate materials. However, chlorofluorocarbons contribute more to fire resistance performance and the alternate materials may contribute less.

The fire behavior of composites can be improved in a number of ways by using additives,[11-21] or halogenated raw materials[22] etc. The use of halogenated raw materials in place of traditional raw materials for the synthesis of polyester resins evolves toxic gases during fire and possibly corrosive smoke.[23] In the past, the flammability rating of polyester resins was increased by incorporating halogens. Reactive halogenated flame retardants are hexachloroendomethylene-tetrahydrophtalic acid (HET-acid) or its anhydride, tetrabromphtalic anhydride or dibromoneopentyl glycol. Ethoxylated tetrabrombisphenol-A was also used as a flame retardant and antimony trioxide as a synergist. When halogenated resins burn, they generate smoke and toxic fumes, which is unacceptable for indoor applications.[24]

A wide range of non-traditional flame retardants was used to improve the fire resistance of polyester system. Further, the effects of different kinds and amount of non-traditional fillers were analyzed. The aim was to establish the effect of these non-traditional fillers on the flame behavior of the polyester system and to make comparison with the unfilled polyester system. At present halogenated compounds used in synergism with antimony are considered to be the most efficient flame retardant, but current research is looking towards environmentally friendly additives.

The aim of this work was to prepare halogen-free fire resistance polyester resin based composites and study the thermal and the fire behavior of natural materials like non-traditional mineral fillers. The study indicates that the mechanical performance, fire resistance properties and thermal behavior of the composites are dependent on the types and amount of fillers. Also eco-friendly and cost-effective composites can be formulated with competitive performance by using cheaper and widely available fillers. These results are encouraging and have potential to expand the horizon of their applications in the areas of marine, automotive, electric and electronic, building, construction, sport and leisure, domestic and sanitary appliances, furniture as well as military and also eco-friendly and cost effective composites were prepared by using non-traditional fillers.

Experimental

Materials

Phthalic anhydride, maleic anhydride, propylene glycol, styrene, hydroquinone and p-toluene sulfonic acid have been purchased from *S. D. Fine Chem.* Ltd. Vadodra, Gujarat, India. All the above materials are of Analar grade. Hydroxyapatite, zinc borate and antimony trioxide were obtained from Chiti-Chem Ltd. Vadodara, Gujarat, India. Fly ash was obtained from Vanakbori Thermal Power Station, Vanakbori, Gujarat, India. The details of different fillers used in this work are given as below.

Hydroxyapatite

The formula of hydroxyapatite is $Ca_{10}(PO_4)_6(OH)_2$. It forms part of the crystallographic family of apatites, isomorphic compounds with the same hexagonal structure. Hydroxyapatite can be found in nature or synthesized by precipitation method using chemical reagents. It is also known as calcium phosphate. This compound is most commonly used for biomaterial and fire resistant applications. This compound can be physically blended in polymers to suppress, reduce, delay or modify the propagation of flame through polymeric materials. The fire-retardant property of hydroxyapatite is due to the presence of phosphate. The technical specifications of hydroxyapatite used in this work are given below:

1. Ca/P molar ratio: 1.61-1.71
2. crystalline hydroxyapatite content: 95%
3. grain size: 1500-2000 mesh
4. moisture: 1% max.

Zinc borate

Zink borate, $2ZnO\ 3B_2O_3\ 3.5H_2O$, is a white crystal powder, which does not dissolve in water and other organic solvent but it does dissolve in hydrochloric and sulfuric acid. It has good thermal stability, lower density and good miscibility with most of the polymers. Zinc borate shows excellent fire resistance performance and can be therefore widely used in polymer, rubber, fiber, paint and ceramic industries. The technical specifications of zinc borate used in this work are given below:

1. B_2O_3: 48%
2. ZnO: 37%
3. particle size: 1250 mesh – 1850 mesh
4. loss on ignition: 13.50 - 15.50%
5. moisture: 1.0% max.

