Causes and Remedies to 7 Instability Patterns in Blown Film Extrusion

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Abstract

Bubble instability in blown film extrusion creates problems that include large gauge variation and wrinkles. These problems affect print quality, film and heat seal strength when converted into packaging. This paper will describe how to adjust bubble cooling systems to minimize the problems caused by seven types of bubble instability patterns.

Introduction

Bubble instability in blown film extrusion creates problems from fluctuating film gauge and width to scratches and tears. Instability patterns include draw resonance, helical “snaking”, slow and fast breathing, sagging, tearing and fluttering. In many cases, operators are reluctant to make adjustments for fear of losing control of the bubble. The first remedy is to adjust air ring settings, stabilizing the bubble from the bottom and working upwards towards the frost line.

Dual lip air ring, common for low melt-strength bubbles, come in three types: iris, perforated chimney and stabilizer ring. Perforated chimney style air rings come with vertical and bowl type stabilizers. The vertical type locks the bubble in more effectively, however the bowl type can is more effective for larger blow-up ratio bubbles. Refer to Figure 1 for the different styles and locking point positions where air velocity between the air ring and the bubble can be precisely controlled. Each type requires different corrective actions to be performed in the recommended sequence until the bubble becomes stable. In some cases, changing the formulation or modifying equipment may help, though these changes take longer to implement. Refer to Figure 2 for details concerning the bubble cooling adjustment options available for different dual lip air rings. This paper will focus on adjustments to bubble cooling system setup, not formulations or equipment.

Discussion

There are only three rules to remember when adjusting air rings: 1. velocity controls; 2. volume cools; 3. climb the stairs.

Rule 1 (velocity controls) refers to the air velocity between the bubble and the air ring. Faster air velocity results in lower pressure, allowing the pressure inside the air ring to push the bubble towards the air ring and locking the bubble into place. The locking points” are unique for each style of air ring. Refer to Figure 1 for details.

Rule 2 (volume cools) refers to the total volume of air delivered to the air ring. Volume and velocity are linked because more volume will result in faster air velocity. More importantly, total volume controls bubble cooling rate and therefore they lowering the frost line height. Air volume is controlled by changing the air ring blower speed or adjusting the damper if the blower had only one speed. The easiest way to track air velocity is to record the static air pressure inside the air ring chamber. A useful analogy is to think about controlling the speed when driving a car. Fine tuning is done with pressure on the gas pedal (adjusting air ring part positions). Larger changes are made by changing gears (blower speed adjustment).

Rule 3 (climb the stairs) refers to the adjustment sequence. Start by stabilizing the bubble as it rises above the lower air ring lip. Then adjust the air flow from the second lip. Lastly, adjust the parts of the air ring above the second lip. It is like climbing stairs. You start at the bottom and work your way to the top.

Adjustments for Bubble Instability

Draw Resonance

Also known as hour-glassing, this pattern is common during start-up or during formulation changes. The root cause is strain hardening before the film exits the air ring. Raw material causes are formulations that contain too much strain hardening material such as LDPE, or an average melt flow index that is too low. Too large a die gap may result in the bubble reaching its drawdown limit too quickly. The best solution is to raise the frost line so that it is above the air ring. If output cannot be increased, then decrease the air volume (slower air ring blower speed) or unlock the bottom of the bubble by opening the lips to reduce air velocity. If IBC cooling is available, reduce the IBC circulation rate. Refer to Figure 3 for the recommended bubble cooling adjustment sequence to eliminate draw resonance.
Helical Instability
Also known as Mae Westing, Snaking or Hula Hooping. This is the most common bubble instability pattern. Raw material causes include not enough high melt strength resin (LDPE) or an average melt flow index that is too high. Die gaps that are too narrow may generate excessive shear heating that reduces melt strength as well. Although bubble cooling adjustments are similar to draw resonance, air velocity is a more critical factor than air volume in this case. A slight vortex pattern of air flow exiting the air ring lips can induce this pattern. Refer to Figure 4 for the recommended adjustment sequence to eliminate helical instability.

