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OSCILLATORY FLOW OF POLYMER BLENDS DURING EXTRUSION

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Summary: *It is shown that oscillatory flow of polymer blends during extrusion is possible to characterize by means of notions from the catastrophe theory.*

1. INTRODUCTION

Oscillatory flow belongs to the types of flow instabilities frequently encountered during extrusion of polymer melts. The onset of these defects corresponds to the flow conditions when the critical shear stresses or the critical shear rates are attained. The value of a critical shear stress (rate) depends on many factors. The most important ones are characteristics of the extruded material, its temperature, length and radius of a capillary, length-to-radius aspect ratio, material of which an extrusion die is made, etc. In contrast to polymers that do not exhibit oscillatory flow, polymers that do are characterized by ambiguous rheograms, in which uniqueness between shear stress and shear rate is violated in the so-called hysteresis region.

2. BEHAVIOUR OF POLYMER BLEND

Fig.1 depicts the rheograms for various weight ratios of two entry polymer components - linear polyethylene Hostalen GM 9255F and branched polyethylene Bralen RB 0323. Their basic characteristics (melt flow index, molecular and molar weights, density, temperature) are given in Bartoš et al.[1]. Unlike the branched polyethylene used, the linear polyethylene itself and its blends with bPE exhibit oscillatory flow and therefore two critical shear stresses and corresponding four critical shear rates were measured for various weight ratios of lPE/bPE (0/100, 10/90, ... 20/80, 90/10). Since density of both components is approximately the same, volume fraction is almost identical to weight fraction. The weight fraction of lPE is denoted by w_2 in Fig.1.

3. CATASTROPHE THEORY

It is interesting that 3-D figure (with axes representing shear rate, shear stress and weight ratio) of this phenomenon, i.e. appearance of ambiguous rheograms for the individual weight ratios of blend, may be characterised by means of notions from the catastrophe theory.

Catastrophes are violent sudden changes representing discontinuous responses of systems to smooth changes in the external conditions. The term catastrophe is used in the cases, roughly speaking, where the continuous changes of the parameters cause the qualitative changes of the states, this is usually denoted as jumps. In fact the notion ´catastrophe theory´ as suggested by Thom [2] represents the combination of singularity theory and its application. Singularity theory predicts the

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geometry of a catastrophe, i.e. transition from one equilibrium state to another on changing the control parameters (see e.g. Arnol´d [3], [4], Bröcker and Lander [5]).

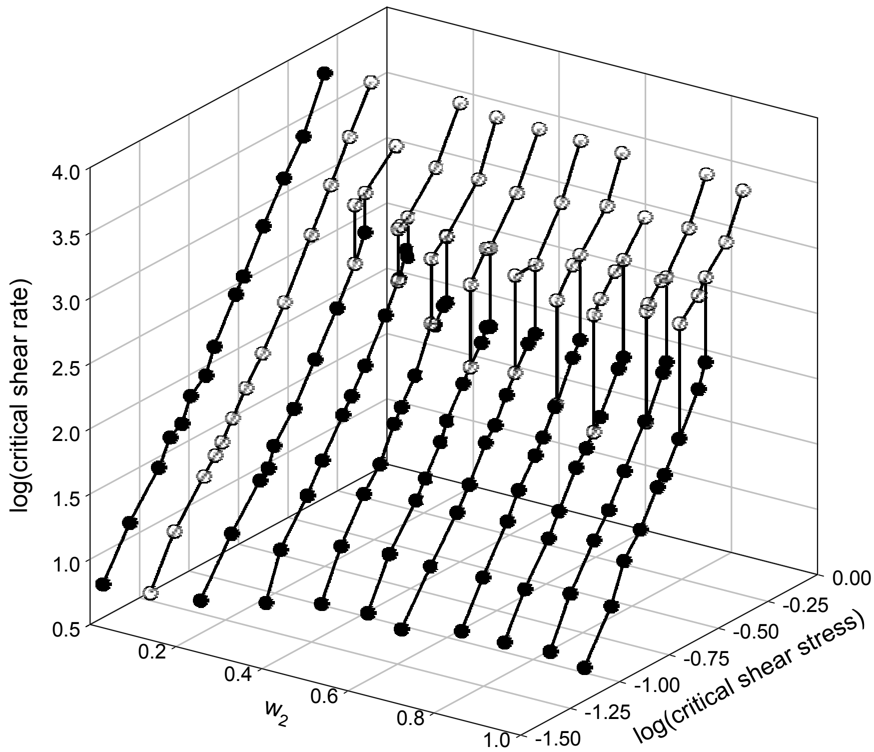

Fig.1 Flow behaviour of blends for various weight ratios
(entry components: lPE Hostalen GM 9255 and bPE Bralen RB 0323)

Thom´s theorem says that up to the addition of a non-degenerate quadratic form in other variables and up to multiplication by ±1, a singularity of codimension ≤4 and ≥1 is right-equivalent to one of the so-called seven elementary catastrophes. One of this seven elementary catastrophes is called a ´cusp´, see Fig.2, geometrical illustration of this manifold is given in detail e.g. in Woodstock and Poston [6], Gilmore [7].

4. ELEMENTARY CATASTROPHE OF A TYPE ´CUSP´

The 3-D behaviour of the manifold formed by the rheograms in Fig.1 corresponds to the elementary catastrophe of the above mentioned type cusp. The projection of the multivalued (hysteresis) region forms a semicubic parabola in the plane of the control parameters (critical shear stress, weight ratio w_2 of lPE) with a cusp in the plane corresponding to a branched polyethylene.

5. ACKNOWLEDGEMENT)

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6. REFERENCES

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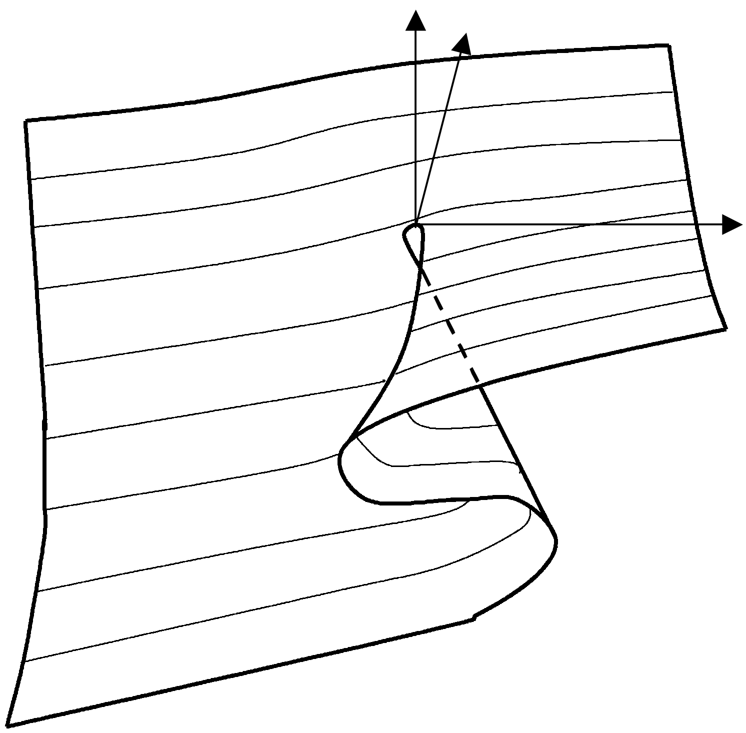

Fig.2 Elementary catastrophe of a type ´cusp´