Fly ash

Fly ash is the finely divided mineral residue resulting from the combustion of coal in electric generating plant. Fly ash consists of inorganic matter present in the coal that has been fused during coal combustion. This material is solidified while suspended in the exhaust gases and is collected from the exhaust gases by electrostatic precipitators and is usually of silt sizes (0.074 - 0.005mm). Fly ash is a pozzolanic material and has been classified into two classes F and C based on the chemical composition of fly ash. In the present study class C fly ash was used. Class C fly ash is produced normally from lignite and sub-bituminous coals. The technical specifications of fly ash used in this work are given below:

1. silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3): 55.0%
2. sulfur trioxide (SO_3): 5.0%
3. moisture content: 3.0% max.
4. loss on ignition: 6.0%

Antimony trioxide

The formula of antimony trioxide is Sb_2O_3. It is a solid white powder and is used mainly as fire retardant additive and as pigment. The substance comes in various grades, depending on particle size. The breakdown of particle size affects both physical properties and pigment property. The finer fraction is used for pigmentation. The flame-retardant property, however, is not affected by particle size. This property is based on antimony trioxide reacting in the event of fire with the surrounding material, with the result that a protective layer of various antimony compounds covers the combustible materials. Since the formation of these compounds consumes heat and because they are generally difficult to ignite, they protect the underlying material from ignition. The technical specifications of antimony trioxide used in this work are given as below:

1. total antimony oxide content: 99.50%
2. bulk density: 0.3 - 1.0gms/cc
3. average particle size: 1.1μm

Synthesis of polyester resin

Polyester resin (Figure 1) was prepared in the present work using the technique reported by T. Sunemi Hidenari.[25] A mixture of 1.25 mol propylene glycol (PG), 0.5 mol phthalic anhydride, 0.2% p-toluene sulfonic acid (PTSA) and xylene as solvent was charged in a three-neck reaction kettle equipped with stirrer, thermometer, nitrogen-gas introducing tube, separator and water condenser. The mixture was mechanically stirred and heated at 120°C under nitrogen gas stream. When the reaction mass becomes clear, it was allowed to cool to 80°C and then 0.5 mol maleic anhydride (MAN) was added and heating at 150-200°C continued until an acid number of 20 was reached. During esterification reaction, water formed as by-product and was continuously removed from the reaction mass as it inhibits the rate of reaction. The xylene was completely distilled out and the reaction product was allowed to cool. When the temperature reached 160°C, 20mg of hydroquinone was added as inhibitor and when resin temperature dropped below the boiling point of reactive diluent (i.e. styrene), the polyester resin was mixed with styrene by 35 weight percent by resin.[26]

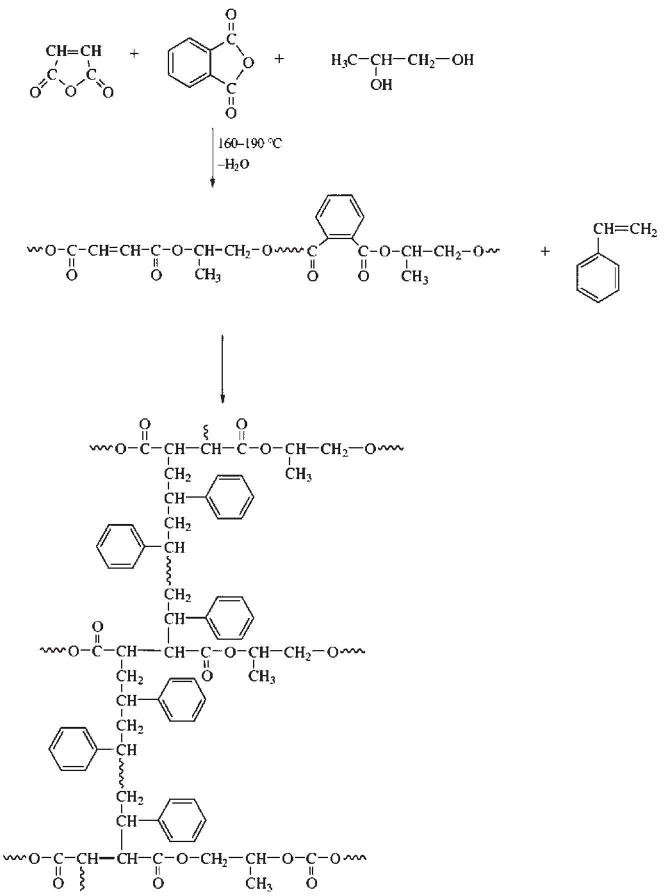

FIGURE 1 - Polyester resin scheme with crosslinking

Fire resistance formulation and composite preparation

Prepolymer polyester resin was mixed with non-traditional fillers like fly ash, zinc borate and hydroxyapatite in combination with traditional filler antimony trioxide (Table 1). Several combinations were tested to determine effects of each additive in the polymer formulations. Fire resistance formulations were prepared by adding various additives viz: antimony trioxide, fly ash, zinc borate and hydroxyapatite in different amounts (10 to 30 wt %) in prepolymer polyester resin.

