THE INFLUENCE OF THE RECYCLED POLYMERIC MATERIALS VISCO-ELASTICITY ON THE PIPE EXTRUSION HEAD DESIGN

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Abstract. There are summarized the experimental researches, previously performed, concerning viscous-elastic characteristics changes of PP due to recycling. There are presented, comparatively, the results for the virgin and 10 times recycled polypropylene. Using CAD-CAM it is studied the influence of the PP viscous-elastic characteristics changes due to recycling on the pipe extrusion head design, aiming to obtain a good extrusion product (expressed in the given case by the pipe dimensions stability). It resulted that it is compulsory to do experimental research to obtain the actual viscous-elastic properties of the polymer after many times recycles, because these properties affect significantly the output and the annular uniformity of the pipes thickness.

Keywords: viscous-elasticity, polymeric material, recycling, extrusion head for pipes.

1. INTRODUCTION

The recycling of different types of products/materials is in very high demand in our days. The researches aim a great variety of topics like: the collecting, sorting, developing friendly environmental recycling technologies etc.

In polymeric materials domain, which knew a fulminate development over the last decades, the situation became critical, so legislation, organizational measures and not the least important the new recycling technologies were imposed.

Many scientific researches studied the recycled polymeric materials, most of them referring to the mechanical behavior and less flow characteristics, the last being very important in reprocessing performances (viscous-elastic, thermal, mechanical, energy recovery etc.) [1-15]. So, it was not make the connection between the changes of material properties due to recycling, re-processing optimal parameters and the product quality.

The authors initiated some years ago an extensive theoretical and experimental research regarding the modifications of polymeric material properties due to recycling [16, 17], which affect the reprocessing parameters, performances and product quality. Here is presented the influence of the changes of the viscous-elastic properties due to recycling. The viscous-elastic properties influence mainly the swell, which could

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determine a product with dimensions out of the standards (especially other thicknesses values) or even other forms of the product transversal section.

In the followings is presented the case of an extrusion head for PP pipes – modeling the effects of the recycling on the needed die gap.

2. MODIFICATIONS OF THE POLYMERIC MATERIAL VISCOUS-ELASTIC PROPERTIES DUE TO RECYCLING

The recycling of the polymeric materials affects not only the flow properties but also the extrusion performances and the product dimensions, if the material is reprocessed on the same extrusion head.

The experimental installation used, the experimental procedures and the experimental data processing were presented in papers [16, 17]. As a conclusion, the former researches showed how the number of recycling modifies the flow properties, in terms of rheological constants/effective viscosity changing; it was also measured the residual swell calculated as ratio between residual cross section area and the area of the capillary, at the room temperature, $K_{u,r}$, function of shear rate [18].

$$K_{u,r} = \frac{S_{e,r}}{S_{e,0}} = \left(\frac{d_{e,r}}{d_e}\right)^2 . \quad (1)$$

This put into evidence two phenomena which happen: the exit die swell of polymer due to viscous-elastic behaviour and the contraction of the extruded polymeric plastic thread as it is cooled from the solidification temperature to the room temperature.

In the present paper it is intended to show the correlation between residual swell index values $K_{d,r}$, in terms of diameters ratio (the residual polymer extruded diameter and the die diameter, both at the ambient temperature) and the pressure at die exit (capillary with circle cross section).

$$K_{d,r} = \frac{d_{e,r}}{d_e} \quad (2)$$

The measured values of $K_{d,r}$, is given in Figure 1.

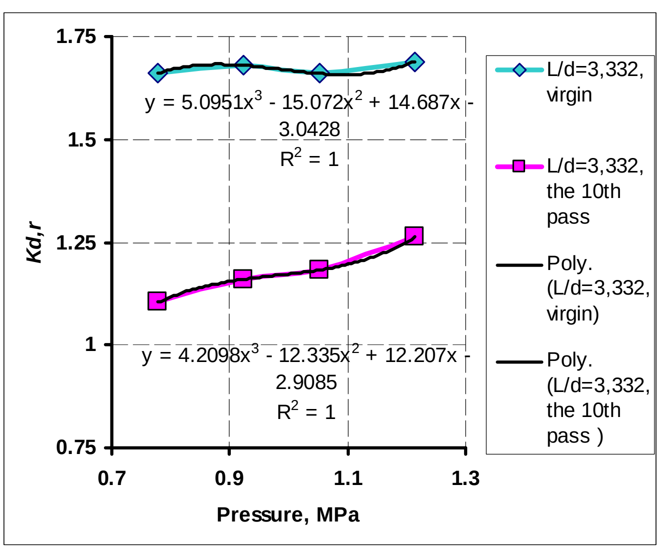

Fig. 1. The residual swell coefficient versus pressure for PP virgin and ten times recycled.

