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Сборник трудов

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В сборник включены материалы XIII международной научно-технической конференции «Машиностроение и техносфера XXI века», отражающие научные и практические результаты в области обработки изделий прогрессивными методами, создания нетрадиционных технологий и оборудования. Представлены современные достижения и перспективные направления развития технологических систем, металлорежущего инструмента и оснастки. Освещены современные проблемы материаловедения в машиностроении. Рассмотрены вопросы механизации и автоматизации производственных процессов, управления качеством и диагностики технических систем. Приведены сведения об особенностях моделирования, экономических проблемах производства, вопросах инженерного образования и других актуальных проблемах техносферы.

Предназначен для научно-технических работников, ИТР и специалистов в области машиностроения и техносферы.

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CALCULATION OF RUBBER COMPOUND DISTRIBUTION
IN EXTRUSION CROSSHEAD

Lashmanov D. (R.T.U., Riga, Latvia)

A model is proposed that is an attempt to describe to some extent the principle of rubber compound flow in a roll covering crosshead.

A relatively simple software based on Microsoft Excel® sheet for the prediction of rubber compound flow behavior in a certain type of side-fed mandrel die (crosshead) is developed. The software allows estimating the velocity profile of a rubber compound across the outlet section of the die and corresponding pressure consumption.

Introduction.

When extruding elastomeric materials, the dimensions of products are essentially determined by the geometry of an extrusion die. When considering rheological point of view, the solution must be found, how should the dimension of the flow channel in the die be selected. In case of crossheads with annular exit cross section, that have been used for the production of rubber hoses and roll coverings, the most important points are the uniform melt distribution and keeping the pressure drop in reasonable limits. The convertation of the theoretical model into a software package allows for quality evaluation of the predictions.

The problem definition

The initial information needed for calculation is material data (Power Law values *n* and *K*, and compound density ρ), required mass throughput, as well as geometry conditions [1].