Additives in different amount were mixed with prepolymer polyester resin in a round bottom flask equipped with high speed agitator. The resultant formulations were compounded with glass fiber as reinforcing materials and benzoyl peroxide as initiator for composite preparation. Composites were prepared by hand lay-up technique using about 50 weight percent of glass fiber and filler. After application of resin on glass fiber the composites were cured by compression moulding at 7 bar pressure and 120°C temperature for 30 minutes. Two percent benzoyl peroxide (BPO) was used as initiator.

The composites obtained from fire resistance formulations were characterized by Limiting oxygen index, (LOI), according to *ASTM D-2863*,[27] thermogravimetric analysis (TGA) and IR spectroscopy.

Result and discussion

Prepolymer polyester resin synthesized by above procedure was analyzed by FTIR, GPC and TGA. Analyzed prepolymer polyester was used for preparation of fire resistance formulation by dispersing various fillers and for composite preparation using glass fiber as reinforcing material.

Gel Permeation chromatography (GPC) of polyester resin

GPC is one of the most powerful and versatile analytic technique available for understanding and predicting polymer performance. It is the only proven technique for characterizing of polymer by its complete molecular weight distribution. GPC of prepolymer polyester resin was done by using Perkin Elmer 200 GPC instrument. The HPLC grade tetrahydrofuran (THF) was used as a mobile phase at a flow rate of 1.0 ml/min. The GPC system was equipped with two ultrastyragel columns packed with styrene-DVB copolymers of 0.1 and 100 mm porosity connected in series to cover an exclusion limit of $2 \cdot 10^2$ to $10 \cdot 10^6$. Refractive index detector was used with internal temperature of 35°C for peak detection. The GPC system was calibrated with eight different polystyrene standards having molecular weight ranging from $2 \cdot 10^3$ to $2.5 \cdot 10^6$. The number average ($\bar{M}_w$) of polyester resin sample is 1554, weight average ($\bar{M}_w$) is 3576 and polydispersity ($\bar{M}_w/\bar{M}_n$) is 2.301. Gel permeation chromatography of polyester resin is shown in Figure 2.

Spectral analysis of polyester resin

An IR spectrum of prepolymer polyester resin is shown in Figure 3. A *Nicolet Impact* 400D FT-IR spectrophotometer was employed for the measurements. The spectrum was run by applying resin sample on KBr cell covering the range of frequencies from 4000-400 cm^{-1} with scanning period of 20 seconds. The crushed powder sample (2-3mg) of composites in the form of a pellet was prepared by mixing with dry KBr (1g) for cured resin. The spectrophotometer was set at 100% transmittance with pure KBr pellet. A strong absorption band at 755cm^{-1} and a weak band at 1004cm^{-1} can be

TABLE 1 - Compositions and fire resistance properties of composites from polyester resin

Composite code	Resin composition, Wt %	Reinforced cement, Wt %	Fillers, Wt %				Limiting Oxygen Index (LOI), %
			Sb_2O_3	Fly Ash	Hydroxy-apatite	Zinc borate	
FRC-1	100	100	-	-	-	-	21
FRC-2	100	70	30	-	-	-	25
FRC-3	100	70	20	10	-	-	27
FRC-4	100	70	10	20	-	-	29
FRC-5	100	70	-	30	-	-	31
FRC-6	100	70	20	-	10	-	28
FRC-7	100	70	10	-	20	-	30
FRC-8	100	70	-	-	30	-	32
FRC-9	100	70	20	-	-	10	32
FRC-10	100	70	10	-	-	20	34
FRC-11	100	70	-	-	-	30	37

