Open bubble with calibration cooling ring

Cooling Technology. The particularly intensive cooling effect of a cooling/calibration cone in the interior of the tubular film can significantly increase the web speed, and therefore the productivity of blown film production. The opening of the tubular film permits lower take-off towers.

Film Production with an Open Bubble

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At K 2004, dr-PAck, Kft, Biatorbágy, Hungary, presented rotating core technology. It operates according to the principle of a self-adjusting rotating core in the blown film die [1]. The concentricity of the core is established by the melt, which keeps the gap size constant around the entire outlet circumference. The blown film die does not require a spiral mandrel system and the rotating core generates a mesh-like film structure. The temperature distribution in the melt is very homogeneous, which also contributes to the uniformity of the film thickness.

The cooling system consisted of outer and inner cooling. In the outer cooling system, the traditional cooling ring has been replaced by a multistage cooling cone, which has the major advantage that the air along the growing film cone can be blown in multiple layers so that it retains its cooling effect. In the interior cooling system, nozzles blow the air tangentially against the film. The hot air is extracted from the bubble higher up. The air blown tangentially against the film cools the bubble at the most effective point. The tangential air flow allows the relative velocity difference between the bubble and the cooling air to be increased, which considerably increased the heat transfer coefficient.

Air as Production Factor

The increase in web speed is limited by several factors. One is the cooling intensity. Recent developments have consequently had the aim of a further increase in cooling intensity, at the same time the cooling homogeneity at the circumference of the bubble is further increased. During the development of the new cooling system, the main goal was to improve the heat transfer, which is particularly impaired by the large volume of air heated in the bubble. The concept of internal air exchange is known from earlier designs; but the large volume of air is difficult to exchange and also does take part in the flow. To prevent this air accumulation, the idea arose of filling the conical section of the bubble with a cone (Title photo). This provides a narrow flow gap for the air between the cone and the film, and the cooling air demand is reduced because it reaches the film directly. As a consequence, the volume of air trapped in the bubble is reduced, and the cooling efficiency is increased. In addition, the surface of the cone is used to supply sufficient air to the film. The cone is also built up in layers and the air is supplied tangentially through the gap between the in-

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dividual layers, similar to a nozzle solution. This allowed the air deficit to be continually compensated as the conical film bubble expands upwards.

The filling cone must be held in the interior of the bubble so that the cooling air can be fed both from below and from above. In the case of feeding from below, a blown film die design is required, which has a suitably sized channel in its core. In the first implementation, the cone was held from above, more precisely suspended in the bubble. At this point, the idea of the open bubble emerged.

Blown Film Production with an Open Bubble

First there were a number of design challenges to solve: How can the cone be suspended? How should the film be drawn up, since the air pressure in the bubble ensures that the melt emerging from the blowing die can be oriented in the cross-machine direction? When the air escapes from the tubular film, the bubble collapses. However, it would be sufficient if the air did not escape from the conical orientation portion of the bubble but the air pressure were retained. The space-filling cone could act as a cork in the bubble, so that an opened bubble would not represent a problem if the air escaping between the film and the cork is blown in again through the gap of the cone. Numerous questions arise.

The solution was a horizontally closed cooling ring above the cone in the interior of the bubble, which ensures that the air cannot suddenly escape when it leaves the conical part (Fig. 1).

With this design, the following results were achieved: The faltering air flow, which impairs the cooling and flow can be eliminated. The cooling air is supplied directly to the film tangentially, improving the heat transfer and, layer by layer, replacing the air deficit resulting from the expanding diameter.

