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Flammability Behaviour of Woven Reinforced With Polyester Resins Composite Fabrics Used In Construction Industry

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ABSTRACT: The fire properties of textile materials are very important factor to be considered for the safety of human. Therefore, it must be taken into account while choosing flame retardant materials, resin and additives where human lives. And also, in recent years, the flame retardancy has been given significant priority, because of current stringent legislation to increase safety. For this reason, in this study, we used woven composite fabrics reinforced with polyester resin with different fabric mass per unit area. The major goal of the research described in this paper has been study flammability of textile fabrics. These results show that flame retardant (FR) has positive effect on improving flammability behaviour of fabrics.

KEYWORDS:**e-glass fabrics, polyester resin, composites, flame retardant, flammability, woven**

I. INTRODUCTION

Composite materials are engineered materials made from two or more constituent materials with significantly different mechanical and physical properties and which remain separate and distinct within the finished structure. In recent years, composite fabrics have become very important engineering materials and have replaced conventional natural and/or synthetic materials in many industry sectors. Composites made of high performance fibres embedded in compliant polymeric resins have been wide range of fields such as construction industry. The use of natural composite materials has been a part of man's technology since the first ancient builder used straw to reinforce mud bricks [1-6].

Most of the textile materials are flammable therefore applying flame retardants to textile fabrics become necessary to assure humans safety under many circumstances. Most recently established federal regulations on the flammability of the fabrics indicate that FR textiles will steadily increase in the near future [2-4].

Most commonly used resin systems are polyester, vinyl ester and epoxy resins. In this study, polyester resin is used because of easy to use, lowest cost of resins available and light weight. Fire resistant polyester resins can be prepared by using halogenated dibasic acids e.g. tetrachlorophthalic anhydride(I), tetrabromophthalic anhydride(II), dibromoneopentyl glycol (III) or tetrabromobisphenol-A (IV) in place of phthalic anhydride or propylene glycol. Fire resistance of polyester resins can be further improved by blending with flame retardant additives such as triphenyl phosphate and antimony trioxide. Such types of resins are generally used in fume hoods, electrical equipments, building panels and navy boats [7].

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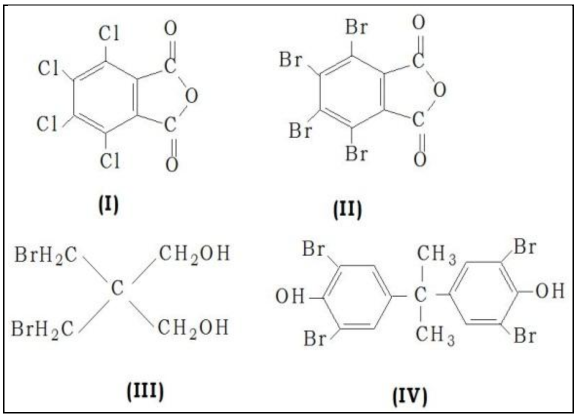

Fig.1Fire Retardant Polyester Resin [7]

Chen and et.al.reported the mechanical and thermal properties of pure PP and PP/aramid fibre composites with AF loadings of 5, 10, 20, 30 and 40 wt %. The mechanical properties of the samples were evaluated by tensile and izod notched impact tests, and the results show that the tensile strength of the composites could reach up to 67.87 MPa and the izod notched impact strength could rise up to 40.1 kJ/m^2. Moreover, the flammability analysis of the PP/AF composites demonstrated that the presence of AF could significantly decrease the peak heat release rate and the total heat release and reduce the melt-dripping of the PP/AF composites [8]. Patel and et.al are prepared bisphthalamic acid by reaction of phthalic and aliphatic diamines. Flame retardant poly(ester-amide)s are prepared by reaction of brominated epoxy resin with bisphthalamic acid and post reaction is carried out with acryloyl chloride to obtained acrylated flame retardant poly(ester-amide) resins. Bismaleimides were prepared by reaction between aromatic diamines and maleic anhydride. Carboxy terminated bismaleimides are prepared by Michael addition reaction of bismaleiimides and 4-amino benzoic acid. Flame retardant poly(ester-imide)s were prepared by reaction between carboxy terminated bismaleimides and brominated epoxy resin. All the obtained products are characterized and analysed by making composites [9].Shi, Z. and et al. (2012), used high thermal conductivity Si3N4 and flame retardant Al(OH)3 (ATH) fillers with different volume fractions (0, 10, 20, 30, 40, 50, 60 %) in the epoxy matrix in order to investigate flammability. Test results showed that the Si3N4 filler has a great influence on thermal conductivity, which markedly increased for Si3N4 for volume fractions >40 %, whereas the ATH filler greatly improved the flame resistance [10]. Kandola and et. al. investigated the influence of surface coating and fire retardant of glass-reinforced epoxy composite fabrics. For all test conditions, there is a significant improvement in the fire performance of surface protected epoxy laminates relative to unprotected samples and peak heat release rates and time to reach fire were significantly reduced in thermally-protected laminates [11].