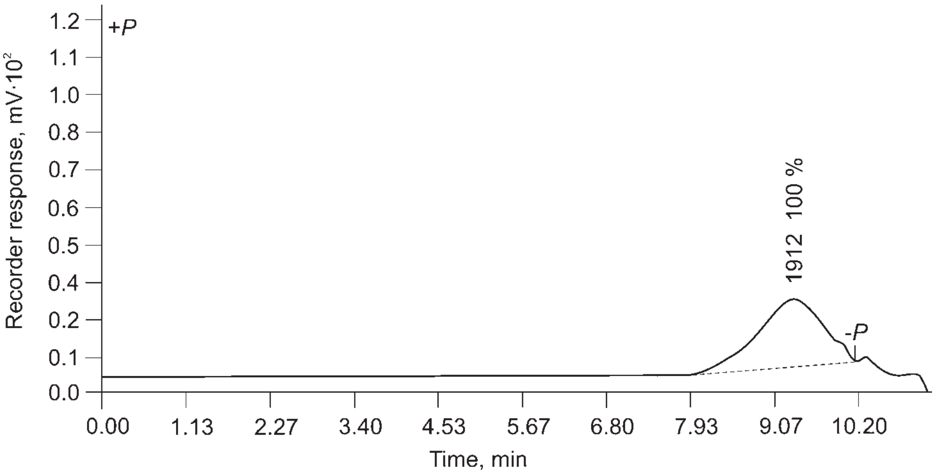

FIGURE 2 – GPC of polyester resin

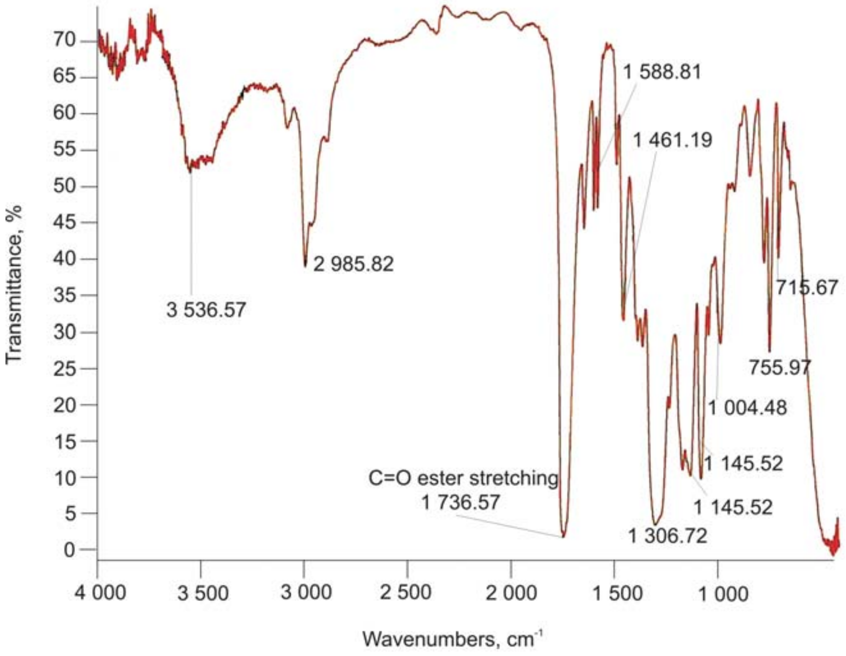

FIGURE 3 – IR spectra of polyester resin

attributed to -C-H bending arising from 1 and 3 position in benzene ring and –C=CH bending arising from isomerization of maleic anhydride to fumarate during polymerization. A broad-spectrum absorption bend at 1145cm^{-1} confirms the presence of –C-O-C- of ester linkage. A strong absorption peak appearing at 1306cm^{-1} was assigned to –C=C– group of polyester. A medium absorption band at 1461cm^{-1} can be attributed to –C-H bending. The presence of –C=O and symmetric –CH stretching was confirmed by the presence of strong bend at 1736cm^{-1} and 2985cm^{-1} respectively. The band at 1736cm^{-1} confirms the presence of –C=O ester group and also confirms the formation of polyester resin. In addition to this, the disappearance of anhydride peak at 1755cm^{-1} in maleic anhydride & phthalic anhydride and hydroxyl peak at 1375cm^{-1} propylene glycol confirms the formation of polyester.

An IR spectrum of cured polyester resin is shown in Figure 4. The band at around 2985cm^{-1} became sharper and bands due to –CH=CH- group almost disappeared in composite and a new sharp band at 1447cm^{-1} became visible in the IR spectrum of composite. This indicates the presence of alkane group, which can be clearly attributed to the participation of –CH=CH- group in the curing process and the conversion of this group to alkane during the crosslinking process.

IR-spectrum of polyester resin (before and after curing) clearly revealed that most of all the absorption bands observed show the same intensity, but the band around 2960cm^{-1} became sharper and bands due to –CH=CH- group almost disappeared in the cured polyester resin and a new sharp band at 1490cm^{-1} became visible in the IR spectrum of composite. This indicates the presence of alkane group, which can be clearly attributed to the participation of –CH=CH- group in the curing process and conversion of these groups to alkane during the crosslinking process.

Thermogravimetric analysis (TGA)

The thermogravimetric analysis (TGA) of the cured composites was carried out on *TA Instruments*, USA model 5000/2960. This instrument measures the weight loss as well as the rate of weight loss of a material continuously as a function of increase in temperature. The present study concerns the percentage weight loss of the material at different temperature at a heating rate of 10°C/min.