It can be seen that it is a slightly variation of the $K_{d,r}$ parameter with the pressure, increased in the case of the 10 times recycled polymer. It is an obvious difference between the $K_{d,r}$ values in the case of 10 times recycled polymer compared with the virgin material (first pass).

In equation (2) $d_{e,r}$ - the residual extruded polymeric plastic thread diameter is determined taking into account the thermal expansion of the capillary, made of steel (determined by means of linear expansion coefficient of the steel at extruding temperature, α_{ol} , and the difference of the extruding and erecting apparatus temperatures, the last one is usually ambient temperature, ΔT_{ol}), the viscous elastic swell, $\Delta u_{v,e}$ and the linear contraction of the plastic thread, characterized by the polymeric material linear contraction coefficient and the difference of temperatures between the solidification point and the ambient temperature.

$K_{d,r}$, parameter, obtained from measurements in the case of the extrusion of virgin and ten times recycled polymer, will be used to evaluate the viscous-elastic die exit swell of the extruded polymer, which will be used afterwards, to determine the design value of the gap for the exit annular die of a pipe extrusion head.

The measurements performed were simplest, on the cooled material up to the room temperature, needing the simplest measurement devices, not like the case of non contact measurement, rather complicated and expensive. But with this procedure it is intended to demonstrate that they provide valuable information which can be used in extrusion head design. In the experimental device the polymeric material was extruded through a capillary. Determining the viscous-elastic swell, by this method, there are used the linear expansion/contraction instead of volumetric one, traditionally used, as can be seen in paper [16].

The proposed method is rapidly applicable.
So, resulted the viscous-elastic exit swell (with the data measured on the capillary) as,

$$\Delta u_{ve} = \frac{d_e \cdot \lfloor k_{dr} - 1 - \alpha_{ol} \cdot \Delta T_{ol} + (1+\alpha_{ol}) \cdot \alpha_{mp} \cdot \Delta T_{mp} \cdot \Delta T_{ol} \rfloor}{(1 - \alpha_{mp} \cdot \Delta T_{mp})}. \quad (3)$$

The simulations to emphasize the influence of the residual modifications of the extruded product diameter, for virgin and ten times recycled polymer, were done on an annular exit gap extrusion head, for pipes. The design value of the gap, taking into account the viscous-elastic die exit swell and the contraction is given by:

$$s_f = \frac{s + \Delta u_{ve} \cdot (\alpha_{mp} \cdot \Delta T_{mp} - 1)}{1 + \alpha_{ol} \cdot \Delta T_{ol} - \alpha_{mp} \cdot \Delta T_{mp} - \alpha_{ol} \cdot \Delta T_{ol} \cdot \alpha_{mp} \cdot \Delta T_{mp}} \quad (4)$$

where $\Delta u_{v,e}$ is given by equation (3). The simulations were done for the parameter values given in Table 1.

Table 1. Calculus values for the main parameters.

D, m	*s*, m	α_{ol} m/m°C	$\alpha_{mp,}$ m/m·°C	ΔT_{mp}, °C	ΔT_{ol}, °C	de, m
0,110	0.015	0.000014	0.00016	110	180	0.002401

The viscous-elastic residual swell, determined with the aid of the experimental measurement (on a capillary device) and with the proposed calculus equation (3), for PP virgin and 10 times recycled is given in Figure 2.

In Figure 3 is presented the annular design gap for annular exit extrusion head (for pipes), determined with the aid of the viscous-elastic residual swell values given by the curves presented in Figure 2 and the calculus model proposed – equation (4). One can observe that the design value of the annular gap decreases slightly with the pressure and, at the same pressure, the value of the needed gap is different when the polymer is virgin compared with the case of 10 times recycled. At the same pressure of 1 MPa, the needed design gap value is ~26 % lower in the case of 10 times recycled PP compared with the case of the first extruding process. Evidently nobody is changing the extrusion head when recycling – so the pipe wall thickness resulted will be different compared with the standard value.

To obtain the same thickness it must be changed the annular exit gap value. This could be possible modifying the design of the nozzles in the extrusion head (the exit nozzle it would be preferable to be divergent conical and the mandrel designed axially displaceable, to make the exit annular gap of a value range, which permits to obtain the standard extruder wall thickness (more or less like in the case of parisson programming in extruding blow molding).

