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Bank Measurement in Film and Sheet Extrusion

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The quality of polished, extruded film and sheet is decisively affected by the distribution of the bank of material in the nip of the polishing stack. An understanding of the size and position of the bank can help in the start-up or conversion of the extrusion line. In addition, the bank size can be used as a reference variable for automatic die control.

Compared with injection moulding machines, extrusion lines have much lower degrees of automation. Even with highly demanding products, the quality still largely depends on the experience and intuition of the operator.

It is a well known fact that the quality of polished film is critically determined by the distribution of the bank of material in the nip of the polishing stack. Parameters such as surface quality, thickness distribution, shrinkage, flatness, the crystal structure of partly crystalline materials and, not least, the forming behaviour of films, are directly dependent on the size of the bank. However, the form of the bank across the width of the nip also has an influence.

Despite this insight, even new lines for the production of thin film polished on both sides do not provide any means of measuring the size and distribution of the bank. This is despite the fact that – with some lines and modes of operation – it may be impossible to visually assess the bank in the roll nip by conventional means.

Measurement Principle

In order to keep the edge swell and lateral shrinkage as small as possible, in practice, the dies are operated as close as possible to the roll nip. That, however, thwarted all attempts in the past to measure the bank directly from the front or from above.

The conditions prevailing during the polishing process are shown in Fig. 1 in a simplified view. The diagram shows a horizontally arranged roll pair with vertical melt feed. If a greater melt flow emerges from the die at this point, the melt web flowing into the roll nip is thicker at this point than in regions with a lower melt flow rate. This results in a thicker bank in front of the roll nip. By contrast, a larger cooling zone (t_g) is available than for the smaller bank (t_k) of the smaller melt flow. The cooling zone is measured from the first point of contact of the melt with the roll surface as far as the narrowest gap in the polishing stack.

The differences in the lengths of the cooling zones are used for the bank measurement. The crucial factor is that the contact times of the melt flows with the roll surface are also different since the web of the larger melt flow (longer cooling zone t_g and longer contact time) has a lower surface temperature downstream of the roll nip. Conversely, the surface temperatures of the smaller melt flow (which therefore has a smaller bank) is higher downstream of the roll nip.

The surface temperature is measured by means of an infrared thermometer (pyrometer) downstream of the roll nip. The camera's measurement wavelength is adjusted to the absorption maximum of the polymer being processed. In the case of polyolefins, for example, this is 6.8 µm.

If the measurement is to provide meaningful values, a uniform nip width should be set across the entire width of the roll nip. Only under these conditions, with equal local melt flows emerging from the die, are the banks sizes in the roll nip the same. In addition, it should be ensured that, with precisely equal melt flows fed into the roll nip, the melt web comes into contact with the polishing roll along a line parallel to the roll nip.

The optimum arrangement is a horizontally arranged polishing stack, when the melt is fed vertically from above into the roll nip. However, as has been shown with experiments on production lines, even with vertically arranged roll nips, the bank measurement system can still be used if the melt is fed into the upper roll nip.

Practical Execution of the Measurement

The infrared thermometer itself is intended to be installed in the polishing stack on a traverse for the measurement beam to register the web surface temperature after it has passed through the first roll nip (Fig. 2). Assuming that the nip size is constant across the entire width of the stack, the local temperatures determined are directly proportional to the particular bank size.

The precise bank distribution across the web width is finally displayed on a monitor. In addition, the system automatically measures the two edges of the web and thus provides information about the current width reduction. A further graphical display shows the setting screws for the die. From these, the plant operator can read in which direction and by how much he needs to adjust the individual setting screws at the die to obtain a uniform bank across the entire nip width.

Benefits of the Bank Measurement Technique

Bank measurement can be used to achieve both economy and quality advantages. The detailed information about size and position of the bank at each point on the polishing stack thus makes it easier for the machine operators to start up the line (Fig. 3). The decisive factor is that they can also simultaneously correct the flow-channel height in the die at several points. In addition, this information can prevent estimation errors when changing over to a different thickness. This results in a better utilisation of plant capacity as well as significantly reducing the amount of production waste during the start-up phase.

The bank measurement system is particularly helpful if very thin films are to be polished on both sides, since the bank cannot be seen at all by the naked eye. There is the risk that, because of a slight reduction in throughput, the web of melt in the roll nip may briefly lose contact with one of the polishing rolls, resulting in rejects. The bank profile also gives an indication of whether the line is already producing within the critical range at certain points.

The bank measurement also contributes to improved product quality, since the uniform bank across the entire nip width results in

- Homogeneous cooling of the film, improving film flatness and leading, for example, to a more regular crystalline structure in the case of partly crystalline materials
- Constant distribution of the nip forces and therefore more uniform mechanical properties, improving, for example, forming properties.