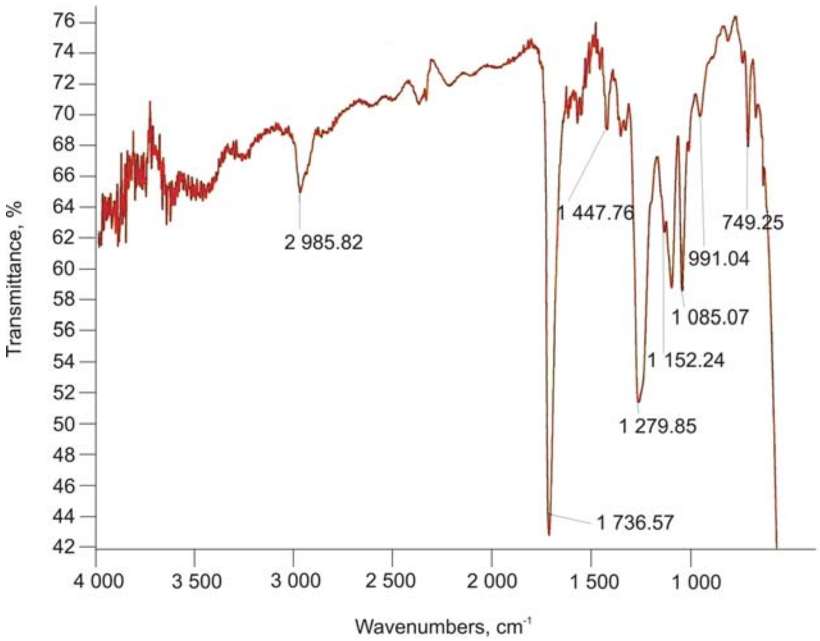

FIGURE 4 – IR spectra of FRC-1

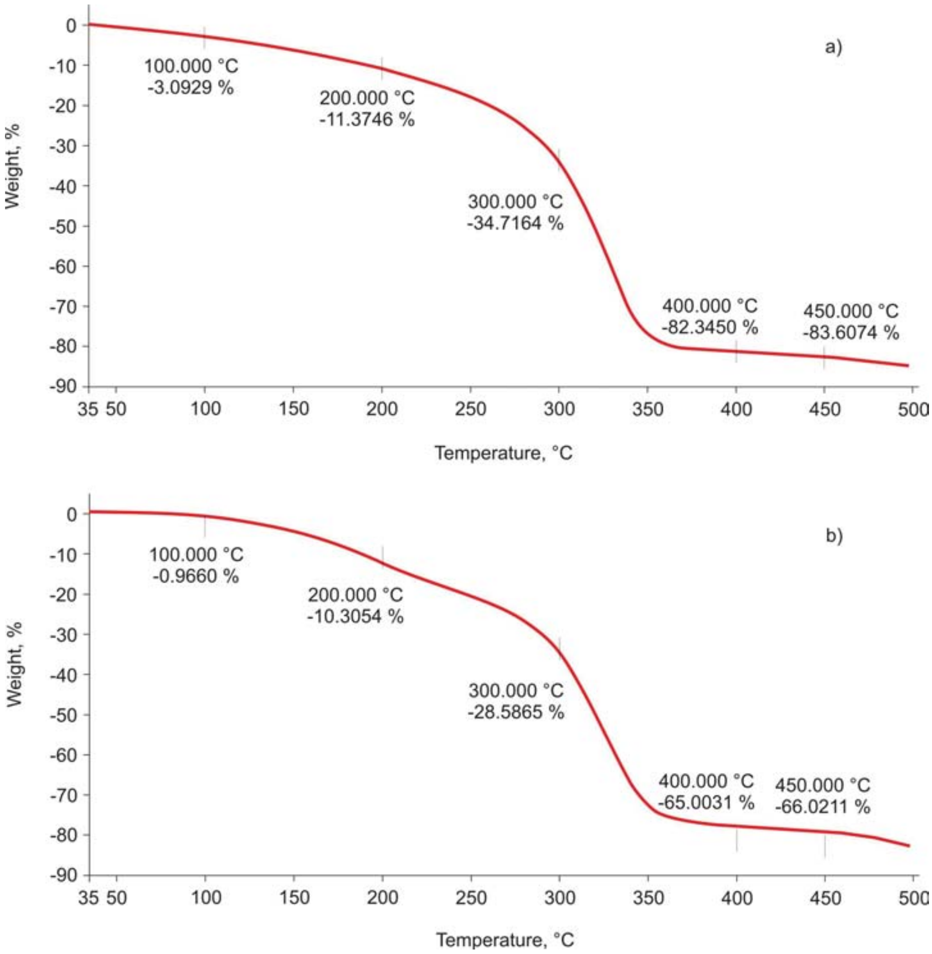

FIGURE 5 – a) Thermogram of FRC-1, b) Thermogram of FRC-5

The specimen for analysis was kept in an oven at 35°C under vacuum overnight. The specimen container i.e., the boat made from aluminium foil, which would hold the polymeric specimen for the thermal analysis was washed properly and dried. It was suspended on a quartz rod in the thermo balance of instrument. The cured specimen (about 8 to 12mg from the flash area containing no fibers) was placed in the boat and suspended on the quartz rod in an atmosphere of nitrogen gas. The weight of the specimen was noted on the TGA balance. The whole assembly was introduced into the furnace and the experiment started by heating the system at constant and definite rate throughout the experiment. Simultaneous change in weight was recorded automatically with the time while temperature was increased at a known uniform rate (10°C/min). This will reveal loss in weight of material as a function of time and also of temperature. The experiment was stopped when no further change in weight could be observed on further heating. The present study deals with the thermal analysis (Figure 5a and 5b) of prepolymer polyester resins. Proper knowledge of the thermal stability of polymers is essential for their appropriate applications.[28-30] The thermal behavior of polymers with reference to their thermal stability is of paramount importance. In most of the processing techniques of thermosetting polymers, the curing process is involved in which the polymeric or oligomeric polyfunctional reactive groups are transformed into a cross-linked macromolecular three-dimensional structure. The thermal methods of characterization are very useful to understand the curing reactions and working temperature range of thermosetting polymers.

The TGA thermograms of all the composites indicate a similar decomposition pattern of two steps degradation. The first step can be assigned to degradation of resin part and the second one to that of the filler part. The initial decomposition in almost all composites starts at around 200°C with only 3-7% loss which clearly shows very good thermal stability of these composites up to 200°C. In unfilled composite (Figure 5a) loss of weight at 100, 200, 300, 400 and 450°C is -3.09, -11.37, -34.71, -82.60 and -83.60%, respectively. In the filled composite (Figure 5b) loss of weight at 100, 200, 300, 400 and 450°C is -0.96, -10.30, -28.58, -65.00 and -66.02%, respectively. The filled composites show better thermal stability than unfilled composites.