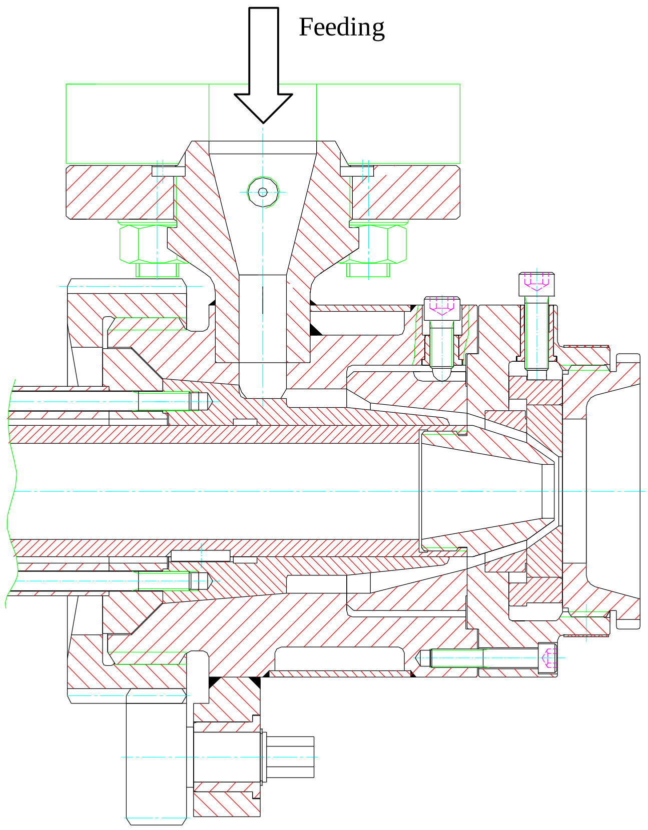


Fig. 1. Typical crosshead design

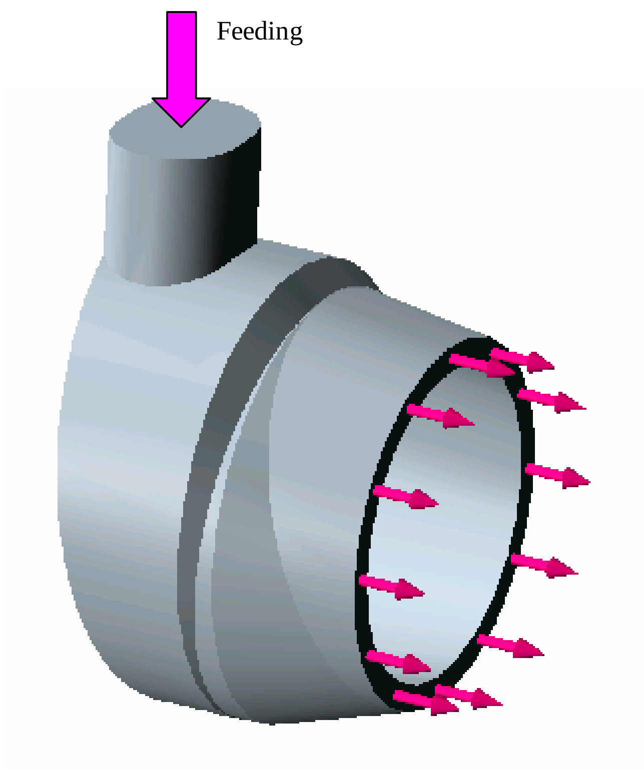


Fig. 2. Representation of rubber flow channel shape

Extrusion dies with annular exit cross-section can often be considered as wide-slit dies wrapped around an axis. Of course, the relation between the flow channel width

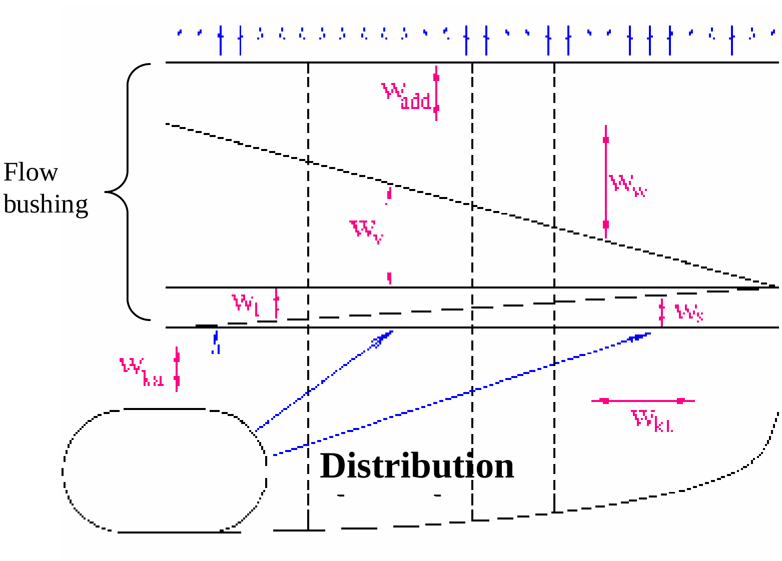


Fig. 3. Sketch of the unwrapped manifold

(perimeter of the circular slit) and the channel height B/H should be big enough. This condition is well satisfied in case the cross-head is of the given type (Fig. 1, 2).

Therefore, we may represent the side-fed manifold as a flat unwrapping. Owing to symmetry, only one half of the flow channel may be taken

The considered model assumes the existence of the following zones in the manifold (Fig. 3):

- Distribution channel. It is assumed that a rubber compound flows in tangential direction in this zone only. During the flow, it meets the resistance $w_{kt,}$ which causes pressure drop in the channel. Besides, the rubber flows in axial direction, as well. On that path, it feels the resistance w_{ka}. It results in the first part of the total pressure drop in the axial direction.
- The adjustable flow bushing. The geometry of the bushing consists of two pairs of intersecting cones (or a cylinder and a cone). This implies that there are four separate zones in the bushing. During the calculation of channel heights, the intersection of two cones because of its complexity has been turned into the intersection of a cone and a cylinder. Necessary corrections are made. The resistances in the four zones are respectively w_s ,w_t ,w_v , w_w.
- The last area where the rubber flow has been calculated is the additional resistance or a flat slit at the exit of the die. The additional pressure drop is caused by the resistance w_{add} .

The geometry of the die is divided into segments; the volumetric flow rates and pressure balances are done in each of them [2, 3].

The main steps of the algorithm are described below.

