



INVESTIGATION OF THERMAL PROPERTIES OF SELECTED POLYMER BLENDS

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Abstract

The influence of co-rotating twin-screw extrusion of polymer blends on their thermal properties has been presented in this paper. The polymer blends that have been taken into consideration consisted of PE and PP processed by BTSK 20 without any compatibilizer. The contents of minor phase, i.e. PP in polymer matrix, i.e. PE in wt. % ranged from: 95/5, 90/10, 85/15 to 15/85, 10/90, 5/95 [1 – 4, 9 – 11]. The main idea of this work was verification of what changes the co-rotating twin-screw extrusion may cause in thermal properties of above mentioned polymer blends as well as polymers used separately. The DSC and TGA methods have been chosen for this purpose. The results may be applied for recycling purposes of mixed plastics, however, in this work the primary polymers have been used to avoid any undesired influence of recycling operations for blends' properties.

Keywords: PE, PP, co-rotating twin-screw extrusion of polymers, polymer composites, thermal properties

1. Introduction

The enhanced interest in application of different compositions of polymers can be observed lately. The analysis of literature reveals that such compositions are thermodynamically immiscible (incompatible) [2 – 4]. It turns out however that the most advantageous content of (MP) positively influencing the properties of (PM) is no more than 15 wt.% to avoid undesirable coalescing phenomena of the (MP) particles at higher concentrations. The advantageous particle size is 1 μm .

It is sometimes estimated that presently 30 % of all produced plastic products are made of polymer mixtures and compositions. The enhancement of this production is of ever growing tendency.

2. Objective of the work

The objective of the present work was to investigate the influence of selected screw configuration of the co-rotating twin-screw extruder type BTSK-20 of very good dispersive – distributive performance on some thermal properties [2 – 4, 10, 11]. The scheme of the segments arrangement has been presented in fig. 1. In spite of practical application for plastics recycling, the

investigation has been conducted using primary granulates of polymers including processing conditions for simulation of the real recycling procedure.

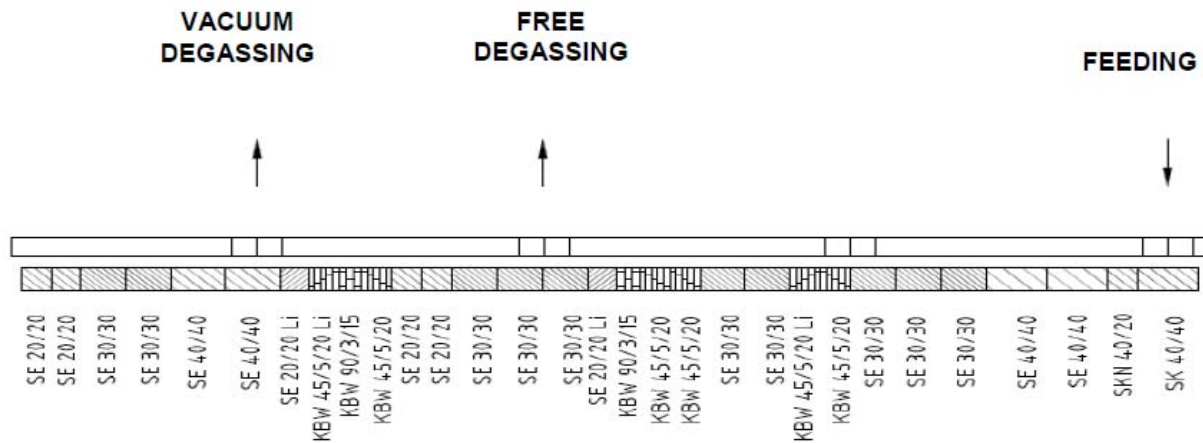


Fig. 1. The scheme of the plasticizing system of the co-rotating twin-screw extruder type BTKS $\Phi 20 \times 40 D$: SK – single winding transport segment, SE – double winding transport segment, SKN – transition segment (single-winding), Numbers: 1. Winding pitch, mm, 2. Length of the segment, mm, KBW – kneading segments, Numbers: 1. Angle between eccentric axes, 2. Number of eccentrics, 3. Length of the segment, mm, Letters: direction of the segment inclination: Li – left-handed segment, no letter – right-handed

3. Experimental

Materials

The polymers that have been chosen for tests were PE and PP of domestic production (Basell Orlen S.A.), of type FGAN 18-D003 and Moplen HP 456J, respectively.

Processing conditions

The component polymers were mixed together and processed twice simulating the real recycling procedure of the single component in conditions as follows:

primary granulate \rightarrow 1st processing to get the product I \rightarrow size reduction, cleaning, a.s.o. \rightarrow 2nd processing to get the product II

When recycling the single component is subjected to two thermal attacks. The simulation of the above mentioned polymer blends also concerns the two reprocessing steps. The processing temperature all over the heating zones did not exceed 190°C, (both for extrusion and injection molding operation), the usual processing temperature of PP and PE. The products of this recycling procedure were polymer compositions in pelletized form. For better understanding of the idea the primary polymers were also subjected to this above mentioned reprocessing [5 – 8].