Fire resistance properties of composites

In this work, fire behavior of composites was evaluated. Many procedures exist to evaluate fire behavior of the composite materials.[31-32] The key fire resistance properties of interest for polymers to be used in fire resistance applications are ease of ignition, flame spread, ease of extinction, smoke obscuration, smoke toxicity, heat release rate and limiting oxygen index. In the present study the limiting oxygen index (ASTM D-2863) was determined to characterize the composites.

Limiting oxygen index (LOI) ASTM D-2863

Fennimore and Martin developed this method.[33] LOI is defined as the measure of minimum amount of oxygen in an environment ($O_2 + N_2$) necessary to initiate and support the burning (flame) under specified conditions. ASTM D2863 is a method to determine the minimum concentration of oxygen in an oxygen/nitrogen mixture that will support a burning of test specimen. The specimen used for LOI test, being 150mm long, 10mm wide and 4mm thick. The apparatus used for LOI was *Stanton Redcroft* FTA flammability unit. The test sample is positioned vertically in a glass chimney and an oxygen/nitrogen environment is established with a flow from the bottom of the chimney. The top edge of the test sample is ignited and the oxygen concentration in the flow is decreased until the flame is no longer supported. The Oxygen Index is calculated from the final oxygen concentrations tested. This is a very simple and advantageous method for assessing fire resistance of polymers. The critical amount of oxygen was measured. LOI is expressed in percentage as:

$$LOI = \frac{[O_2]}{[O_2]+[N_2]} \cdot 100$$

The limiting oxygen index was evaluated for all the composites filled with different weight percentage of fillers. Table 1 represents the limiting oxygen index of filled and unfilled composites. In the present study the values of limiting oxygen index of filled composites are in the range of 25-37. In practice the material is often called self extinguishing material if LOI is greater than 26.[34] Thus the results of the present study are in good agreement with the reported values. The results clearly indicate that the composites of the present study can be used in all fire resistance applications. The composites prepared using fillers give better fire resistance than unfilled composites and also there is increase in fire resistance with the increase in the amount of filler.

