Effect of silicone processing aids on the mechanical properties of flame retardant polyolefin compounds

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Abstract

Flame retardant polyolefin compounds have been used in a growing number of wire and cable markets, such as transportation, electrical & electronic, building & construction and appliance applications. In the flame retardant polyolefin compounds, halogen free flame retardants such as alumina trihydrate (ATH) or magnesium hydroxide (MDH) become really effective when used at high loadings, such as more than 40% by weight, yet deeply affecting the mechanical and rheological properties. Normally, traditional formulations of flame retardant polyolefin compounds use silicone processing aids to improve rheological properties, yet very little attention was paid to the influence of silicone processing aids on the mechanical properties of polyolefin compounds.

Influence of the addition of small (0 to 10% by weight) amounts of silicone processing aids on the mechanical properties of flame retardant polyolefin compounds for wire and cable was systematically investigated. The composites were prepared in a twin-screw extruder, using linear low density polyethylene (LLDPE) and ethylene vinyl acetate (EVA) as matrix materials. Alumina trihydrate (ATH) was added a lot in composites as halogen free flame retardants. The results shows that the increase of silicone processing aids content in composites can lead to high scratch resistance and elongation at break but lower tensile strength. With the content of silicone processing aids increase to 10% by weight, the mass loss of scratch damage decreased by 42%, comparing to the sample without silicone processing aids. The elongation at break increased by 12%, and tensile strength decreased by 26%. Besides, the silicone additives acted as very efficient processing aids, reducing processing torque and dramatically by 26%.

While, influence of silicone processing aids on the mechanical properties of flame retardant polyolefin compounds varies from one formulation to another. Therefore, optimum content of silicone processing aids depends on application requirement to obtain the best integrated properties of the composites.

Key Words: Silicone processing aids; flame retardant polyolefin compounds; tensile strength; mass loss of scratch damage.

1. Introduction

Flame retardant polyolefin compounds have been used in a growing number of wire and cable markets, such as transportation, electrical & electronic, building & construction and appliance applications. Flame retardants，elastomers，reinforcing materials，fillers，etc. play important role in the compounds[1]. The tendency to eliminate halogen-based substances to reduce smoke toxicity during combustion has promoted research on halogen free formulations [2-3]. In the flame retardant polyolefin compounds, halogen free flame retardants such as alumina trihydrate (ATH) or magnesium hydroxide (MDH) are regarded as efficient methods for providing flame retardancy properties to polymer formulations in a safer way with respect to halogens and halogen derivatives[4-5]. Metal hydroxides become really effective when used at high loadings, such as more than 40% by weight, which determines a significant worsening of the compound mechanical properties and does not allow to consistently reach the mechanical and rheological properties level comparable with that derived from the use of halogens.

Normally, traditional formulations of flame retardant polyolefin compounds use silicone processing aids to achieve various enhanced properties such as improved processing and water repellency. And silicone processing aids are also useful for eliminating or diminishing surface defects. The use of silicone processing aids to improve rheological properties has been extensively described [6-8], yet very little attention was paid to the influence of silicone processing aids on the mechanical properties of polyolefin compounds. Depending on the polymer matrix, the additives, the loading level of the fillers and the compounding technologies, the properties may be varied in a very wide range. Therefore, Influence of the addition of small amounts (0 to 10% by weight) of silicone processing aids on the mechanical properties of flame retardant polyolefin compounds for wire and cable was systematically investigated. Furthermore, Influence on the rheological properties havs been investigated through torque rheometer test.

2. Experimental

2.1 Materials

Three commercial available polymers were used as matrix materials, including linear low density polyethylene (LLDPE), ethylene vinyl acetate (EVA) and polyolefin elastomer (POE). Alumina trihydrate (ATH) was added a lot in composites as halogen free flame retardant. Silicone processing aids and other processing aids were also used.

2.2 Preparation and characterization

The matrix resin and fillers were first premixed in high-speed mixer for 5 min. The compounds were prepared by homogenisation of components in a twin-screw extruder, at 130^{o}C - 150^{o}C. In total, six formulations were prepared with each batch weighing 2500g. In all formulations, silicone processing aids were used in the different amount (0 to 10% by weight), while keeping the matrix and other fillers at the same level.

Samples were hot-pressed under 15 MPa for 5 min at about 170^{o}C to render the sheet suitable thickness and size for analysis. The tensile strength and elongation at break were performed according to DIN EN ISO 527-3[9] using a material testing machine and corresponding software. Mass loss of scratch damage was carried out with weightlessness of wear method by a rotary apparatus with test bar covered with abrasive paper. Coefficient of sliding friction was characterized by coefficient of Friction Tester. Melt flow rate (MFR) was investigated by melt flow rate tester. The rheological measurements of all the formulations were carried out by torque rheometer test. The Limited oxygen index (LOI) was determined to use an HC-2 oxygen index meter (Jiangning Analysis Instrument Company, China) according to DIN EN ISO 4589-2[10].

3. Results and Discussion

3.1 Mechanical properties

Figure 1 plots the tensile strength as a function of the content of silicone processing aids. Figure 2 displays elongation at break. It is noteworthy that the presence of silicone aids strongly affects the tensile strength. The elongation at break improved moderately due to the effect of silicone aids, whereas the tensile strength shows an apparent decline. With the content of silicone processing aids increase to 10% by weight, the elongation at break increases by 12%, and tensile strength decreases by 26%, comparing to the sample without silicone processing aids. This may have been due to material deficits introduced by silicone processing aids. Material deficits increase along with the increase in number of silicone aids particle aggregates, which have negative impact on the stress dispersion. As material deficit content increases, the tensile strength of compounds decreases.