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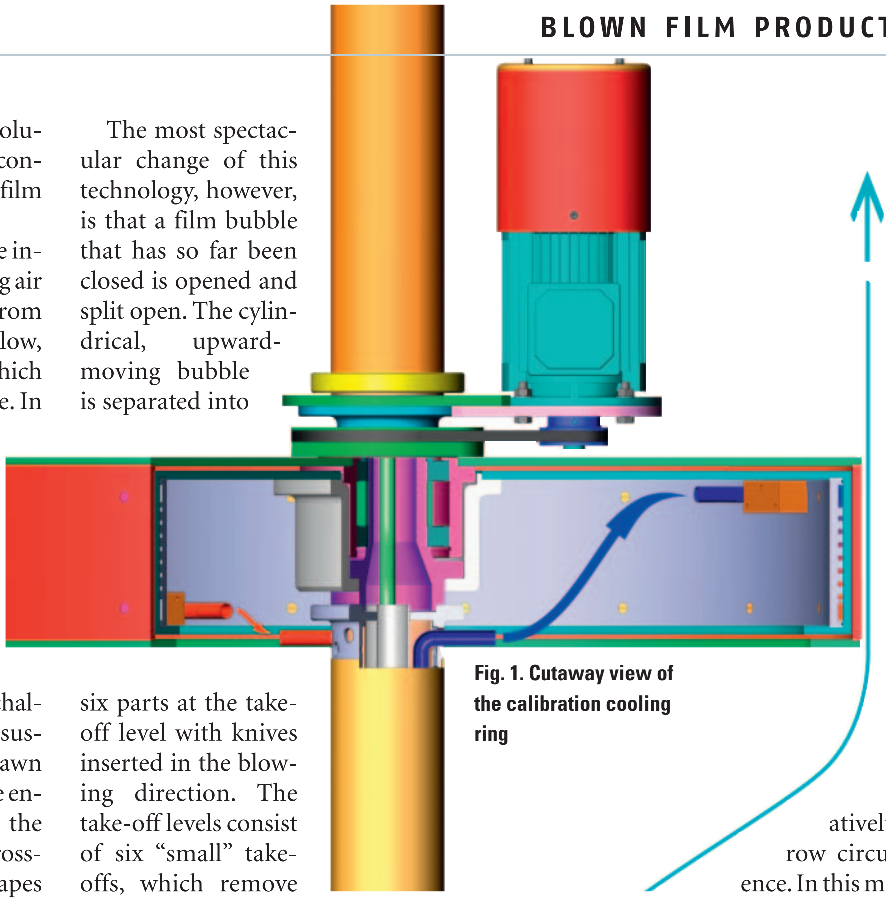

Fig. 1. Cutaway view of the calibration cooling ring

The most spectacular change of this technology, however, is that a film bubble that has so far been closed is opened and split open. The cylindrical, upward-moving bubble is separated into six parts at the take-off level with knives inserted in the blowing direction. The take-off levels consist of six "small" take-offs, which remove the films at six separate winding units. The open bubble does not collapse, since the cooling unit acts as a cork. The air leaves the bubble through the gap between the film and the cooling disk in a natural way.

The theoretical starting point of the further developments was again the heat-transfer coefficient, more precisely its dependence on velocity. Since the value of the heat transfer coefficient depends first and foremost on the relative velocity difference between the cooling medium and the surface to be cooled, the aim is to increase this difference by means of the tangential nozzles. This was achieved by causing the air to impinge almost perpendicularly on the film in comparison to the vertical travel direction, as a result of which the efficiency could be increased by about one and a half times. In the next step, the upper, already cylindrical part of the cooling cone, in which the ultimate solidification of the film takes place, is rotated and provided with an air recooling system. The inner cooling cone is designed such that the air is blown at the bottom in several layers and tangentially. The air is heated as it flows upward along the cone. Where the greatest cooling intensity is required, recooling takes place with the aid of the disc, which rotates with a large circumferential velocity and continually dissipates the removed heat. The system cools the film very intensively at the end of the orientation, and freezes it rapidly and completely in a column of relatively narrow circumference. In this manner, highly accurate film is produced in a rapid and completely homogeneous process.

In the gap between the film and the cooling cone, there are other advantageous effects. The first ensures intensive heat exchange between the surfaces moving perpendicularly against one another by ensuring that the interfacial surfaces intermesh with one another. As a result of the collision at the interfaces, turbulence occurs in the gap, which greatly promotes and improves the heat transfer. The surface of the heat exchanger virtually comes into contact with the film, while in conventional systems the distance is several meters.

Another positive effect is that the air flowing in the gap at high velocity sucks the film over a large area and, in this way, ensures a high accuracy of the bubble diameter. The diameter is some millimeters larger than the diameter of the cooling disc. This internal cooling unit thus serves as calibration. This results in films with narrow thickness tolerances and an accurately dimensioned diameter. To determine the size of the calibration disk, the size of the final product is used as basis. Stretch films can therefore be extrusion blown on the system without edge trim waste.

Effects on Quality

The properties of the film are strongly influenced by when and how it cools, or solidifies. To produce a film with the most ▶

advantageous properties, the freezing should take place rapidly and completely in the zone after the orientation cone. The refreezing of the film also conventionally starts at the end of the conical zone. But this process continues significantly beyond the tubular portion and takes place around the circumference at different times, which results in fluctuations of the mechanical parameters of the film. The fact that the mechanical properties of the film do not increase proportionally with the increase of wall thickness and dimension can be attributed to the fact that the time required for recooling increases proportionally with the increase in dimensions. If the material is in a plastic state for a prolonged time, the mechanical properties of the film are weaker, not to speak of the fluctuation of thickness.