The fire behavior of polymeric matrices can be improved by adding non-traditional fillers such as fly ash, hydroxyapatite and zinc borate in combination with antimony trioxide. Hydroxyapatite and zinc borate give good results as compared to other fillers. Tests show that the fire results are good with decrease in heat and smoke production during combustion and also decomposition does not release additional toxic gases. Hydroxyapatite and zinc borate filled composites having very good thermal stability as compared to other composites and also all filled composites show better thermal stability than unfilled composites.

Mechanical properties of composites

Mechanical properties measured in this study include Izod impact strength, Rockwell hardness and flexural strength.

Izod impact strength

The impact properties of the polymeric materials are directly related to the overall toughness of the material. The objective of the Izod impact test is to measure the relative susceptibility of a standard test specimen to the pendulum type impact load. The results are expressed in terms of kinetic energy consumed by the pendulum in order to break the specimen. A study of Izod impact strength was carried out in terms of resistance to breakage under high velocity impact conditions, according to ASTM D-256.[35]

Zwick model *No. 8900 Impact Machine* was used for the present study. For the measurement, a specimen was cut from the fabricated composite (6.4 · 1.27 cm^2) and V notched (2.5 mm) at the middle. The test specimen was clamped into position so that the notched end of the specimen remained facing the striking edge of the pendulum. The impact test indicates the energy to break the standard test specimen of specified size under the stipulated conditions of specimen mounting and pendulum velocity at impact. All the measurements were carried out at room temperature.

Rockwell hardness

Hardness of material is defined as the resistance to deformation, particularly permanent deformation, indentation or scratching. The Rockwell hardness test measures the net increase in depth impression as the load on an indentor is increased from a fixed minor to a major load and then returned to minor load. Rockwell Hardness study was carried out at room temperature according to standard method of testing ASTM D-785.[36]

In the present study, Rockwell hardness tester model *RAS/Saroj Engg*. Udyog Pvt. Ltd., Jaysingpur was used. The load of 98N was applied for each measurement. The specimen with parallel flat surfaces was placed on the avail of the apparatus and minor load (98N) was applied by lowering the steel ball onto the surface of the specimen. The dial was adjusted to zero on the scale under minor load and the major load (980N) was immediately applied by releasing the trip lever. After 15 seconds the major load was removed and the specimen was allowed to recover for 15 seconds. Rockwell hardness was read directly on the dial.

Flexural strength

One of the most important mechanical properties of interest for any comparison of rigid materials is the modulus of rupture. Flexural strength is the ability of the material to withstand bending forces applied perpendicularly to its longitudinal axis. The test specimens were conditioned in accordance to ASTM D 790.[37]

A *Dutron's Tensile Tester Model No. 130* was used in the present study. For the measurement, a strip of the dimensions 8.0 · 1.25 cm^2 was cut from the laminate. It suited the gauge length of 7.5cm i.e. the experiment was carried out at a distance between two jaws of 7.5cm apart. The results were recorded with the chart speed of 2mm/min at room temperature. The test was initiated by applying the load to the specimen at the specified crosshead rate. The deflection was measured by gauge under the specimen in contact with it in the center of the support span.

Table 2 represents Izod impact strength, Rockwell hardness and flexural strength. Mechanical properties of composites improve remarkably with the increase in the filler content except in case of antimony trioxide and fly ash. The increase in mechanical properties with the increase in filler content is due to the reinforcement action provided by the filler particles to the polymer matrix. The composites prepared using non-traditional fillers, fly ash, zinc borate and hydroxyapatite in combination with traditional filler antimony trioxide give better performance than unfilled composites and also there is an increase in mechanical properties with the increase in amount of fillers, antimony trioxide gives poor results compared to other fillers and also mechanical performance decreases with the increase in the amount as antimony trioxide is poor in mechanical performance. For antimony trioxide and fly ash the best results were obtained for 20:10% weight of antimony trioxide to fly ash in composites. So, cost-effective composites can be prepared by using both these fillers in the above mentioned proportion.

TABLE 2 - Mechanical properties of composites from polyester resin

Composite code	Izod Impact, Jcm^{-1}	Flexural Strength, MPa	Rockwell Hardness (M Scale)
FRC-1	5.09	238.85	59
FRC-2	4.15	230.85	57
FRC-3	5.00	238.75	59
FRC-4	4.00	230.15	57
FRC-5	3.50	225.00	50
FRC-6	7.00	240.00	60
FRC-7	10.05	245.85	62
FRC-8	11.50	247.90	64
FRC-9	7.25	242.00	61
FRC-10	10.10	246.15	63
FRC-11	11.80	247.90	66

* FRC=Fire resistance composites of prepolymer polyester resin

The results revealed that the concentration and type of filler remarkably affect the mechanical and fire behavior of composites.

