The introduction of technology for producing thin, multilayer, polyethylene heat shrink films with improved processing and service characteristics

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Summary

An analysis is made of the characteristics of films based on recycled polyethylene and a developed composite material for the production of three-layer shrink wrap film of 50 µm thickness with improved processing and service properties. The results of research into modifying the composite and optimising the technology for producing multilayer shrink films are presented.

The development of technology for the production of a multilayer polyethylene film as heat shrink material is an avenue of plastics processing industry development that is of current interest.

In the capacity of heat shrink films, use is made of uni- or biaxially oriented films, which change their linear dimensions when heated and wrap tightly around the article being packaged.

The main requirement of polyethylene heat shrink film is that the optimum service characteristics, with which losses of packaged goods during transportation are minimised, are achieved.

The North Caucasus Federal Okrug is developed in the sphere of market relations and the transportation of goods. An important avenue is the production of mineral waters, which for the most part are bottled in polymer containers and wrapped in heat shrink film, a consequence of the high concentration of heat shrink film manufacturers in the region.

Keen competition is forcing packaging manufacturers to come up with new approaches and to introduce up-to-date methods in the area of polyethylene shrink film production.

The most economically favourable and at the same time most widely used variant of low-cost film production is the production of one-layer, two-layer, and three-layer film from 100% recycled polyethylene feedstock: waste and used polyethylene, including cling film.

We have conducted research in the area of the production of films based on 100% recycled polyethylene at the technical production base of OOO Torgovyi Dom Yug-Polimer.

The normal way to produce three-layer heat shrink films is to produce a thick (80 µm) film from 100% recycled feedstock.

To many manufacturers it seems that they have found a golden niche in the market, but in the process of film production, they are faced with a number of problems concerning the physicomechanical properties of the film during the processing of the recycled polyethylene feedstock.

Research into the properties of film at the certified laboratory of OOO Torgovyi Dom Yug-Polimer showed that specimens produced from 100% recycled polyethylene feedstock possess the characteristics given in Table 1.

The form of the elongation diagram of specimens of the given films is shown in Figure 1.

An analysis of Figure 1 reveals the main stress–strain...
relationships. Curve 1 indicates that the stress–strain relationship under an elongation of up to 9 mm (or 180%) and in the range of elongations from 90 to 190 mm (or from 180 to 380%) is inhomogeneous and non-linear. This indicates that plastic strain is predominant in the behaviour of the film material, and here the achieved tensile strength of the specimens amounted to 13.7 MPa. The limiting strain in this case amounted to 190 mm (or 380%). After these stages, the stress falls sharply and the specimen fails.

Curve 2 likewise demonstrates that the stress–strain relationship is non-linear within the region of elasticity. Curve 2 can be divided into three main sections. The first section corresponds to elastic strain in a range of elongation of about 10 mm (or 20%). On the second section, a considerable non-linear strain of the specimen (plastic flow) is observed, associated with the achievement of the yield point of the material, the maximum stress at which amounted to 10 MPa. The third section corresponds to strain hardening on account of orientation of the macromolecules and the occurring processes of recrystallisation, because with subsequent increase in strain the strength of the material increases by 34%. After the strain hardening stage, the specimen fails.

Comparing the obtained results with the requirements of the polyethylene film [1] and polyethylene heat shrink film [2] industry standards, it can be concluded that the obtained results do not meet the standard requirements concerning product quality.

Investigations of the performance of films during the transportation of pallets with bottles wrapped in the given heat shrink film showed that pallet transportation on sections of roads with an incline leads to an irreversible change in the shape of the pallets and to crumpling and loss of integrity of the goods – a critical failure to comply with freight transportation conditions (Figure 2).

On the basis of an analysis of the obtained results, it can be concluded that, at the stage of production and service of films from 100% recycled feedstock, critical amounts of losses and waste are formed, which on the material balance and cost calculation graph come under the heading “irreversible losses and wastage” in a quantity of 40% of the processed volume of material [3]. The low strength of the film affects the conditions of transportation of the packaged goods, and the case formed is unable to hold bottles stacked on a group pallet. The film customer will suffer significant losses on account of irreversible wastage of film and packaged products.

Above all, large production losses occur on account of imprecise production technology and the inhomogeneous composition of the feedstock. The process is unstable, which leads to frequent breaks of the film roll during production, and consequently to an increase in the percentage return waste on readjustment of equipment.

In the search for new technological solutions to this problem, an economically profitable technology has been developed for the preparation of polymer feedstock for the production of film with improved deformation and strength properties.

We have developed a composite for the production of a three-layer packing film of 50 µm thickness. The properties of the film were investigated, and technology was developed for the industrial production of heat shrink film.

The given composite makes it possible to realise a high-quality process for the production of roll film of 50 µm thickness with a high degree of transparency, and to produce an end product with the necessary strength characteristics.

Tests of the properties of film were conducted in accordance with the standard requirements [1, 2, 4] at the certified laboratory of OOO Torgovyi Dom Yug-Polimer. Test results obtained in accordance with GOST 14236-81 “Polymer films. Tensile test method” [4] showed that film of 50 µm thickness possesses the mechanical characteristics set out in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Longitudinal direction</th>
<th>Transverse direction</th>
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<tbody>
<tr>
<td></td>
<td>Actual value</td>
<td>Standardised value</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>25</td>
<td>14.7</td>
</tr>
<tr>
<td>Breaking elongation (%)</td>
<td>1552</td>
<td>250</td>
</tr>
<tr>
<td>Shrinkage properties (%)</td>
<td>72</td>
<td>70</td>
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</tbody>
</table>
The elongation curves of specimens of the obtained film are given in Figure 3.

Comparing the form of the dependence of specimen 1 (Figure 1) with the dependence presented in Figure 3, it can be seen that the tensile strength of the latter was 46% higher, and the limiting strain amounted roughly to 776 mm (or 1552%).

The elongation curve for specimen 2 (Figure 3) likewise clearly demonstrates several differing sections of elongation, including strain, plastic flow, and strain hardening. The limiting strain and the tensile strength of specimens 1 and 2 of the developed composite (Figure 3) are considerably higher (25 MPa, 1552%; 21 MPa, 1620%) than for specimens 1 and 2 presented in Figure 1 (12 MPa, 630%; 13.5 MPa, 380%).

An analysis of the properties of experimental films showed that the maximum flow stress amounted to 15 MPa. The given index is more than 33% higher than the corresponding index of films from 100% recycled feedstock.

On the basis of the obtained data, it can be concluded that the quality of film based on the developed composite, in terms of physicomechanical properties, is higher than the requirements established by the industry standards.

<table>
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<tr>
<th>Characteristic</th>
<th>50 μm thickness</th>
<th>80 μm thickness</th>
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<tbody>
<tr>
<td>Weight of film per unit of packaging (g)</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>Number of packaged PET containers (number in 100 kg of packaging material)</td>
<td>25 000</td>
<td>20 000</td>
</tr>
</tbody>
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using the developed technology by OOO Torgovyi Dom Yug-Polimer.

The production of thin multilayer heat shrink films is being implemented on an industrial scale at OOO Torgovyi Dom Yug-Polimer in Kislovodsk, and the 50 µm thick heat shrink film is being used by the following:

- ZAO Kavminvody (Mineralovodskii District, Novotersk Peninsula);
- OOO “Ob’edinennaya vodnaya kompaniya” (Predgorny District, Vinsady);
- OOO “Essentuki zavod mineral’nykh vod na KMV” (Essentuki).

REFERENCES