Fig. 2 compares the recooling curves of film bubbles of different diameters that were produced with dr-Plast technology and with traditional bubbles. The film thickness increases in proportion to the diameter of the bubble. If we consider the thermal curves, it becomes clear that the film cools much faster in the starting zone – conical orientation – as a result of the filling cone technology. After the cylindrical section has been reached, this difference becomes even more marked, because the air is very rapidly and uniformly recooled in a relatively narrow gap of the rotating disc, while, in the conventional case this process takes place over a longer zone of the cylindrical section and at different times along the circumference. The fact that the film is recooled faster than with traditionally extruded bubble, even when the bubble is relatively large, can be explained by the fact that the new cooling technology permits a much faster production rate. In this way the material spends a much shorter time in a plastic

Intensive Cooling

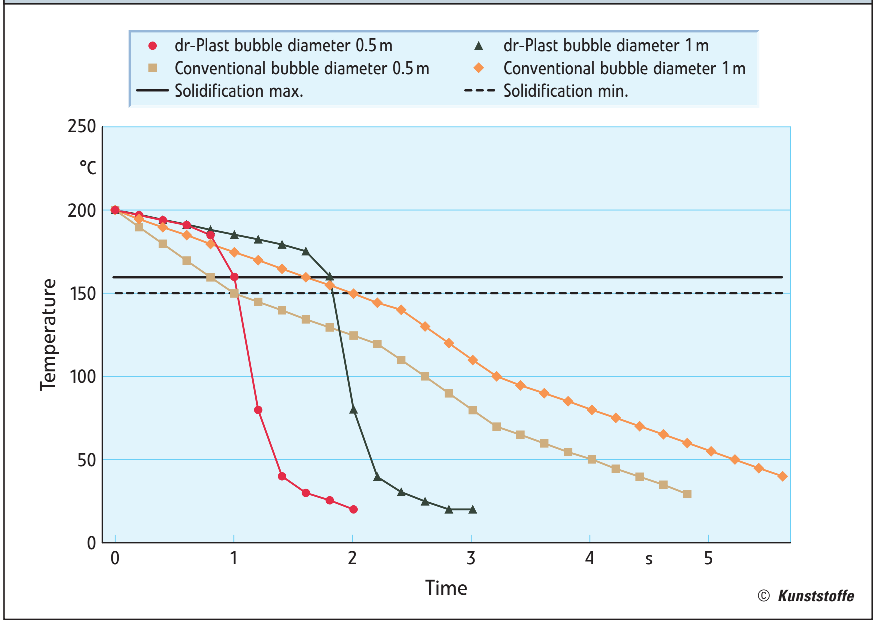

Fig. 2. The recooling of the film as a function of time

Fig. 3. Winder with jumbo roll

Fig. 4. Calibration cooling ring with closed bubble

state, and the properties of the film are therefore better.

Individual Winding Technology

The plant is primarily designed for producing stretch kitchen film of polyethylene (PE). The tubular film cut into six webs is made up by six winding stations into twelve rolls with a width of 300 mm, without edge trim waste. The winding units are designed to manage even jumbo rolls of 1 m diameter (Fig. 3). To allow easy unwinding of large rolls, the winding unit has a tension controller. Even when jumbo rolls are important for the economic operation of the automatic rewinding machines, individual winding technology offers interesting advantages. It allows a final product make-up unit (revolver winding machine) to be mounted on each of the six winding units. In this case, the winding unit produces several relatively small reels of several tens or 100 m in length. This possibility allows the machine capacity to be utilized more effectively. In addition, the combination of the two winding solutions makes the production line particularly flexible. Thus, jumbo rolls and finished products can be produced simultaneously, both on as many webs as necessary.

With the current machines and a web width of 600 mm, rolls with a length of 100,000 m are produced, in the case of earlier machines, by comparison, rolls with a length of 8,000 to 10,000 m were produced.

By changing the cooling-calibrating unit, the film blowing line would also be suitable for producing industrial film in a width of 500 mm.

Closed Bubble

It has been described above how the calibration unit permits production with an open bubble, and what advantages are associated with this.