Conclusion

The results revealed that the fire retardancy of the polyester-based composites can be improved by using non-traditional fillers like zinc borate, hydroxyapatite and fly ash. They have an advantage over traditional filler antimony oxide to increase the fire retardancy without decreasing mechanical and thermal properties of the composites. There is, however, considerable variation in the efficiency of these fillers. The adequacy of the fire resistance performance of these filled composites is dependent on both type of the filler and incorporation level of the fillers. The use of antimony oxide and fly ash increases the fire resistance behavior but there is decrease in mechanical properties and thermal stability. The optimum result obtained was with 30% zinc borate as filler with good improvement in fire resistance with considerable increases in mechanical properties and thermal stability. So, considerable amount of fire resistance is improved with the increase in mechanical properties and thermal stability obtained in prepolymer polyester resin composite system using different types and levels of fillers. The use of such fillers can also solve the problems of toxic emissions of halogenated fire retardants and also it reduces the cost of polyester resin. Also cost-effective and halogen-free fire resistance composites can be formulated with competitive performance by using cheaper and widely available fillers. The composites can be used for facade elements, dome light crowns, in the transportation sector, in the electrical industry, e.g. for cable distribution cupboards, for boats and shipbuilding, tanks, tubes, vessels and others electrical, electronic and electro technical applications like circuit breakers, switch board cabinets, automotive distributor caps, printed circuit boards etc.

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Vijesti

Priredile: **Ana PILIPOVIĆ i Maja RUJNIĆ-SOKELE**

Plastika i igračke

Više od polovine svih igračaka prodanih u EU proda se u vrijeme Božića. Od *Barbie* preko *Playmobila* pa sve do *hi-tech* proizvoda kao što su igraće konzole *Wii*, *Playstation* ili *XBox* osnovni je materijal plastika. Najpoznatije su vjerojatno *LEGO* kocke. Danska tvrtka proizvodi oko 19 milijardi kockica godišnje, odnosno oko 30 000 t. S tehničkog stajališta kockice nisu tako jednostavne kako se čini. Tvrtka troši najmanje 20 različitih materijala, zbog zahtjeva za različitim mehaničkim i toplinskim svojstvima raznih proizvoda. Najčešći su akrilonitril/butadien/stiren (ABS) i polikarbonat (PC) zbog njihove dimenzijske stabilnosti, što se nije promijenilo već 30 godina. Boja je sljedeće važno svojstvo, iza najvažnijega – dobre međusobne spojivosti kocaka. U prošlosti su *LEGO* kocke bile dostupne u samo tri boje, a danas u više od 55. Tvrtka većinom sama boji svoje proizvode, dodavanjem boje granulatu.

LEGO kocke

Bez obzira na popularnost *hi-tech* igračaka i videoigrica, najprodavanije igračke prošlog Božića bile su mješavina starih favorita i novih hitova, a jedna od njih bila je i Rubikova kocka, još jedan primjer primjene ABS-a, iako je moguća uporaba i nekih drugih plastomera, npr. PP-a, PS-HI-ja itd.

Macplas, ožujak 2009.

Sjeckana staklena vlakna za ojačavanje polipropilena i polietilena

Novi proizvod tvrtke *3B*, *Advantex DS 2200-13P*, suha sjeckana *E - staklena vlakna* bez dodataka bora, dodaju se polipropilenu (PP) i polietilenu (PE) kao ojačavalo. Tako bi PP i PE mogli zamijeniti metal i druge ojačane plastomere u nekim automobilskim komponentama i primjenama gdje se zahtijevaju izvrsna mehanička svojstva i postojanost na starenje. Smjesa PP-a s više od 50 % staklenih vlakana *DS 2200-13P* dobre je krutosti, izvrsne savojne žilavosti, visoke gustoće za optimalno tečenje materijala i izvrsne disperznosti. Takvi su proizvodi iznimno postojani na deterdžente, vodu i alkalnu otopinu, čime postaju idealni za izradbu dijelova perilica za rublje i posuđe. Omogućuju dulji vijek trajanja, nižu cijenu i uštedu na materijalu zbog mogućnosti izradbe tankostjenih proizvoda. Vlakna *DS 2200-13P* mogu se također upotrebljavati s manjom količinom veziva bez utjecaja na mehanička svojstva.

3B Press Release, 4/09.