The aim of this study is to investigate the effects of flammability behaviour of e-glass woven reinforced with polyesterresin felt composite fabric’s by coating flame retardant chemicals.

II. MATERIAL AND METHODS

Material

In this study, woven reinforced with polyester resin composite fabrics are produced with different fabric mass per unit area (Table 1) and coated with FR in different volume ratio (% 1,3,5) for determining the flammability behaviour (Table 2). MAGNIFIN H-10 A is tailor-made for plastic and elastomer applications, e.g. XLPE, XL-EVA, EPDM, und EPM, and represents a halogen free flame retardant with low smoke emission and high thermal stability up to 340°C. During the decomposition process no toxic or corrosive gases are generated. The surface treatment favours the compatibility of filler and polymer matrix and therefore improves the mechanical properties of the compound [12].

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TAB. 1. Technical properties of fabric

Fabric Structure		Mass Per Unit Area (g/m^2)	Thickness (mm)
		Woven Glass Fabric	
1	Plain	100	0,105
2		200	0,127
3		300	0,325
4		500	0,484
5		600	0,680
6		800	0,719
7		900	0,896

TAB. 2. FR chemical technical properties [12]

Commercial Name	MAGNIFIN H-10 A
Formül	$Mg(OH)_2$
Moisture at 105 ºC (%)	≤ 0.3
Specific Surface Area (m^2/g)	8.0-11.0
Electrical Conductivity (µS/cm)	≤ 350
Particle Size (µm)	0.3-0.5
Bulk Density (g/l)	300-500
Loss on İgnition at 1200 ºC (%)	31
Density (g/cm^3)	2.4
Mohs Hardness	2.5
Reflection Index	1.56-1.58
Whiteness % for DR LANGE 457 mm	> 96

Method

The vertical test method is used to measure flammability resistance of samples according to ASTM D6413-08 standard under controlled laboratory conditions. The conditions of the fabrics and environment were on an average temperature ranged between 20 ºC and 22 ºC, and relative humidity (RH) ranged between 65 and 67 %. This test method determines the response of textiles to a standard ignition source, deriving measurement values for after flame time and afterglow time. Test cabinet is galvanized sheet metal. Entire inside back wall of the cabinet are painted black to facilitate the viewing of the test specimen and pilot flame. The test cabinet is set up in a laboratory hood so that combustion gases can be removed from the test laboratory environment. Before the test, vertical flammability device must be adjusted shown in Table 3. Samples are cut five machine directions (MD) five cross directions (CD) and five bias directions (BD) 76 mm by 300 mm. They are selected as homogenous as possible. Test specimens are clamped between the two halves of the holder. It is rectangular aluminium frame for inserting the fabrics. The specimen holder containing specimen is inserted into the test cabinet vertically. Specimen holder is centred above the burner. Nearby lights to the test devices is turned off to make sure of the accuracy of intersect of the midpoint of the flame with the mounting clamp. Flame impingement timer is started and exposed the specimen for 12 ± 0.2 s. The specimen is observed for melting or dripping during the flame exposure and recorded any observation after the flame is removed. Afterflame and afterglow time is recorded. It is observed that how long the specimen continues to glow after the afterflame ceases or after removal of the flame. Char length is measured at the end of the each test. The specimen is punctured with the hook approximately 6 mm from the bottom edge and from the side edge of the specimen. A mass per unit area of sufficient mass (over 203 to 508 g/m^2- 6oz, over 508 to 780 g/m^2- 15 oz) is attached to determine tearing force. The specimen is raised upward in a smooth continuous motion until the total tearing force is supported by the specimen. Any fabric tear is noted in the charred area of the specimen.

