OPTIMIZING THE COMPOSITION AND TECHNOLOGICAL MODE FOR THE PRODUCTION OF PVC PROFILES FOR DOORS AND WINDOWS

P. Naydenova, P. Velev

University of Chemical Technology and Metallurgy
8 Kl. Ohridski, 1756 Sofia, Bulgaria
E-mail: pepiw@dir.bg

Received 15 February 2011
Accepted 129 April 2011
121

ABSTRACT

The impact of different brands of stabilizers, modifiers, fillers and pigments on the performance properties of the finished products was studied at the operational production line of Weiss Profil Ltd. The optimal composition of polyvinyl chloride profiles was defined based on the studies.

The most appropriate mode of extrusion technology for the optimized composition was established, having studied its effect on the physical and mechanical properties of polyvinyl chloride profiles for doors and windows.

The whiteness and impact resistance of the profiles subjected to two types of accelerated aging for 300 hours - with xenon and ultraviolet light sources were defined. It was proven that xenon source leads to more intensive aging of the polyvinyl-chloride composite.

Keywords: PVC, profiles, production, aging.

INTRODUCTION

The production of profiles for doors and windows of polyvinyl chloride (PVC) is one of the fastest growing industries in the construction industry. The annual production capacity of some leading European manufacturers is between 150 and 200 thousand tons.

From a technological point of view one of the most important advantages of PVC window profiles is that they may be re-processed and recycled with keeping the characteristics of the material, i.e. the ideal conditions to create a closed cycle - a significant contribution to protecting the environment.

One way to optimize the composition of the dry blend polyvinyl chloride used for the production of profiles has been researching the impact of different brands of stabilizers, modifiers and fillers on the physical and mechanical properties of the finished products and choosing the optimum composition.

It was established that the addition of MgO in combination with TiO\(_2\) reduced elongation and impact resistance at -10°C of the material. The most appropriate profile with respect to change of colour comes from a compound containing MgO and TiO\(_2\), with ratio of MgO and TiO\(_2\) of 1:3 [1].

Each manufacturer optimizes the composition of their products, but in the literature there is no information about the optimal composition and the effect of the combination of different brands of additives on the properties of the product.

It is necessary to optimize the technology and mode of extrusion in the selected optimal composition of the composite because it also has a substantial influence on the performance properties of the products.

Creating an efficient composition for the extrusion of PVC profiles unconditionally requires the thorough investigation of the existing extrusion equipment - machinery parameters, temperature, pressure, speed, download speed, etc., with in-depth prior research on the influence of various additives on the rheology and thermo stability of the composite stock and the establishment of the relationship between the technological mode, the chemical composition of the material and performance properties of the finished PVC profiles.
The operating conditions of extrusion can affect both the transitory properties of the profiles and their durability. Therefore, the products obtained in the three investigated technological modes were subjected to artificial light aging under the effect of irradiation with ultraviolet (UV) and xenon (Xe) light source.

**EXPERIMENTAL**

The following materials were used:
- PVC suspension with K (value) 67, brand Ongroyl S5167 - Hungary;
- Stabilizers were added in amounts recommended by the manufacturers, using the following brands: IKA - 7598C3G, Austria; Akdeniz Kymia - Akropan 76/2GB, Turkey; Reagens - A9097/30, Italy, Baerlocher - Baeropan 9766FP, Germany and Chemson - GWX523B, Germany.
- Modifiers

The following brands were used: Paraloid - Production Company Rohm and Haas - United States; FM 50 Company Kaneka - Belgium; Baerodur Company Baerlocher - Germany.

The modifiers are copolymers of methyl methacrylate and acrylic ester. All brands are white powder with a bulk density of 0.300 g cm$^{-3}$ to 0.500 g cm$^{-3}$ and humidity < 0.3 %.
- Used fillers

The following brands of calcium carbonate were used: company Huntsman - Zeta fil 1.CST - Belgium Company Eriyce micron - PRF1 - Turkey; Eriyce micron - SF1C - Turkey and the firm Omya - Hydrocarb 95T - France.

All are inert fillers - white powder spherical particles with diamond structure and particle sizes of 0.4 μm to 1 μm. Humidity is less than 0.3 %.

The following brands of titanium dioxide (rutile) were used: Dupont-USA, RFK - Turkey, R-TC 30 - Turkey, Tiona - France, Kronos 2220 - Belgium.

These fillers are powdered with tetraedrical crystal lattice. A density of 4.00 g cm$^{-3}$ up to 4.30 g cm$^{-3}$ and decomposition temperature 1640°C.

The products subject to our testing and analysis were made with extruder “Titan 68” with the following characteristics:
- Screw diameter 30 mm;
- Length of screw 30 D;

The extruder was equipped with a nozzle, ensuring products in accordance with the requirements of the standard “Non-plasticised PVC profiles for doors and windows” - BS EN 12608.

After selecting the optimal composition it was necessary to determine the impact of different modes of extrusion on the productivity and the physical and mechanical parameters of the profiles.

The selected modes of extrusion, depending on the final temperature of the nozzle were conventionally called: “Technological Mode 1” -194°C, “Technological Mode 2” - 196°C and “Technological mode 3 –191°C

To determine the performance characteristics of the extrudates, the following characteristics were determined:
- Charpy impact strength - in accordance with ISO 179-2 1993;
- Falling weight impact strength- BS EN 477:2003;
- Cleavage strength of welded joints - BS EN 514;
- Change of size of with the accumulation of heat - BS EN 479:2002;
- Determination of the reflection of non-metallic reflective coatings varnishes, BS EN ISO 2813 and spectral analysis (brilliance and whiteness) by colour system Lab (L = 100 means white, “a” - green, + a “- red; “b” - blue, “+ b” - yellow).