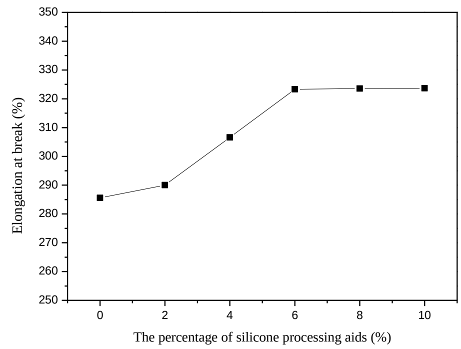

Figure 1. Effect of the content of silicone aids on tensile strength of compounds

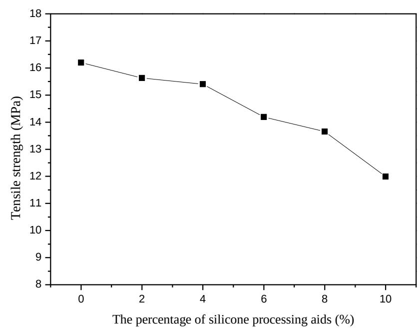

Figure 2. Effect of the content of silicone aids on elongation at break of compounds

Figure 3 presents the effects of different content of silicone aids on the coefficient of sliding friction of polyolefin compounds. As depicted in Figure 3, the compounds based on a higher content of silicone aids tended to have a lower coefficient of sliding friction. It is known that, in the presence of processing agents, a thin lubricating layer rich in the processing agents is formed during flow on the material's surface[11]. The new surface may be covered fully or partially by the layer that is rich in processing aids, which have contributed to lower surface roughness, improve scratch resistance. This statement was further confirmed by the data shown in figure 4. With the content of silicone processing aids increase to 10% by weight, the mass loss of scratch damage decreases by 42%, comparing to the sample without silicone processing aids.

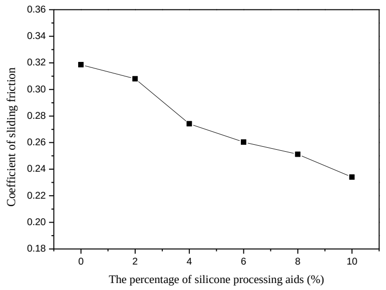

Figure 3. Effect of the content of silicone aids on coefficient of sliding friction of compounds

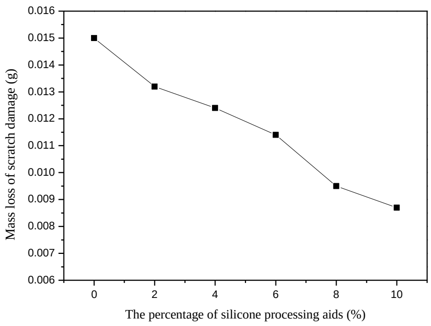

Figure 4. Effect of the content of silicone aids on mass loss of scratch damage of compounds

3.2 Rheological properties

Table 1: Effect of the content of silicone aids on rheological properties of compounds

Wt.% of silicone aids	0	2	4	6	8	10
Torque (Nm)	46.05	44.85	44.05	39.40	36.85	34.20
Throughput (g/min)	57.06	63.40	66.11	66.73	66.28	67.34
MFR (g/10min)	14.67	15.91	16.31	17.74	19.23	23.41

The presence of silicone aids turns out to promote the rheological properties for all the formulations investigated, as clearly indicated in table 1. In particular, this effect is very significant on torque. The silicone processing aids gave a reduction in extruder torque at constant rpm. With the content of silicone processing aids increase to 10% by weight, the processing torque dramatically decreased by 26%, comparing to the sample without silicone processing aids. Besides, the improvement in the throughtput was more than 18%. Similar trends were observed in MFR of polyolefin compounds. The extrudate of all formulations appeared to be smooth to the eye.

Because of the high filler content and nonlubricious nature of the additives, high torque and machine wear are problems during processing. With the addition of silicone processing aids, friction of intermolecular and interface between resins and fillers decrease, and processing characteristics improve.

3.3 Flammability

Comparative data for LOI value are shown in table 2.The LOI value of compounds without silicone aids was 31.0%, while the LOI value of 2 wt. % -10 wt. % silicone aids-based polyolefin compounds increased to the same 32.0%. In the presence of silicone processing aids, a thin lubricating layer rich in the silicone aids is formed during flow on the material's surface. When polyolefin compounds burn, the thin lubricating layer could turn into heat-insulating layer, which served as the thermal insulator and prevented the combustible gas from feeding the flame, protecting the underlying matrix from further burning and regarding the pyrolysis of the polymer[12]. Consequently, with the addition of silicone processing aids, the LOI value of polyolefin compounds improved moderately.

Table 2: Effect of the content of silicone aids on flammability of compounds

Wt.% of silicone aids	0	2	4	6	8	10
LOI (%)	31.0	32.0	32.0	32.0	32.0	32.0

4. Conclusion

Influence of the addition of small (0 to 10% by weight) amounts of silicone processing aids on the mechanical properties and processing behavior of flame retardant polyolefin compounds for wire and cable was systematically investigated. The results shows that the increase of silicone processing aids content in composites can lead to high scratch resistance and elongation at break but lower tensile strength. With the content of silicone processing aids increase to 10% by weight, the mass loss of scratch damage decreased by 42%, comparing to the sample without silicone processing aids. The elongation at break increased by 12%, and tensile strength decreased by 26%. Besides, the silicone additives acted as very efficient processing aids, reducing processing torque dramatically by 26%. The LOI value of polyolefin compounds also improved moderately with the addition of silicone processing aids.

While, influence of silicone processing aids on the mechanical properties of flame retardant polyolefin compounds varies from one formulation to another. Therefore, optimum content of silicone processing aids depends on application requirement to obtain the best integrated properties of the composites.

5. References

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