TAB. 3. Vertical flammability test adjustment

Gas Mixture	99 % pure methane
Gas Pressure (kPa)	17.2±1.7
Flame Height (mm)	3
Timer- Test Flame Duration (s)	12

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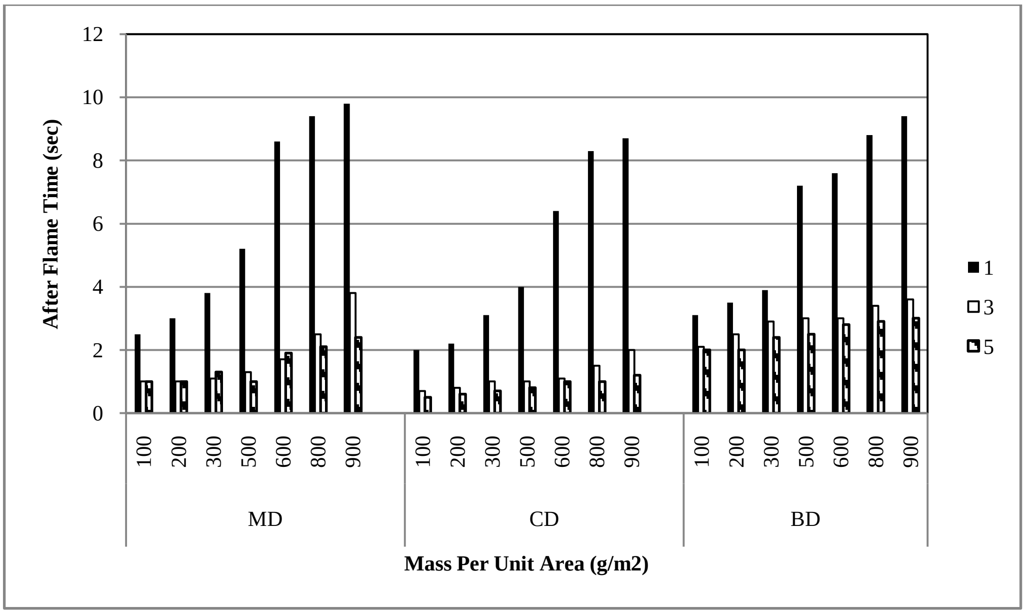
III.EXPERIMENTAL RESULTS

Flammability tests were carried out machine direction (MD), cross direction (CD) and bias direction (BD), respectively. In Figure 2, the flammability resistance of composites tested in this study is displaced.

These figures reveal that, while the fabric mass per unit area is increasing, after glow time and char length is increasing. After flame time, after glow time and char length in the direction of MD are slightly higher than in the direction of CD and BD. The lowest flammability resistance and char length is occurred in CD direction of composites with 0.5 sec (after flame time), no burning occurred (after glow time), 0.8 mm (char length) 100 g/m^2 plain woven e-glass reinforced polyester resin composite because of fibre orientation. The highest flammability resistance and char length is occurred in MD direction of composites with 9.8 sec (after flame time), 3.1 sec (after glow time), 9.2 mm (char length) 900 g/m^2 plain woven e-glass reinforced polyester resin.



a.

