NEW COUPLING AGENT FOR CARBON FIBER REINFORCED POLYPROPYLENE

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Abstract

Carbon fiber reinforced polypropylenes (CFR-PP) have received keen attention because they offer the lowest densities available for reinforcing fiber composites. Coupling agent between polypropylene and carbon fiber is one of keys for mechanical properties of CFR-PP. It is well known that maleic anhydride (MAH) grafted polypropylene can be applied for coupling agent of CFR-PP. Mitsui Chemicals has recently developed a new MAH-PP coupling agent, ADMER™ AT2305A. In this paper, the properties of CFR-PP with AT2305A is described with comparisons to other compounds, such as glass fiber reinforced nylon and polypropylene.

Background

Automotive industry today is facing increasing fleet mileage requirements, and must continue to engineer significant weight reduction into its vehicles. This is a driving force for greater use of polymer composites to replace conventional metals of construction and design with the lowest density composites possible.

Carbon fiber reinforced polypropylenes (CFR-PP) are one of solution for replacing metals of constructions. On the other hand, sometimes questions, such as “why would we put expensive carbon fiber into conventional polymer like polypropylene?” or “why would we develop CFR-PP when there are no applications or market today in North America?”, arise.

To answer the first question, it is important to look at the large market of glass fiber reinforced polypropylene (GFR-PP) in automotive industry. Obviously, there is the possibility that the combination of high performance carbon fiber and polypropylene enlarges this market field, since CFR-PP offers lowest density available for reinforcing fiber composites, as is described in this paper.

As for the second question, it should be worth mentioning that CFR-PP market situation in Europe and Japan is totally different today from in US. In Europe and Japan, there is an emerging market for CFR-PP, there are suppliers developing and introducing CFR-PP, and there are applications being produced out of CFR-PP.

From a material development point of view, coupling agent between polypropylene and carbon fiber is one of keys for mechanical properties of CFR-PP. It is well known that maleic anhydride (MAH) grafted polypropylene can be applied for coupling agent of CFR-PP. Mitsui Chemicals has recently developed a new MAH-PP coupling agent, AT2305A.

In this paper, the properties of CFR-PP with AT2305A will be described with comparisons to other compounds, such as glass fiber reinforced nylon (GFR-PA) and GFR-PP.
1. MAH grafted PP coupling agent

1.1. What is MAH grafted PP coupling agent?

MAH grafted polypropylene is produced via grafting reaction of MAH functional group to polypropylene. MAH grafted polypropylene functions as a binder in CFR-PP, since MAH grafted polypropylene reacts to chemically modified surface of carbon fibers, and has compatibility with PP.

Figure 1 shows the comparison of SEM pictures obtained for blends of carbon fibers and PP, where Figure 1(a) shows the blend with MAH grafted polypropylene and Figure 1(b) shows without MAH grafted polypropylene. The functionality of MAH grafted polypropylene as binder was clearly confirmed by the fact that the surface of fibers was completely covered by polymer.

1.2. New Coupling Agent for CFR-PP Application

Mitsui Chemicals has recently developed a new MAH-PP coupling agent, AT2305A. Table I shows fundamental properties of AT2305A.
Table I: Fundamental properties of AT2305A

<table>
<thead>
<tr>
<th>AT2305A</th>
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<tbody>
<tr>
<td>Melt flow rate @ 230 °C, 2.16 kg [g/10min]</td>
</tr>
<tr>
<td>Density [g/cm³]</td>
</tr>
<tr>
<td>Melting point [°C]</td>
</tr>
<tr>
<td>Grafting level</td>
</tr>
<tr>
<td>Physical form</td>
</tr>
</tbody>
</table>

Mechanical properties of CFR-PP were improved by the addition of 3 wt % of AT2305A. Table II shows the data obtained for the system in which PP / short carbon fiber = 70 / 30 [wt %]. The tensile strength of CFR-PP with AT2305A was twice higher than that of without it.

Table II: Comparison of mechanical properties of CFR-PP between with and without AT2305A

<table>
<thead>
<tr>
<th>property</th>
<th>Test method</th>
<th>unit</th>
<th>with AT2305A (3 wt %)</th>
<th>w/o AT2305A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>ASTM D638</td>
<td>MPa</td>
<td>120</td>
<td>54</td>
</tr>
<tr>
<td>Flexural modulus</td>
<td>ASTM D790</td>
<td>GPa</td>
<td>13.8</td>
<td>9.7</td>
</tr>
</tbody>
</table>

AT2305A is highly MAH modified PP. This feature helps us to reduce the dosage of coupling agent in CFR-PP. Figure 2 shows the dependence of coupling agent blend ratio on tensile strength of CFR-PP. This figure shows that the efficiency of AT2305A as a coupling agent is extremely high.

Figure 2: Dependence of coupling agent blend ratio on tensile strength of CFR-PP. The composition was PP / short CF / coupling agent = 70-x / 30 / x.
2. Features of CFR-PP with AT2305A

Mechanical properties obtained for various kinds of fiber reinforced plastics were compared in this study.

Figure 3 shows the comparison of flexural modulus obtained for CFR-PP, GFR-PP and GFR-PA. Figure 4 shows the comparison of tensile strength among these composites. These figures indicate that CFR-PP offers densities 20% to 25% lower than GFR-PA.

Figure 3: Comparison of flexural modulus obtained for various kinds of fiber reinforced plastics. Numbers in figure denotes the weight fraction of fiber.

Figure 4: Comparison of tensile strength obtained for various kinds of fiber reinforced plastics. Numbers in figure denotes the weight fraction of fiber.
Good moisture resistance is one of benefits of CFR-PP. Figure 5 shows the change of tensile strength during hot water soaking testing. Y-axis of Figure 5 shows the retention of tensile strength after hot water soaking. As is clearly indicated, reduction of tensile strength was observed for GFR-PA after hot water soaking due to hydrolysis. On the other hand, the tensile strength of CFR-PP kept the same level during testing period.

Figure 5: Retention of tensile strength of CFR-PP and GFR-PA during hot water soaking test
3. Concluding remarks

By applying AT2305A, mechanical properties of CFR-PP were significantly improved. It was revealed that AT2305A has high efficiency as a coupling agent due to its high maleic anhydride grafting level.

Features of CFR-PP with AT2305A are summarized as follows.

- 20% lower density than GFR-PA
- Superior mechanical properties deliver weight savings up to 50% or more.
- Hydrolytic stability – two times stronger than GFR-PA after heat/water aging

These features of CFR-PP with ADMER™ will bring benefits for automotive applications, such as door module, front-end module, and seat frame.