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# EFFECT OF POLYETHYLENE MOLECULAR MASS CHARACTERISTICS ON SLIP EFFECT*

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*The rheological properties of polyethylene with different molecular weight characteristics were studied. Difference of molecular weight characteristics was found on the basis of melt flow index, and slip effect in the molten polyethylene flow was studied. The presence of slip effect is found in case of flowing polyethylene with a higher molecular weight in contrast to polyethylene with lower molecular weight at different temperatures. Changes of the slip effect parameters upon mixing polyethylenes with very much different molecular weight characteristics were studied.*

***Keywords:*** *molecular weight, the effect of slip, polyethylene, high density polyethylene, HDPE.*

In order to optimize processes related to the flow of polymer melts various processing and rheological additives are added into polymeric compositions: internal and external lubricants, softeners, stabilizers etc. Many rheological additives are low-molecular polymers or polymeric wax that are added in amounts of several percent. Due to the presence of such additives sliding effect is implemented at polymer melt flow, which facilitates its processing.

Polymers with high melt flow rates (about 40–60 g / 10 min) are often used for processing by injection molding, especially when producing thin-walled articles. Such polymers have excellent fluidity even without rheological additives.

The purpose of this work is to estimate the possibility of sliding effect in a low viscosity polymer, as well as the efficiency of using it as a rheological additive to a polymer with a higher molecular weight.

## Experimental

In this study high-pressure polyethylene (HPPE) 10803-020 (State standard 16337-77) with a melt flow rate of 2.0 ± 0.2 / 10 min and high-density polyethylene SABIC F04660 with a melt flow rate of 50.0 ± 0.5 / 10 min were used. The melt flow rate values indicate essential difference in the molecular weight of the studied polyethylene brands.

A complex rheological study was performed with the use of a Dynisco-LCR 7001 capillary viscosimeter (USA) with a set of capillaries differing in diameters and lengths. Capillaries with diameters 1 and 2 mm and lengths 10 and 20 mm were used for the study. Flow curves (Fig. 1) of

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HPPE 10803-020 and SABIC F04660 were obtained in a wide range of rates and shear stresses at various temperatures by a standard technique [1]. The values of shear rates for each chosen value of shear stress (τ) were determined by the the flow curves obtained with the use of capillaries with different diameters.

**Results and Discussion**

In order to estimate the sliding effect upon the flow of PE composites at different temperatures, rates and shear stresses the following characteristics were deterimed: slide rate and critical shear stress at the beginning of sliding.

Figure 1 shows that both SABIC F04660 polyethylene melt and HPPE melt show pseudo-plastic properties upon flow. However, no slide effect is registered according to the results presented in Figure 2. The absence of slide effect in case of a low viscosity polymer is confirmed by studying the rheological properties of SABIC F04660 at different temperatures (170, 190 and 210°C).

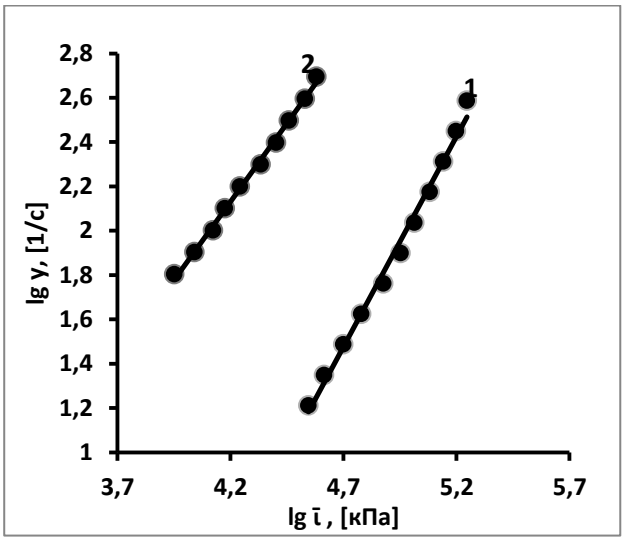


**Figure 1.** Flow curves of HPPE 10803-020 (1) and SABIC F04660 (2) at 190°C.

[c means s; кПа means kPa]

Figure 2 shows dependences of slide rate on shear stress at 190°C. It follows from the presented dependences that slide effect is observed upon PEVD 10803-020 melt flow, in contrast to SABIC F04660.

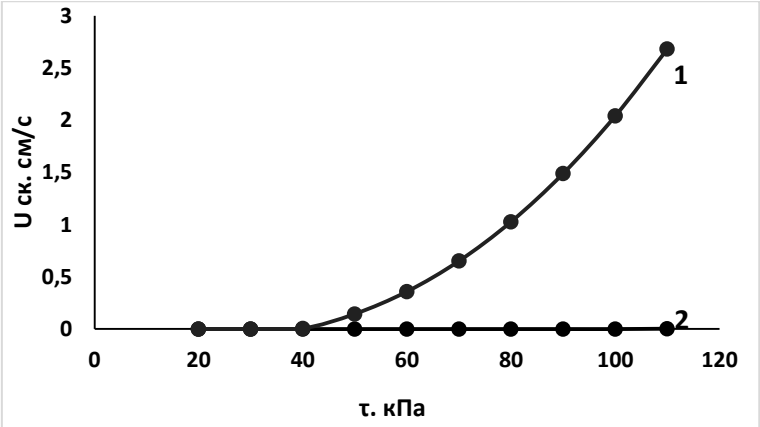


**Figure 2.** Dependences of slide rate of HPPE 10803-020 (1) and SABIC F04660 (2) at 190°C on shear stress.

[ск means sl; см means cm; с means s; кПа means kPa]

Most rheological additives working due to slide effect have low viscosity. Due to the light viscosity such additives create an interlayer between the material melt and the capillary surface, which causes the slide effect. No slide effect is implemented upon the flow of only one low viscosity polymer in the absence of a higher viscosity component of the composition (the main polymer into which additives are introduced) on the channel axis.