The configuration used in this work, consisting of transporting, kneading and returning (braking) segments of strong mixing and dispersive function was thought for good homogenizing effect of polymer blends. The problem relies on using four special left – handed screw segments acting as returning (braking) segments, (marked as Li), situated just before the degassing points that enhance the effectiveness of the mixing function.

Test methods

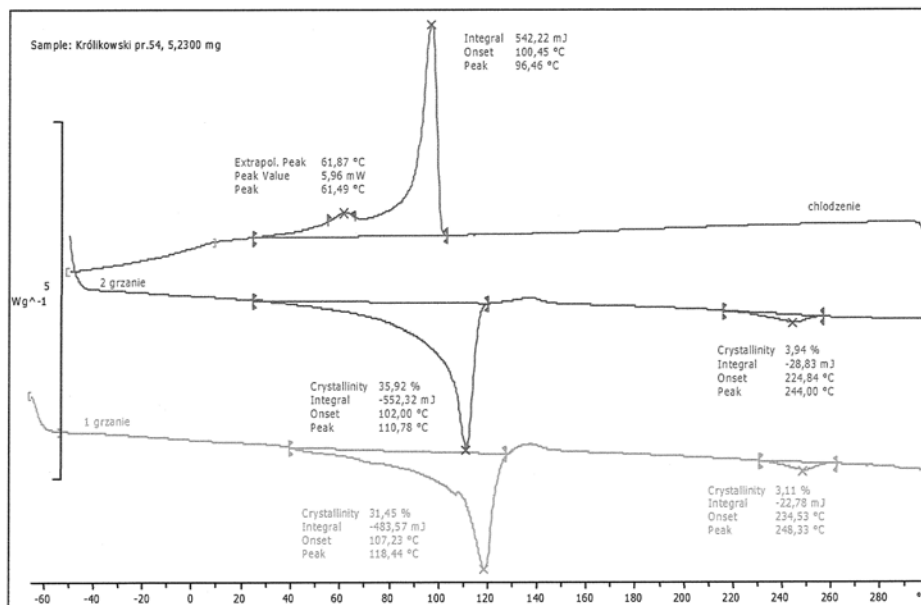
The selected parameters that have been taken into consideration during the investigation were as follows:

- DSC values using Mettler – Toledo calorimeter type DSC 822^o/700 after PN-EN ISO 11357-1:2002 standard,
- TGA values using thermogravimetric device Mettler – Toledo type TGA/SDTA 851^o/1100 after PN-EN ISO 11358:2004 standard.

4. Results and discussion

The results of investigation have been gathered and presented on figures 2 – 5. They concern results of thermal properties for polymer blends, primary polymers and primary polymers reprocessed with this configuration. The results after selected parameter values give information how far double reprocessing using a selected screw configuration can influence the above mentioned properties of investigated separate polymers as well as in blends compared to primary polymers.

S_K investigation of the mixture PE/PP after DSC shows two separated phases of different crystalline degree (scheme 1). Both polymers PE and PP, being of crystalline structure show strong mutual influence of (PM) on (MP) (fig. 2) depending on what polymer prevails as a polymer matrix. It confirms the immiscibility of PE and PP.



Scheme 1. The example of the run of DSC analysis of a polymer blend showing characteristic parameter values including S_K

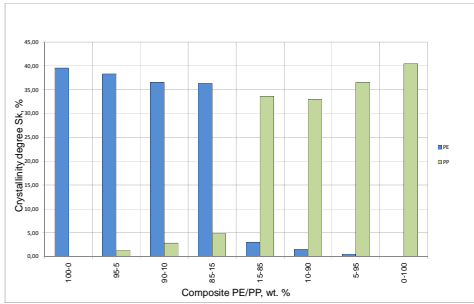
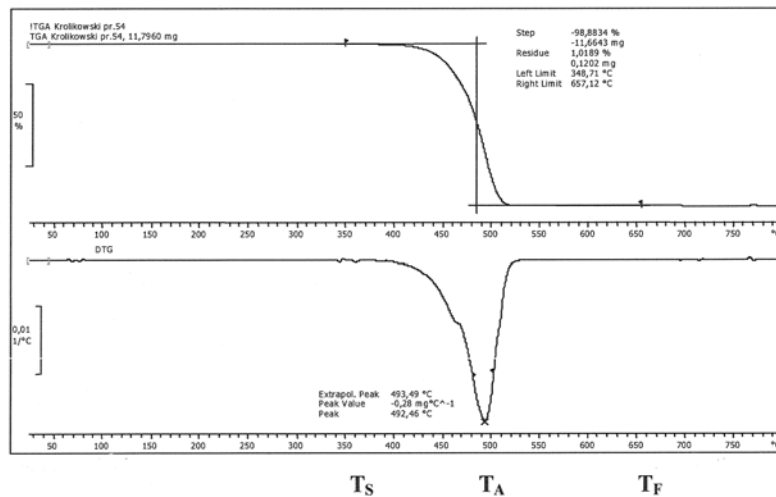


Fig.2. The influence of MP on crystalline degree S_K of PM after DSC

The thermal results, i.e. melting temperature as well as crystalline degree for single polymers (not presented in the work) show slight changes when reprocessing and may be neglected in further discussion.