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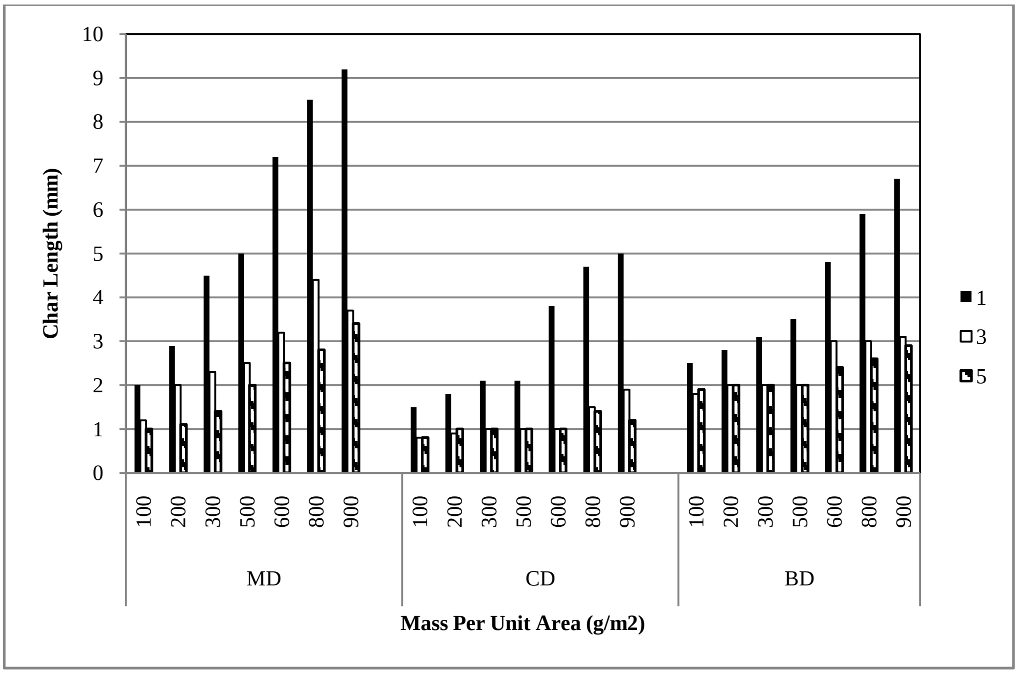
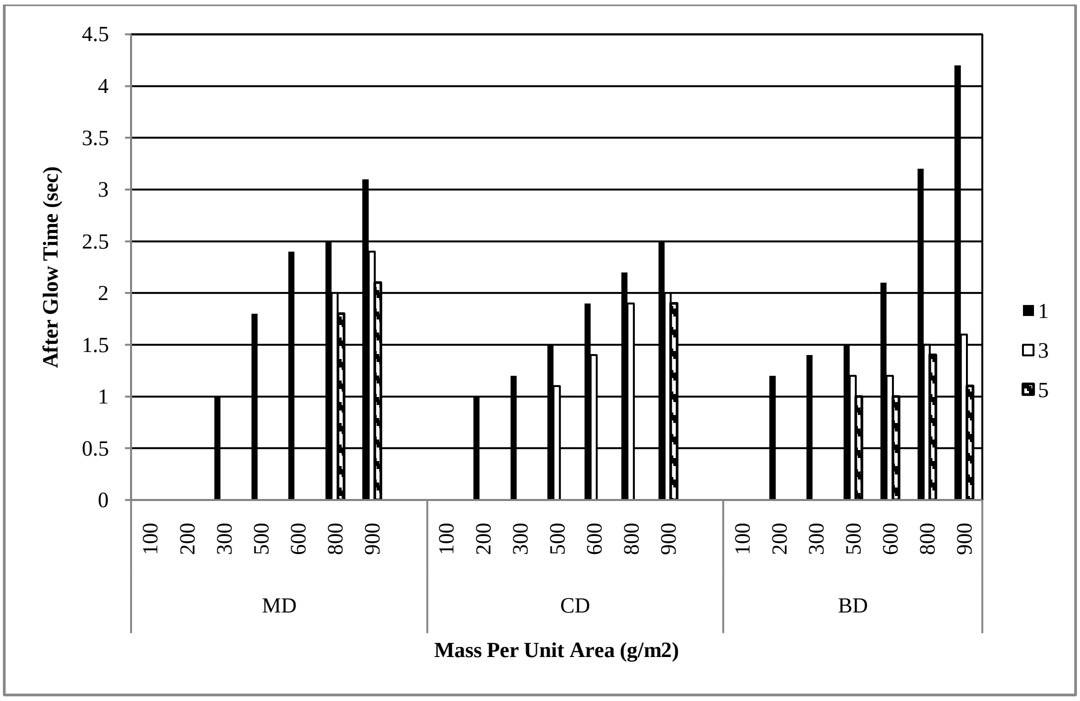


b.



c.

Fig. 2.Flammability Behaviour of Woven Composite Fabrics (a) Afterflame, (b) Char Length,(c) Afterglow

According to the results of the tests for all thicknesses, FR chemicals played positive effects on flammability resistance of composite fabrics, which agrees with the results of earlier studies. Composite fabrics which are treated with 3 % volume ratio flame retardant are very similar to that of 5 %. If we look at the after flame time, the flame can't be seen at samples treated with the volume ratio of 3 and 5 % FR. Afterflame and afterglow time of composites treated with 3 % volume ratio FR is slightly lower than composites treated with 1 and 5 % volume ratio FR. This means that the volume ratio of 1 % is inadequate, the volume ratio of 5 % is excessive and optimum results are obtained at samples treated

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with 3 % volume ratio FR. Therefore there is no need to apply more chemicals with epoxy resin to the samples. And also the stronger influence of 3 % volume ratio FR is obtained with higher flammability resistance of former (1 %) and the later (5 %), as reported in Figure 2.

As can be seen in Figure 2, some composite fabrics that is not burned is lower than samples treated with 3 and 5 % FR chemical. The reason of this result is composite fabrics do not damaged due to burning.