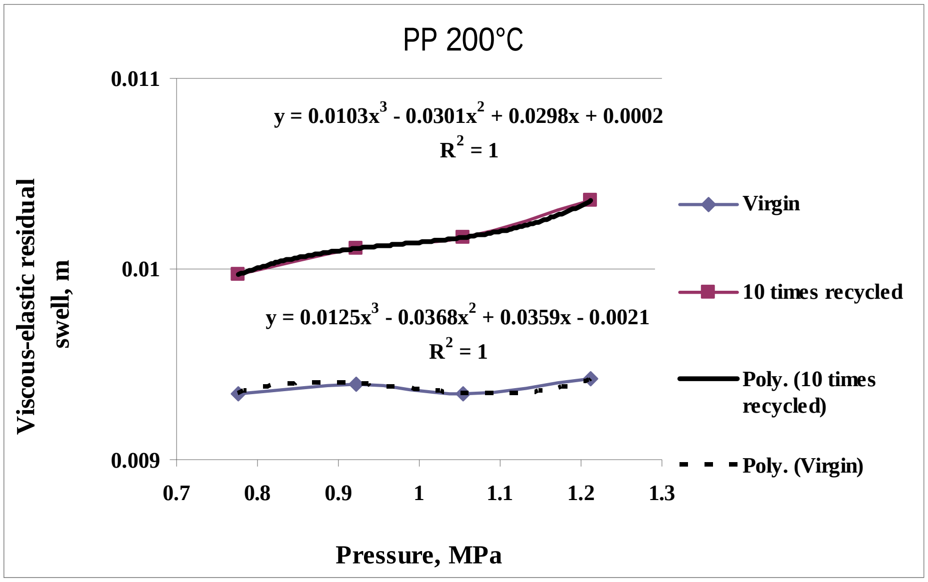

Fig. 2. Residual swell index versus pressure ($K_{d,r} - p$)
for PP at 200°C, extruded in a capillary of 2.401 mm diameter.

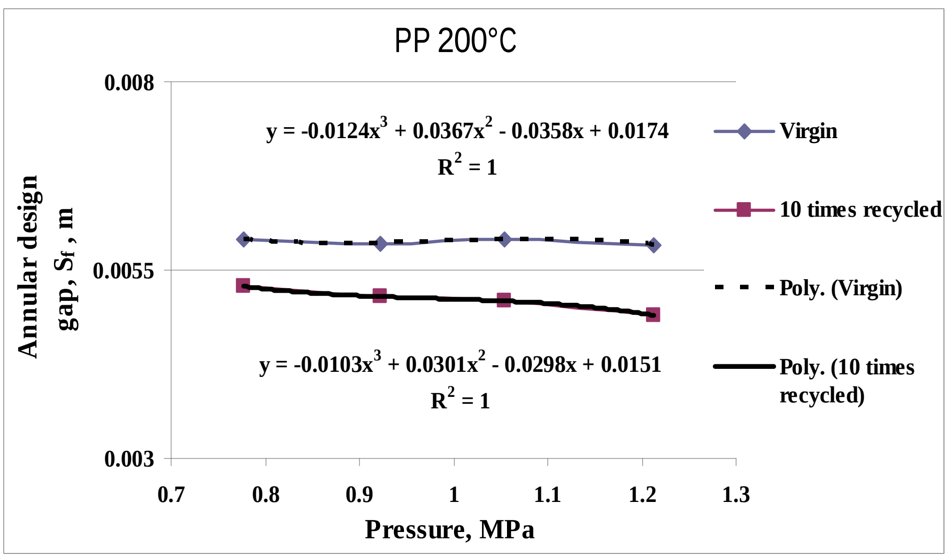

Fig. 3. Annular design gap versus pressure, for PP at 200°C, virgin and 10 times recycled.

3. CONCLUSIONS

As it can be observed, valuable data for virgin and many times recycled polymers can be obtained from laboratory experiments. The reprocessing modifies the flow properties; here were presented the viscous-elastic properties changing and their influence on design parameters. It was tested the polypropylene, Midilen type, virgin and 10 times recycled at 200^{o}C. The choice of the PP was because this is one of the two most recyclable plastic (the other one is LDPE). It was proposed the substitution of a difficult and expensive non-contact measurement with a simply one which can provide essential information for design. No matter which is the experimental research method on the many times recycled material the conclusion is that this is compulsory. Further it is intended to see how the recycling influence the extrusion head feature, $Q(\Delta p)$.

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