The problem of TGA analysis (scheme 2) is shown on figs. 3 and 4 presenting starting T_S and average T_A temperatures of blends' decomposition when heating samples up to 600°C.



Scheme 2. The example of the run of the TGA analysis of a polymer blend showing characteristic temperature points

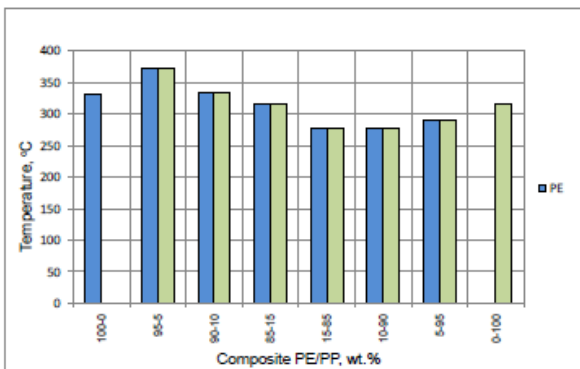


Fig.3. The influence of MP on starting temperature T_S of decomposition of PM after TGA

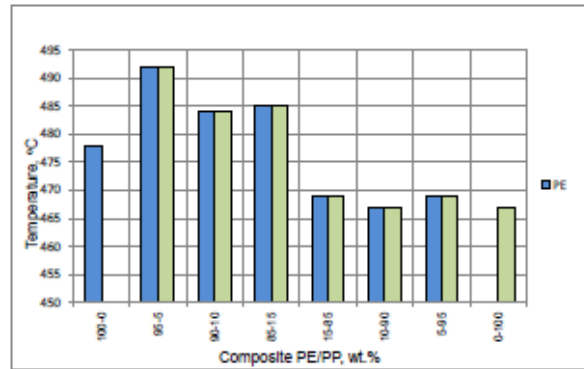


Fig.4. The influence of MP on average temperature T_A of decomposition of PM after TGA

The diagrams do not show any phase separation. The analysis only confirms the homogenization of the components, not miscibility. The enhancement of T_S and T_A in almost all cases of PE/PP compositions may indicate the arising of new fractions shifting both temperatures in higher values. The mixtures PP/PE indicate shifting T_S and T_A towards lower temperatures what may indicate quicker decomposition of PP/PE compositions because of PP matrix. The changes in T_S values are much stronger than in case of T_A for compositions PE/PP (scale comparison).

On the other hand, the fig. 5 shows the differences in decomposition temperatures T_S , T_A and T_F for pure separate primary polymers compared to reprocessed ones. Starting temperature may differ by 80°C and final ones even by 150°C.

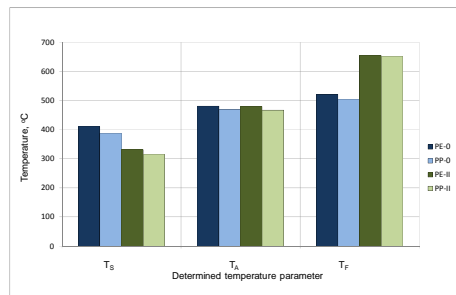


Fig. 5. Comparison of TGA results for primary and reprocessed separate polymers used in the work

The fall of T_S means that a new polymer fraction of lower decomposition temperature may arise. On the other hand, the increase of T_F temperature indicates a presence of the new fraction of higher decomposition temperature. The average temperature T_A however varies very little. So, it may be considered as a resultant temperature for above mentioned polymers and all thermal phenomena arising in polymers when reprocessing. Such great differences are not observed for blends. The changes in above mentioned temperature values vary stronger for PP resin than for PE, indicating higher susceptibility of PP to thermal decomposition and to possible mechanochemical reactions than PE. The same case may concern PE/PP and PP/PE compositions after figs. 3 and 4.

5. Conclusions

The conclusions that may be drawn from the above mentioned results are following:

- the thermal behaviour of the tested samples shows immiscibility of both components, however their homogeneity is quite well and they may be processed together,
- in spite of possible formation of different fractions in reprocessed polymers the average as a “resultant” temperature of the blend decomposition (T_A) remains almost unaffected,
- the results may be very interesting for the recyclers dealing in processing of recovered plastics, because the presented idea may help to influence the final costs connected with plastics recycling.

Some abbreviations used in the text:

(MP) – minor phase	S_K – crystalline degree
(PM) – polymer matrix	T_S – starting TGA temperature
PE – low density polyethylene (LDPE)	T_A – average TGA temperature
PP – polypropylene	T_F – final TGA temperature

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