1) V_1 (the flow in the first slice in axial direction) has been iteratively assumed by the program user.
2) Starting from the V_1 and the initial data it is possible to find out the pressure drop in the first slice Δp_{a_1} :

$$\Delta p_{a_1} = \Delta p_{ka_1} + \Delta p_{S_1} + \Delta p_{T_1} + \Delta p_{V_1} + \Delta p_{W_1} + \Delta p_{add_1} \qquad (1)$$

Each of the parts of this sum can be calculated as follows:

$$\Delta p = \left(\frac{\dot{V} \cdot 2(1+2n)}{n \cdot H^2 \cdot B} \right)^n \cdot \frac{2KL}{H}$$

Here: n and K – the parameters of the Power Law; $\dot{V}$ – the volume flow through the slit; H – the middle height of the lot; B – the width of the lot; L – the length of the lot.

3) The volume flow in the distribution channel V_{k_1} is calculated as the difference between the initial entering flow (one half of the full required flow) $V_{full}/2$ and V_1:

$$V_{k_1} = \frac{V_{full}}{2} - V_1$$

4) From the known volume flow in the channel we can find the pressure drop in the channel between the centers of two neighboring slices with consideration of wall presence on one side of the channel:

$$\Delta p_{k_1} = \left(\frac{\dot{V}_{k_1} \cdot 2(1+2n)}{n \cdot H^2 \cdot B} \right)^n \cdot \frac{2KL}{H} \cdot \frac{1}{F_p{}^n}$$

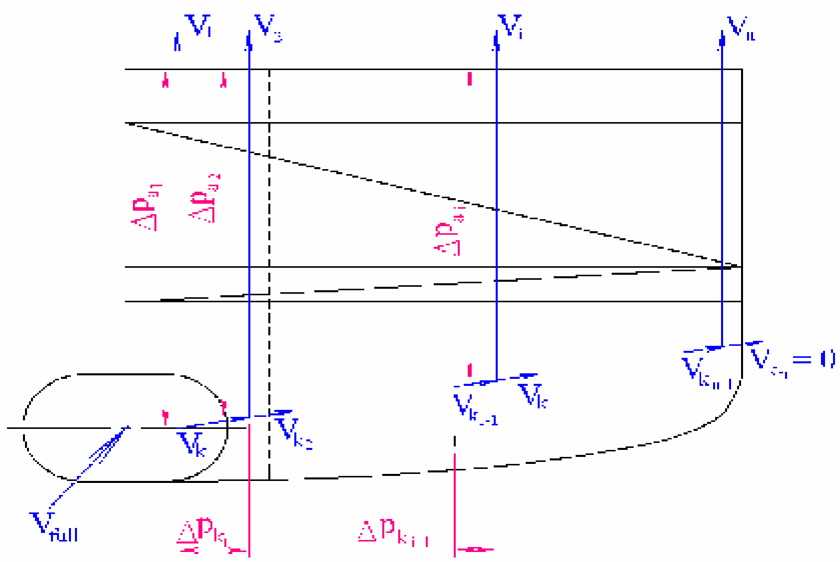


Fig. 4. Segmentation of the manifold for the calcula-

where F_p is the coefficient of shape:

$$F_p = 1{,}5766(H/B)^2n^2 - 3{,}1156(H/B)^2n + 1{,}6457(H/B)^2 - 1{,}9895(H/B)n^2 + 4{,}071(H/B)n - 2{,}7738(H/B) - 0{,}0211n^2 + 0{,}0394n + 0{,}9835$$

5) The pressure difference acting along the second slice is equal to the pressure drop along the first slice decreased by the pressure drop in the distribution channel between the first and the second slices: $\Delta p_{a_2} = \Delta p_{a_1} - \Delta p_{k_1}$

6) Now the problem is to find the volume flow through the second slice. Analogically with the equation (1) we have:

$$\Delta p_{a_2} = \Delta p_{ka_2} + \Delta p_{S_2} + \Delta p_{T_2} + \Delta p_{V_2} + \Delta p_{W_2} + \Delta p_{add_2} \qquad (2)$$

Pressure drop on each of the sections can be described [7] as

$$\Delta p = K \cdot V^n \cdot w^n \qquad (3)$$

where w is the channel resistance: $w = \left(\frac{2L}{H} \right)^{\frac{1}{n}} \cdot \frac{2 \cdot (1+2n)}{n \cdot B \cdot H^2}$

