The Tribological Properties of PP/EPDM/CaCO$_3$ Composites Modified by HDPE

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Abstract. PP/EPDM/CaCO$_3$ composites were prepared by melt blending in twin-screw extruder and injection molding, and analyzed by mechanical testing (tensile, tribological properties) and SEM. The results demonstrate that the HDPE improve the properties of PP/EPDM/CaCO$_3$ composites significantly. Which have excellent tribological properties (coefficient of friction is 0.27, the weight loss is 0.40mg) when the content of HDPE is 25g, while the tensile strength is 30.4MPa.

1. Introduction
Composites materials are designed to possess enhanced structural, tribological, and other properties. Polypropylene (PP) is a widely used plastic, because of its low price, light weight manufacturing versatility etc.. But it’s still not enough on the mechanical and tribological performances. To modify the properties of PP, adding appropriate filler into PP matrix has demonstrated to be a feasible method [1-3]. Yet, PP cannot be widely used because of its high friction coefficient. In order to increase the tribological performances, we use some particulate to fill PP composites. HDPE, glass fiber, B$_4$C, etc., were added to modify PP to get the better tribological performances [4-7]. Various rubbers and elastomers, such as EPDM, have been employed to toughen PP [8, 9]. We used DCP (dicumyl peroxide) and sulphur to improve the interface between PP and EPDM during peroxide induced dynamic vulcanization. PP and EPDM had micro-crosslink structure after dynamic vulcanization. EPDM made the molecular chain of PP closer to each other, and then improved the tensile and tribological properties. The addition of CaCO$_3$ could reduce the cost and increase the heat resistance.

HDPE was added to support the development of strong interfaces among rubber and plastic, which could make the components closer to each other. Besides the compatibility effect, the use of HDPE can decrease the processing temperature, support interfacial adhesion, and allow cost reductions [10, 11].

In this article, we prepared PP/EPDM/CaCO$_3$ composites by melt blending in twin-screw extruder. The compounded material was injection molded to make test specimens to evaluate mechanical and tribological (wear, friction) characteristics. The friction and wear tests were conducted under dry sliding conditions at 200N. It was found that the incorporation of the HDPE significantly contribute to enhance the wear resistance of PP composites.
2. Experimental section

2.1. The Preparation of PP/EPDM/CaCO$_3$ composites
The PP/EPDM/CaCO$_3$ composites were prepared by melt blending in twin-screw extruder and injection molding. The reagents materials and formulas are shown in table 1.

| Reagent Content (g) | PP   | HDPE | CaCO$_3$ | EPDM | DCP  | Sulphur |
|---------------------|------|------|----------|------|------|---------|
| 1                   | 500  | 0    | 150      | 25   | 50   | 0.5     |
| 2                   | 500  | 10   | 150      | 25   | 50   | 0.5     |
| 3                   | 500  | 25   | 150      | 25   | 50   | 0.5     |
| 4                   | 500  | 50   | 150      | 25   | 50   | 0.5     |
| 5                   | 500  | 100  | 150      | 25   | 50   | 0.5     |

2.2. Tests of PP/EPDM/CaCO$_3$ composites

2.2.1. Mechanical Tests. According to the national standard GB/T1040.2-2006 of China, the tensile strength was tested by ETM104C electronic universal testing machine. Five samples of each composite were tested.

2.2.2. Tribological Tests. According to the national standard GB/T3960-2016 of China, The friction tests were performed for 120min with a load of 200 N. The rotational speed was 200r/min. Three samples of each composite were tested.

2.2.3. Morphology. The morphology of PP/EPDM/CaCO$_3$ composites after wear was tested by INSPECT S50 scanning electron microscopy (SEM) after the composites were covered with gold.

3. Results and discussions

3.1. Mechanical properties of PP/EPDM/CaCO$_3$ composites
Mechanical properties of PP/EPDM/CaCO$_3$ composites filled with different contents of HDPE are showing in figure 1. PP and EPDM were micro-crosslinked because of the Cross-linking agent DCP and sulphur. A small amount of HDPE could be interspersed in the crosslink network, because of that the tensile strength was increased. When the content of HDPE was 25g, which was saturated in the micro-crosslink network, the tensile strength reaches the maximum value of 30.4MPa. HDPE couldn’t enter the crosslink network as the increase of the content, which become another phase in PP/EPDM micro-cross structure. Then the tensile strength was decreased because of the lower strength of HDPE.
3.2. Tribological properties of PP/EPDM/CaCO₃ composites

Tribological properties of PP/EPDM/CaCO₃ composites were showed in figure 2, due to the lubrication of HDPE, the friction coefficient of the PP/EPDM/CaCO₃ composites decreased with the increased of HDPE gradually. The weight loss of composites decreased as the content of HDPE, which increased when the content of HDPE exceed 25g. That’s because the tribological performance of HDPE is more excellent than PP. A small amount of HDPE was added as a lubricating component in PP/EPDM/CaCO₃ composites, which reduced the friction coefficient. For the increased with the content of HDPE, the heat was produced from the process of samples grind with metal ring, which would melt the HDPE. In this way, the abrasive wear was changed into adhesion wear, and then the weight loss was increased. It can conclude that PP/EPDM/CaCO₃ composites have excellent tribological properties (coefficient of friction is 0.27, the weight loss is 0.40mg) when the content of HDPE is 25g.

3.3. Morphology

SEM morphology of PP/EPDM/CaCO₃ composites filled with different contents of HDPE after wear is showing in figure 3. There are many clastics on the contact surface for samples with grinding rings without HDPE, with the addition of HDPE, the clastics decreased gradually. This indicate that the addition of HDPE improve the tribological performances of PP/EPDM/CaCO₃ composites.

Figure 1. Mechanical properties of PP composites filled with different contents of HDPE.

Figure 2. Tribological properties of PP/EPDM/CaCO₃ composites filled with different content of HDPE (a) coefficient of friction; (b) weight loss (%).

Figure 3. SEM morphology of PP/EPDM/CaCO₃ composites filled with different contents of HDPE after wear.
Figure 3. SEM morphology of PP/EPDM/CaCO$_3$ composites filled with different contents of HDPE after wear (a) 0g; (b) 10g; (c) 25g; (d) 50g; (e) 100g.
4. Results

The addition of HDPE improves the properties of PP/EPDM/CaCO$_3$ composites significantly. The clastics on the contact surface of samples with grinding rings decreased gradually as the addition of HDPE according SEM. The friction coefficient of the PP/EPDM/CaCO$_3$ composites decreased with the increased of HDPE gradually. The composites have lowest weight loss (0.40mg) and the biggest tensile strength (30.4MPa) when the content of HDPE was 25g. In summary, PP/EPDM/CaCO$_3$ composites have excellent properties in that case.

5. References

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