IV. STATISTICAL SIGNIFICANCE ANALYSIS

The experimental results have been statistically evaluated by using the Design Expert Analysis of Variance (ANOVA) software with F values of the significance level of $\alpha = 0.05$, with the intention of exploring whether there is any statistically significant difference between the variations obtained. We evaluated the results based on the F-ratio and probability of F-ratio (prob>F). The lower the probability of F-ratio, it is stronger the contribution of the variation and the more significant the variable. The best models for each fabric were obtained and the corresponding regression equations and regression curves were fitted. The test results of the related fabrics were entered into the software for the analysis of the general design.

Table 4 summarizes the statistical significance analysis for all the data obtained in the study which have been evaluated separately. In the table, variables are fabric mass per unit area (g/m2), fabric direction and flame retardant (%). Moreover, abbreviations in Table 4: F-V is the F-Value, P-V is the P-Value, A- Fabric Mass Per Unit Area (g/m^2), B-Fabric Direction(MD, CD and BD) andC-Flame Retardant (%), Ra^2 –Adjusted R^2, Rp^2- Predicted R^2. Here, the p values of models smaller than are considered to be significant. The ANOVA table also indicates the significant interactions between flammability properties and flame retardant. The term A, B and C in this table is independent variables, whereas the flammability properties are dependent parameters. The term “model” is the sum of the model terms in the ANOVA table. The regression equations were also developed by considering the ANOVA table. And also, a linear design was suggested by the software for flammability behaviour of composites.

TAB 4. Statistical significance analysis (ANOVA table)

	After Flame Time (sec)		After Glow Time (sec)		Char Length (mm)	
Factor	**F-V**	**P-V**	**F-V**	**P-V**	**F-V**	**P-V**
Model	17.52	< 0.0001	19.00	< 0.0001	32.53	< 0.0001
A	40.17	< 0.0001	68.12	< 0.0001	54.17	< 0.0001
B	126.11	< 0.0001	13.99	< 0.0001	44.78	< 0.0001
C	245.20	< 0.0001	229.99	< 0.0001	415.70	< 0.0001
AB	7.26	< 0.0001	40.80	< 0.0001	384.49	< 0.0001
AC	8.19	< 0.0001	7.87	< 0.0001	1.18	< 0.0001
BC	2.45	< 0.0001	4.57	< 0.0001	8.83	< 0.0001
ABC	17.64	< 0.0001	4.61	< 0.0001	8.21	< 0.0001
R^2	0,95		0,94		0,94	
R_a^2	0,91		0,85		0,89	
R_p^2	0,89		0,83		0,82	

When ANOVA table (Table 4) is examined, it can be seen that fabric mass per unit area, fabric direction and flame retardant have significant impact on after flame time, after glow time and char length values. In addition, according to the table, the R^2 value of the model turned out to be approximately 0,95. In this case, terms in the model can explain the model at 95 % ratio. This case shows that the model created for response values (after flame time (sec), after glow time (sec), char length (mm)) can express with rather high accuracy the relation between independent variables and dependent variable and that experimental work results were acceptable as accurate.

A normality test (normal distribution test) was also applied on the data obtained from flammability behaviour by changing fabric mass per unit area (g/m^2), fabric direction (MD, CD and BD) and flame retardant (%). The results are demonstrated in Figure 3. In general probability plotting is a graphical technique for determining whether sample data conform to a hypothesized distribution based on a subjective visual examination of the data. The assessment is very simple. From the data, which are scattered around the normality line as shown in Figure 3, we can see that they conform to normal distribution. This analysis also supports the conformity of chosen model.

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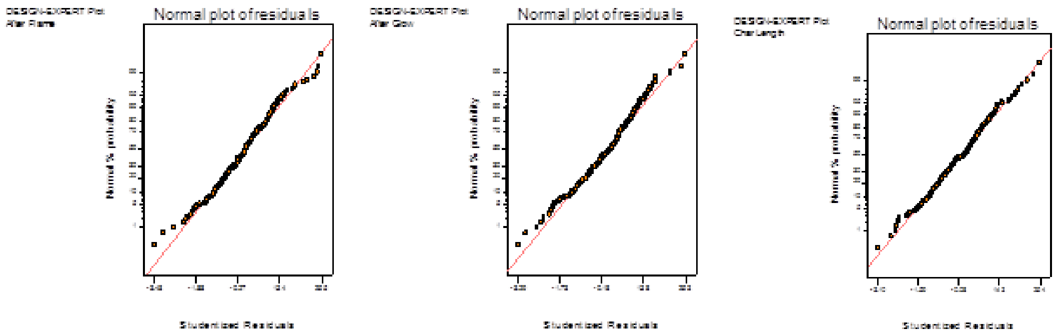

.
a. b.c.

