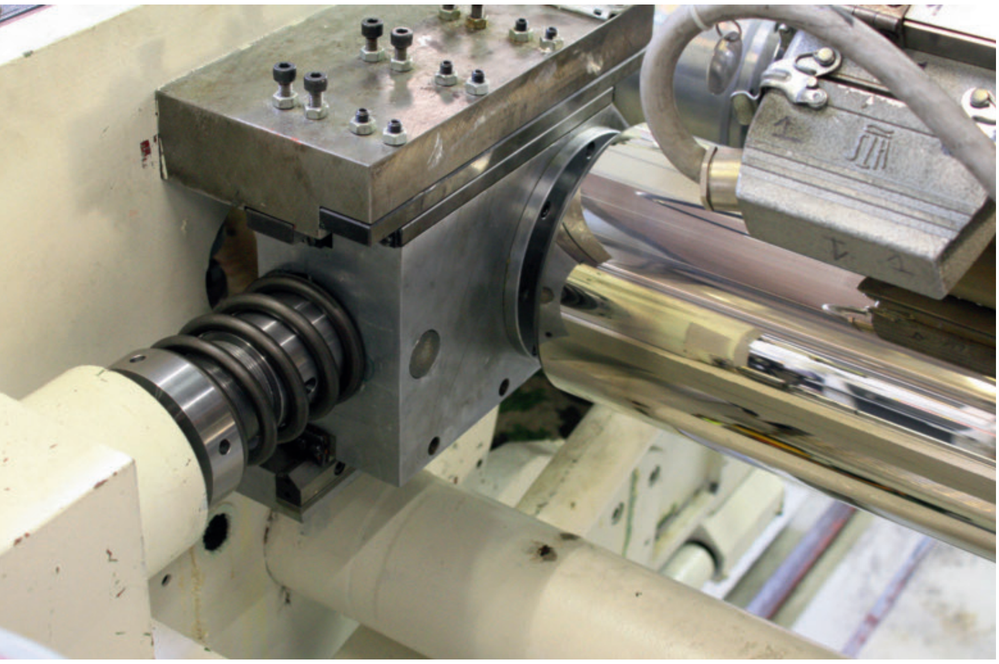
Touch-Up Polishing

Film Production. Extremely thin films in optical quality could be produced immediately on a pilot line by using a specially modified polishing roll stack. Its polishing roll is relatively small in diameter and equipped with a flexible steel jacket.



Polishing roll stack with vertical roll array which has been retrofitted with spring clamping and has a polishing roll with a flexible surface integrated into it (photo: Gross)

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In order to extrude films with top optical quality, a polishing roll stack is required much like those used to produce transparent sheets. The main component of a polishing roll stack consists of two counter-rotating rolls with highly polished surfaces. The rolls cool the melt and pass their surface quality along to the film surfaces. This process is relatively trouble-free when thicker sheets are produced, but problems arise when film thickness falls below certain limits. Generally speaking, these limits depend to an extent on the type of material. By and large, we can say that it is extremely difficult to polish both sides of relatively wide films less than 100 µm thick. What causes the problem is the extreme thinness of the melt curtain as it falls into the roll gap: it solidifies almost immediately upon touching the first cooled roll surface. Then there is no more melt, and only solid material is left in the narrowest gap between the rolls. However, the melt curtain emerging from the flex lip die always exhibits minimal thickness differences. The combined result is that the thickest area on the melt curtain determines how far apart both roll surfaces are at the narrowest point of the gap. Consequently, even minimally thinner adjoining areas on the curtain fail to come in contact with a roll surface. Then it is impossible for roll surface quality to be transferred to the entering melt curtain in such areas.

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State of the Art

Various approaches to solving this problem can be found in the patent literature [1–3]. In actual practice, two methods have become established. Either the polishing roll is equipped with an elastically yielding rubber jacket **(Fig. 1)** that adapts to thickness variations in the incoming melt at a low clamping force, or the second film surface is smoothed by a relatively thin steel belt that adapts to the surface geometry of the melt curtain.

Both approaches tend to reduce the desired take-off speed, since neither the steel band nor the rubber-covered roll have anything like the cooling capacity that can be expected from a straight steel roll. Moreover, the service lives of both steel bands and rubber-covered rolls are relatively short. But even more critical is the fact that the quality achievable by rubber-covered rolls, in particular, cannot be compared with what can be achieved by using a highly polished steel roll.

Efforts to polish the melt curtain across its entire width by increasing the clamping force on the polishing roll stack have resulted in intolerable roll deflection, thus leading to a worsening of film thickness tolerances. To solve this problem, the roll was either crowned, or roll diameter was increased, and rolls were specially designed to compensate bending lines. The resulting detail problems need not be discussed here. They are described in detail by [4]. That is why we suggested using small rolls and minimizing clamping forces on the polishing roll stack. However, at that time, the thickness tolerances for melt curtain emerging from the slit die were not as small as they are today. Consequently, the polishing roll had to equalize thickness differences notably greater than those we are faced with nowadays.