Artificial aging was carried out using a climatic chamber ILKA Feutron 3001 and xenon chamber Q-SUN Lab Xe1.

**RESULTS AND DISCUSSION**

Profiles of non-plasticised polyvinyl chloride (PVC-U) with different brands of stabilizers were prepared.

The determination of the physical and mechanical properties of the resulting profiles showed that the brand of stabilizer used affects the quality of the resulting product. The indicators that change significantly are presented in Fig. 1.

The stabilizer brand affects the linear extension of the studied compositions. Best results were obtained using the stabilizer brand Reagens, and lowest with Baerlocher.

The stabilizer brand does not significantly influence the impact strength with a falling weight.

In spectral analysis (whiteness) - the results vary with the L-value 93.9 of Company Akdeniz Kymia to
L-bedroom with 97.1 of the company IKA. Samples meet the standard requirements, but best results are obtained using Chemson GWX523B \((b = 0.88)\).

The specular reflection (gloss) ranged from 34.5 to 48.2 for Baerlocher of Chemson GWX523B.

The cleavage strength of welded joints (welded angle strength) is also affected by the type of stabilizer, as the lowest is the result of Baerlocher - 5.00 kN, the highest stabilizer Chemson GWX523B 6.00 kN.

Based on research and not least given the price of raw materials, the stabilizer Chemson GWX523B was chosen as most suitable for subsequent studies.

The influence of three types of modifiers on the properties of the profiles of PVC-U was investigated. Best results (Fig. 2) are obtained using the FM modifier 50 of the company Kaneka. In testing the falling weight impact strength, the samples prepared with modifier 50 FM (Kaneka) were not broken. The worst results for the same indicator were obtained when using Baerodur (80 % broken pieces). The results are not shown.

The results presented in Fig. 3 show a significant influence of the type of calcium carbonate on the linear extension of profiles, as well as on brilliance.

For the indicator falling weight impact strength the changes are minor:

After selecting the stabilizer and the modifier, the influence of the five brands of titanium dioxide on the properties of the profiles of PVC-U was studied. The results obtained for the linear expansion (1) strength of welded corners (2) and brilliance of the (3) profiles are presented in Fig. 4. The brand of the titanium dioxide affects all indicators [2].

Based on the results, titanium dioxide Kronos 2220 was selected for use.
Fig. 5. Depending on linear expansion (%) and the strength of welded corners, kN on the mode of extrusion.

<table>
<thead>
<tr>
<th>Linear expansion, %</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Strength of welded corners, kN</td>
<td>1.6</td>
<td>1.7</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Fig. 6. Modification of gloss depending on the mode of extrusion.

Fig. 5 presents the modification of the linear extension (Resize in storage of heat, according to EN 479) and the strength of welded angles depending on the operating conditions of extrusion for the material.

From the results it is clear that performance indicators (with a tolerance of maximum 2 %) for the linear expansion are the best in the first mode of extrusion. The strength of the weld is not substantially altered.

Fig. 6 presents the results of brilliance change in different modes of extrusion.

As seen from the figure, the highest gloss is obtained at mode 3. This technological mode differs from the other two with the lowest temperature of extrusion.

With increasing the temperature of the machine the gloss is reduced. This is due to thermal destruction processes occurring on the profile surface. The lower temperature, pressure, and consequently less strain contribute to increasing the brightness, which is achieved in the third mode. These results are consistent with literature data [3, 4].

Fig. 7 presents the change of whiteness (by value L *) of the samples tested, depending on the extent and type of exposure.

As it is clear from the results, the change in L * value is the least with the most friendly mode of extrusion - 3.

Fig. 8 presents the results of Charpy impact test in the three modes of extrusion, and the change in these
Fig. 7. Change the primary color depending on the mode of extrusion: 1 - before artificial aging; 2 - after 150 h UV exposure; 3 - 150 h after irradiation with Xe - source; 4 - after 300 h UV exposure; 5 - after 300 h irradiation with Xe - source.

Fig. 8. Impact strength (by Sharpy) depending on the mode of extrusion of samples subjected to artificial aging: 1 - before artificial aging; 2 - after 150 h UV exposure; 3 - after 300 h UV exposure.

CONCLUSIONS

The influence of different brands of stabilizers, modifiers, fillers and pigments on the physical and mechanical performance of composites was studied. Based on studies carried out, the compositions containing stabilizer Chemson GWX523B, FM modifier 50 of company Kaneka, calcium carbonate Hydrocarb 95T and titanium dioxide Kronos 2220 were selected as the most suitable.

The influence of the operating conditions of extrusion on the physical and mechanical properties of products was studied. It was found that mode 3 is the most suitable for the production of profiles for doors and windows of the selected optimal composition of dryblend.

The whiteness and impact resistance of PVC profiles were defined, subject to two types of accelerated aging for 300 hours - with xenon and UV - B light sources. It was found that the studied parameters decreased over time. Xenon source leads to more intensive aging of PVC composite made of PVC-U. For example, the impact resistance of articles obtained by extrusion mode 3 after 300 hours exposure is decreased by 25 % with UV-B light source, and with xenon at 77 %.

indicators after 300 hours exposure to artificial aging with UV and xenon light.

The results show that the highest impact resistance is obtained by extruding at technological mode 3.

Samples age more intensively under the influence of xenon light sources. This is due to the spectrum of the source and the fact that the profiles are made of poly(vinyl chloride) containing UV stabilizer [5-7].
REFERENCES