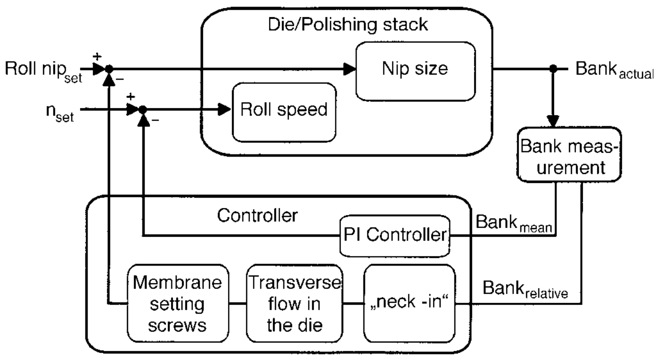

Fig. 4. Concept for mould control based on the bank measurement process, suitable for both film and sheet manufacture

The results of the bank measurement can also help with the fault analysis. For example, particular surface phenomena can be attributed to certain bank states in the roll nip, but the measurement system can also indirectly measure the roundness tolerances of the polishing and cooling rolls. This only requires monitoring of changes in the bank at one point in the polishing nip with respect to time. Usually a swelling and shrinkage of the bank in synchronisation with the rotational frequency of the roll can be ascertained. The amplitude of this oscillation correlates with the cyclical increase and reduction in the nip size as a consequence of roundness tolerances.

Once the optimum data has been determined, it can be saved and used later for repeated production of the same product. Start-up or thickness changes during production can thus be carried out faster and more economically.

Outlook

One function of a bead measurement system is to provide information for plant operators who have to set the die manually. However, the system only develops its full benefit for the production of polished film or sheet, if the bank size is used as a reference variable for a die controller (Fig. 4). For example, in film production, the conventional thickness measurement is unsuitable as reference variable if the product subsequently runs through a polishing roll nip. In this case, the result of the measurement provides information about the roll deflection or the differences in the melt stream emerging from the die, but being changed by the polishing roll nip.

A mould control concept based on bank measurement was developed at the German Institute for Plastics Processing (IKV) [1]. It is suitable for both film and sheet production. Conventional flex-lip dies with thermal expansion pieces can still be used. However, it is better to use dies that are adjusted by extremely small geared motors [1, 2, 3]. This solution not only reduces operating costs, but also has the advantage of allowing control with almost no dead time. The bank measurement, as reference variable, promotes rapid response of the controller, since the measurement takes place closer to the die than is the case with, for example, thickness measurement.

In sheet production, the introduction of membrane dies has opened the way to automatic die control [2]. Only micro geared motors come into consideration as actuators, since they can easily cope with the required travel distances of over two millimetres.

A closed-loop die controller has been found to provide a more stable process. For larger lines, it can easily take two to three hours until the line has reached a stable condition after start-up. During this time, slight fluctuations in the melt-flow distribution across the width of the die with respect to time occur. With a closed-loop die control, these differences can be compensated by adjusting the flow-channel geometry. As a consequence, the chief economic benefit of a bank-measurement dependent die controller results in the reduction of the amount of production waste on start up. Since, a product of satisfactory quality is produced quickly after start-up of the line. For large lines with throughputs of over 1000 kg/h, and where expensive raw materials are processed, the bank-dependent control pays off extremely quickly. (101090)

Fig. 1. Side view of a horizontal polishing stack, which receives different melt streams
Großer lokaler Schmelzestrom = Large local melt stream; Kleiner lokaler Schmelzestrom = Small local melt stream; Walze = Roll

Fig. 2. Schematic view of the measurement set up
Extrusionsrichtung = Extrusion direction; Schmelzevorhang = Melt curtain; Glättwerkswalzen = Polishing rolls; IR-Strahlung = IR radiation; Bewegungsrichtung des Pyrometers = Direction of movement of pyrometer

Fig. 3. Bank profile on change of the geometry of the flex lip at the slit die (IKV)
Folientemperatur = Film temperature; Position im Walzenspalt = Position in roll nip; Flex-Lippe rechts zugedreht = Flex-lip closed at right; Folienbreite = Film width; Folientemperatur = Film temperature; Position im Walzenspalt = Position in roll nip; Flex-Lippe rechts zugedreht = Flex-lip opened at left; Folienbreite = Film width; Folientemperatur = Film temperature; Position im Walzenspalt = Position in roll nip; Flex-Lippe rechts zugedreht = Flex-lip closed in centre; Folienbreite = Film width

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Wrinkle-Free Film Winding

Winding Systems for Web Materials

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During the production of web materials, such as blown or flat films, the winding process is a decisive factor in product quality. The problem is thus one of finding the correct winder for the product. Alternatively, a modular universal winder can be used, which can be adapted to suit various products in extrusion or coating technology.

The quality of extruded film depends to a great extent on the melt homogeneity and constancy of delivery of granules to the extruder. These factors are in turn closely bound up with the screw geometry and process parameters [1 to 5]. To obtain the most uniform film thickness possible, it is also important to design the extrusion die appropriate to the polymer [4].

Even if, after all these measures, the process is running optimally, the wound film reel may still show wrinkles, or the film may be unevenly distributed across the reel [6]. The reason is to be sought in the winding operation or the type of winder used.

Winder Types

The function of a winder is to wind the films in a compact reel with a reel quality that is constant with respect to length. This is carried out by various winding principles, according to which the winders are classified.

Contact Winder

In contact winding, one roll of rubber or chromium steel is driven and the film reel is pressed by mechanical or pneumatic means against the winding drum (Fig. 1) [7]. The advantages of the contact winder are the simple drive unit, large reel diameter and stable webs. However, the film reels are hard. With this type of web tensioning, the reel hardness is affected by the web tension and contact pressure.