Spring Clamping

Given state-of-the art technology, the only entering melt curtains that have to be compensated exhibit thickness differences less than 0.01 mm. This tolerance range is so small that the use of purely

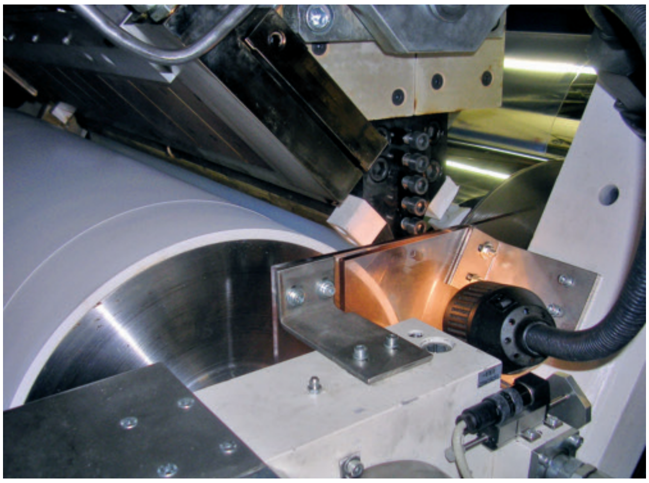

Fig. 1. Film polishing roll stack with integrated rubber covered polishing roll (photo: KraussMaffei, Berstorff)

metal rollers would appear quite realistic. Consequently, the old strategy that combined minimal clamping forces with small-diameter polishing rolls [4] was dusted off and a polishing roll stack correspondingly modified. In addition, an entirely new all-metal roll with a relatively small diameter of only 180 mm was designed and constructed in close cooperation with van Baal GmbH of Krefeld, Germany. This roll was also modified insofar as it has a very thin outer jacket. The resulting reduction in stiffness enables it to adapt to thickness differences in the entering melt curtain.

An innovative production method was specially developed to manufacture this thin, flexible jacket. Above all, a roll with a very thin roll jacket had to be produced that could also maintain the rotation tolerances of conventional rolls. The second challenge involved polishing the thin, yielding roll jacket in such a way as to achieve the same surface quality as is demanded from conventional stiff polishing rolls. This was achieved by optimizing several details and modifying the manufacturing technique. A prototype pilot line polishing roll could be manufactured in the required quality with a face width of 800 mm and a diameter of only 180 mm.

This roll was mounted in a polishing roll stack specially designed for polishing thin films [5] by aligning the roll axes that form the polishing gap in a horizontal plane. Previously, thin films had been produced on this polishing roll stack using two conventional rigid polishing rolls 300 mm in diameter. In order to minimize gap forces during the tests, and especially to keep them constant, the required low gap forces were applied by two simple spiral springs. In effect, the film surface is only touched up by the roll in the polishing gap. The spring clamping and the edge of the highly polished flexible roll can be seen in the **Title photo** of a segment of the polishing roll stack.

Pilot Polishing Roll Stack produces Optical Quality

Extremely thin films in optical quality could be produced immediately using the thus modified pilot polishing roll stack **(Fig. 2)**. The films were equal in quality to those produced on a larger production line for greater thicknesses and with years of experience in terms of the processing parameters to be set. Using the modified roll stack and the flexible jacket roll mounted in it, a 35 % reduction in thickness could be achieved immediately compared with the smallest thickness previously achieved on the pilot polishing roll stack in various test runs using conventional rolls. This was achieved without the problems of extreme variations in gap parameters that come from using massive rolls and rigid roll clamps. One reason for this was the fact that ultimately the films could be produced at a specific line load of only 60 N/cm. At such low clamping forces, only negligible roll deflections took place even with the small roll diameters. A clear indication of this was the circumstance that the test film was only minimally thicker at the edge than at the center.

Fig. 2. Comparison of the silhouette of the test films produced in the Chill-Roll process (right half with die lines running in the direction of extrusion) and those with a closed polishing gap (left half without die lines) (photo: Gross)

Outlook

To be sure, the tests were achieved with a polishing roll stack that, for one, has the advantage of horizontal roll alignment and was also modified in respect to clamping. However, when all the results obtained within the test framework are given closer consideration, it can be presumed that, no matter how the rolls are aligned and what kind of clamping is present in a particular polishing roll stack, many existing problems that arise from the current attempt to polish films with ever smaller thicknesses could be solved quite simply by replacing a conventional stiff roll with a roll with a flexible steel jacket. But, if the attempt is to be made to handle the very least thickness possible, then a special polishing roll stack will be required that has the advantageous horizontal roll array and a clamping solution that ensures that the film surface is polished even at small and above all constant gap forces. To this end, two production-size rolls are in the planning phase which are, of course, configured according to their respective jacket yields. One roll is intended to be integrated into a quite conventional polishing roll stack with vertical roll array. The second roll is specially designed to be integrated into a polishing roll stack configured horizontally analogous to the pilot line roll stack described above. ■

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