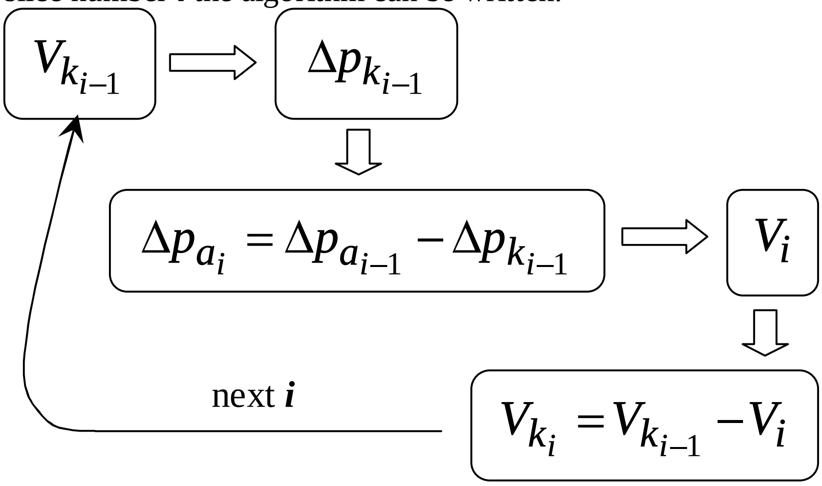
Substituting (3) for (2) we receive

$$V_2 = \left(\frac{\Delta p_{a_2}}{K \cdot \left(w_{ka_2}{}^n + w_{S_2}{}^n + w_{T_2}{}^n + w_{V_2}{}^n + w_{W_2}{}^n + w_{add_2}{}^n \right)} \right)^{\frac{1}{n}}$$

7) The following channel flow is

$$V_{k_2} = V_{k_1} - V_2$$

The calculation returns to step Nr. 4 and repeats consequently for all the slices. For the slice number ***i*** the algorithm can be written:



The control value of the program is the channel volume flow from the last slice. Obviously, this amount must be as close to zero as possible. In order to get this, user of the program should every time iteratively find an appropriate value of the assumed volume flow through the first slice V_1.

Conclusions.

The main result of the calculation is the graph of the flow distribution at the exit from a crosshead (Fig. 5). It represents the relative volume flow distribution along the perimeter of the exit slit (0°-180°) in comparison to theoretically even distribution.

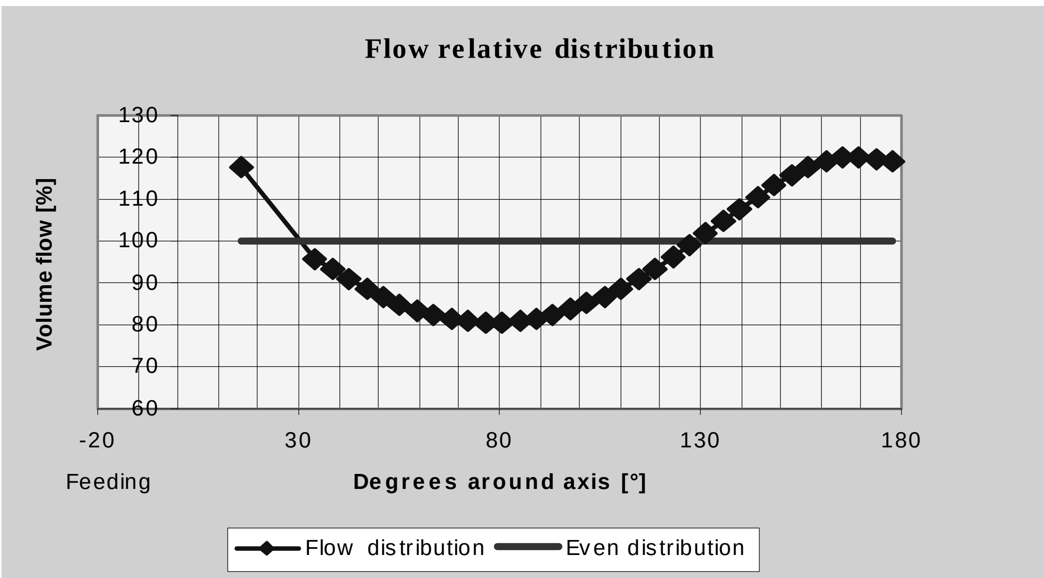


Fig. 5. Flow relative distribution

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