Slow Bubble Breathing
Minimum cycle time for fast bubble breathing is 15 seconds. The first step is to confirm that the root cause is not extruder surging. IBC sensors too far above the frost line can induce this pattern as well. Modern IBC systems have real time feedback to help operators minimize layflat width variation by adjusting IBC sensor position relative to the frost line. The most effective strategy to minimize slow bubble breathing is to increase air velocity (close air ring lips) and adjusting air volume (air ring blower speed) if required. Refer to Figure 5 for the recommended adjustment sequence to eliminate slow bubble breathing.

Fast Bubble Breathing
Maximum cycle time for fast bubble breathing is 15 seconds. As with slow bubble breathing, key questions to ask are: how much variation; how fast is the cycle; does it coincide with rotation of dies or nip; does it continue when all blowers and valves are locked in one position. IBC sensors too far below the frost line can induce this pattern as well. This pattern can start about 20 minutes after a bubble is set up if a flexible pipe in the IBC exhaust duct begins to pulsate. Another common cause for this pattern is excessive drag resistance in the collapsing frame. The most effective strategy to minimize fast bubble breathing is to decrease air volume (slower air ring blower speed) and decrease air velocity if required (opening air ring lips). Refer to Figure 6 for the recommended adjustment sequence to eliminate fast bubble breathing.

Bubble Sag
Also referred to as heavy bubble or sleeping bubble. This problem usually occurs when gauge or blow-up ratio is increased during a product change. It can also occur when air temperature changes in the factory, the formulation melt strength is too weak (not enough LDPE), the melt flow index is too high or the die gap is too wide and the bubble is too thick at the die lips. It is important to keep in mind that the air exiting the air ring not only cooling the bubble, it supports it. Incorrectly positioned air ring parts will induce this problem. The most effective solution is to increase air volume (close air ring lips) and increase air velocity (faster air ring blower speed) if required. Refer to Figure 7 for the recommended adjustment sequence to eliminate bubble sag.

Bubble Tear
Also known as snap off and is sometimes confused with random holes that are referred to as blow holes. The root cause is drawing down the melt too quickly, resulting in strain hardening that causes the resin to stop stretching and tear away from the die lip. Strain hardening occurs when there is too much LDPE in the formulation, the average melt flow index is too low, the line speed is too fast or the die gap is too wide. The most effective way to eliminate this problem is to decrease air volume (slower air ring blower speed) and velocity (open air ring lips). Refer to Figure 8 for the recommended adjustment sequence to eliminate bubble tear.

Bubble Flutter
Also known as trembling or shaking below the frost line. Flutter above the frost line is common and usually does not affect bubble stability if proper bubble supports (cage) are used. This problem is more common with LLDPE rich formulations or when the target gauge is too thin to withstand the buffeting from the air ring. The most effective way to eliminate this problem is to decrease air velocity (open air ring gap) and decrease air ring blower speed.
speed) if required. Refer to Figure 9 for the recommended adjustment sequence to eliminate bubble tear.

**Triple Lip Air Rings**

Triple lip air rings are usually similar to Type 1, with an additional lip to blow downward to precool the bubble and form a solid skin on the outside surface. These air rings are usually set up to run between 0.5 and 1.5 die diameters above the die, depending on the blow up ratio and formulation. The adjustments to height are required when the bubble is not stable below the air ring. All other adjustments will be the same as conventional Type 1 air rings.

**Conclusions**

Controlling bubble stability by adjusting bubble cooling systems is a frequently overlooked skill. Most instabilities can be minimized if not eliminated by following the three simple rules described in the introduction.

**References**

Figure 1 – Air Ring Locking Points for Different Dual Lip Air Rings

Figure 2 – Bubble Cooling Adjustments for Different Dual Lip Air Rings

Figure 3 – Bubble Cooling Adjustments for Draw Resonance
Figure 4 – Bubble Cooling Adjustments for Helical Instability

Figure 5 – Bubble Cooling Adjustments for Slow Bubble Breathing

Figure 6 – Bubble Cooling Adjustments for Fast Bubble Breathing
Figure 7 – Bubble Cooling Adjustments for Bubble Sag

Figure 8 – Bubble Cooling Adjustments for Bubble Tear

Figure 9 – Bubble Cooling Adjustments for Bubble Flutter