Alternatively, a solution has been developed for producing blown film with a traditionally closed bubble, while still making partial use of the new technology (Fig. 4). Film blowing machines in which there is a hole in the centre of the blowing head can be easily retrofitted with the cooling calibration unit, and allow precise diameter control, a uniformly frozen film and increased production speed. In addition, the external cooling-air consumption, and therefore the operating costs, are reduced. Systems operating with radial spiral mandrel dies are suitable for retrofitting.

The cooling-calibration unit can also be used for the production of PE-HD film, in which axial orientation is performed first and then radial orientation (Fig. 5). In addition, external cooling can be replaced with the internal cooling.

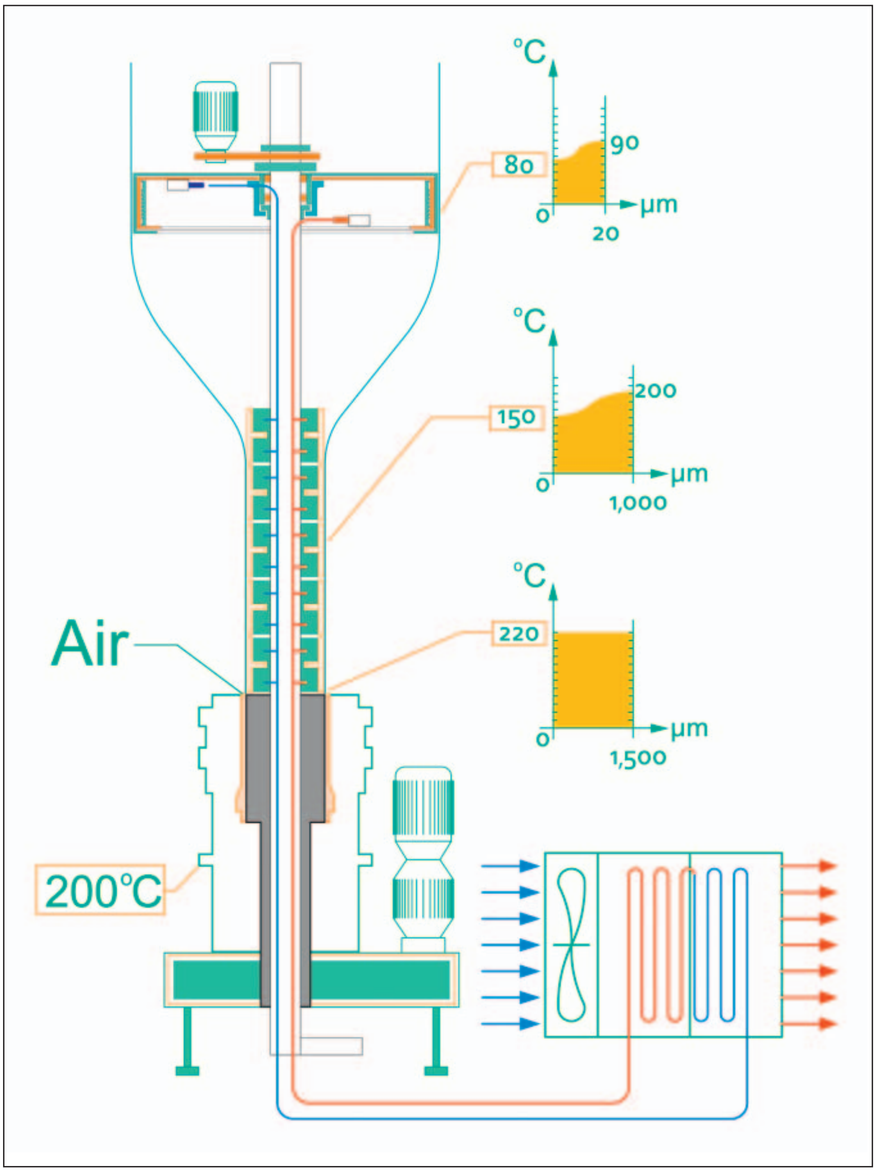

Fig. 5. Concept for producing PE-HD film with calibration cooling ring (graphic: Zoltán Gergely)

Summary

The production of blown films with an internally suspended calibration cooling unit in the open film bubble has been realized. The most obvious advantage of the open bubble is that the heated air does not have to be extracted, because it can escape at the top. As a result of the new system, the film is recooled far more rapidly and can be produced with greater precision.

The rapid freezing increases both the production speed, and therefore the cost efficiency and film quality.

A sophisticated winding technology improves the flexibility of the production line until finished make up. ■

REFERENCE

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