In order to illustrate this phenomenon compositions obtained by mixing HPPE 10803-020 with SABIC F04660 in 75/25 (75%), 50/50 (50%) and 25/75 (75%) w/w ratios, respectively, were prepared and studied (Figure 3).

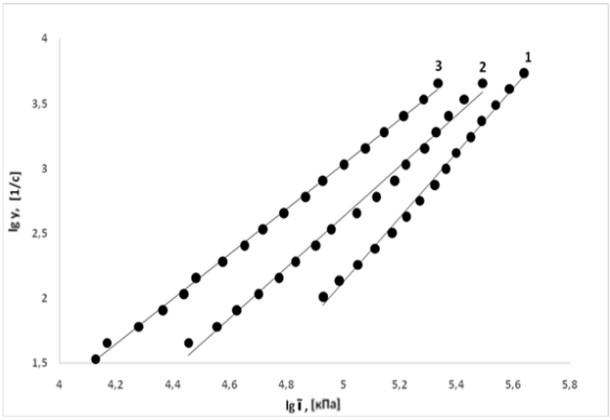


**Figure 3.** Flow curves of mixed composites based on HPPE 10803-020 (1) with the content of SABIC F04660: 2 % (1), 50% (2) and 75% (3) at 190°C.

[с means s; кПа means kPa]

For the studied mixtures of HPPE 10803-020 and SABIC F04660 slide rates were calculated, and dependences of slide rates vs shear stress (Figure 4) were plotted.

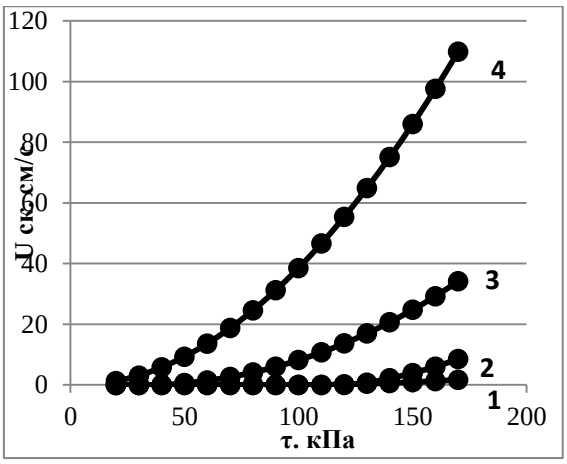


**Figure 4.** Dependences of slide rates of composites based on HPPE 10803-020 (1) containing SABIC F04660: 25% (2), 50% (3), 75% (4) at 190°C vs shear stress. [ск means sl; см means cm; с means s; кПа means kPa]

The dependences in Figure 4 show that introducing the more low-viscous component SABIC F04660 into HPPE 10803-020 increases the slide effect: the slide rate of the mixture becomes higher than the slide rate of initial HPPE 10803-020. The addition of 25% of SABIC increases the threshold shear stress required for slide effect up to 120 kPa as compared to 80 kPa for initial HPPE 10803-020. Further increase of the content of the low-viscous SABIC F04660 polymer in HPPE 10803-020 considerably increases the slide rate and reduces the threshold shear stress to 40 kPa and 20 kPa for mixtures containing 50% and 75% of SABIC, respectively.

## Conclusion

The obtained results enable to conclude that the emergence of slide effect is caused, first of all, by the presence of low-viscous components in the polymer melt. The flow of the melt of the most low-viscous polymer can occur without sliding.

The slide effect in polymer blends is due to the existence of the more viscous component that slides on the layer formed by the less viscous component on the channel wall. Blending polymers with strongly differing melt viscosities results in the formation of layer-by-layer flow in the channels of processing equipment. This leads to the emergence of slide effect. This is true both in case of addition of a high-viscosity polymer into a low-viscousy one one and vice versa. This allows assuming that the emergence of slide effect can be due to molecular mass distribution rather than to the change in the polymer molecular weight.

**Acknowledgment**

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**REFERENCES:**

1. Simonov-Emel'yanov I.D., Shembel' N.L., Prokopov N.I., Ushakova O.B., Gerval'd A.Yu., Surikov P.V., Markov A.V., Pashkin I.I. // In: «Metody opredeleniya tekhnologicheskikh svojstv napolnitelej i polimernykh materialov» (Methods for determination of technological properties of fillers and polymer materials). M.: MITHT, 2014. 130 p. (in Russ.)

2. Vinogradov G.V., Malkin A.Ya., Yanovskij Yu.G., Bor'senkova E.K., Yarlykov B.V., Berezhnaya G.V., Shatalov V.P., Shalganov V.G., Yudin V.P. // Polymer Science, Series A: Chemistry, Physics. 1972. V. 14. № 11. P. 2425–2442. (in Russ.)

3. Yurkin A.A., Surikov P.V., Simonov-Emel'yanov I.D. // Vestnik MITHT (Fine Chem. Tech.). 2014. V. 9. № 3. P. 86–91. (in Russ.)

4. Simonov-Emel'yanov I.D., Prokopov N.I., Volodin V.P., Surikov P.V., Il'in A.I., Oliferenko M.S., Yurkin A.A., Anshin V.S. // Plasticheskie massy. 2011. № 12. p. 59–64. (in Russ.)

5. Cvajfel' Kh., Maer R.D., Shiller M. Dobavki k polimeram: spravochnik / trans. by Eng. 6th Ed. Red. by V.B. Uzdenskogo, A.O. Grigorova. SPb.: COP «Professiya», 2010. 1144 p. (in Russ.)