FIG. 3.Normality test for e-glass woven composites (a.After flame time, b. After glow time, c. Char length)

V. DISCUSSION AND CONCLUSION

As a result of experimental study on the statistical investigation into the analyses of the flammability behaviour of composite fabrics, general factorial regression model was developed. Considering the overall performance of the model (ANOVA, normality test), it is determined that the model created for response values from this study can be used to predict the flammability behaviour satisfactory. It is concluded that the model generated is practical and useful for woven e-glass composite fabric manufacturers in order to predict the flammability behaviour of composites.

The research on the flammability behaviour of samples with different mass per unit area can be summarized as follows;

- FR with different volume rate had a great influence on flammability resistance of composites,
- Mass per unit area, fabric direction and FR volume ratio is an important parameter for flammability behaviour,
- The content of FR (3 %) in composite fabrics made it to sufficient for flammability resistance,
- Increasing mass per unit area causes also increasing flammability.

In the next stage of the investigations the correlation between flammability, thermal conductivity and Limiting Oxygen Index (LOI) is checked. This characteristic of material is chosen because they both influenced the flammability of fabric.

REFERENCES

[1] Ozdemir, D., Mecit, H.D.,Seventekin, N., Öktem, T., "Glass Fibers", TekstilveKonfeksiyon, Vol.16, No: 1, pp. 281-286, 2006.
[2] Mostashari, S.M., Mostashari, S.Z,"Verification concerning the relative superiority of a cellulosic fabric with regard to polyester in terms of flammability", Polymer-Plastics Technology and Engineering, Vol.47, pp. 313-317, 2008.
[3] Mikucioniene, D., Baltusnikaite, J., Milasius, R.,"Influence of the number of yarns in a loop on the flammability of knits", Fibres&Textiles in Eastern Europe,Vol.19, No.6, pp. 71-74, 2011.
[4] Allen, J.G., Stapleton, H.M., Vallarino, J., McNelly, E., McClean, M.D., Harrad, S.J., Rauert, C.B., Spengler, J.D., Exposure to flame retardant chemicals on commercial airplanes, Environmental Health, Vol. 12, No.17, pp. 2-12, 2013.
[5] Papaspyrides, C.D., Pavlidou, S., Vouyiouka, S.N., "Development of advanced textile materials: natural fiber composites, anti-microbial, and flame-retardant fabrics", Materials: Design and Applications. Vol.223, pp. 91-102, 2009.
[6] Kandare, E., Kandola, B.K., Myler, P.,"Evaluating the influence of varied fire-retardant surface coatings on post-heat flexural properties of glass/epoxy composites", Fire Safety Journal, Vol.58, pp. 112-120, 2013.
[7] Intech Polyester Open Acsess Book, "Unsaturated Polyester Resin for Specialty Applications Bharat Dholakiya Materials Science", Book edited by Hosam El-Din M. Saleh, ISBN 978-953-51-0770-5, Published: September 26, 2012
[8] Chen, X., Zhang, S., Xu, G., Zhu, X., Liu, W.,"Mechanical, flammability and crystallization behaviour of polypropylene composites reinforced by aramid fibers", Journal of Applied Polymer Science, Vol.125, pp. 1166-1175, 2012.
[9] Patel, B.,Patel, H.S.,"Synthesis, characterization, and glass reinforcement of flame retardant acrylated poly (ester-amide) and flame retardant poly (ester-imide) resins based on brominated epoxy resin", International Journal of Polymeric Materials and Polymeric Biomaterials, Vol.62, pp. 455-461, 2013.
[10] Shi, Z., Fu, R., Agathopoulos, S., Gu, X., Zhao, W.,"Thermal conductivity and fire resistance of epoxy molding compounds filled with Si_3N_4 and Al(OH)"$_3$, Materials and Design, Vol.34, pp. 820-824, 2012.
[11] Kandola, B.K. Horrocks, A.R. Blair, P.M., "Mechanical performance of heat/fire damaged novel flame retardant glass-reinforced epoxy composites", Composites Part A,Vol.34, pp. 863-873, 2003.
[12] Magnifin H-10A Albemarle [Internet], 2016. Available from http://magnifin.com/magnifin_flame_htm (accessed 2016.02.01)