Optimisation of Production Output and Film Quality from Blown Film Extrusion Systems

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In our quest to increase production capability we generally tend to concentrate our efforts to increase the most influential parameter of extrusion throughput to achieve our production goals. In blown film extrusion systems we tend to give significant attention to the influence of cooling systems in our quest for higher throughput levels. However, while this is an important factor in the blown film process it must be remembered that this is one component in what should be regarded largely as a sequential process. In this situation subsequent processes are dependent on the optimization of the preceding element. One interesting function in the blown film process is the functionality of the collapsing geometry employed to form a flat tube. This is one element that can influence both upstream and down stream conditions. It has also been recognized that film winders are often at the mercy of upstream conditions. It is the intention of this paper to highlight key elements of a blown film extrusion system and process that can have a significant effect on the opportunity to maximize the output, efficiency and film quality.

1. Introduction

The film extrusion process has been developed over a period of more than 70 years. The one thing that has not changed over that time is the basic need to heat the polymer, distribute, form and cool the film. The range of materials available to formulate packaging solutions however has increased substantially. During this time the optimization and improvement to each element of the blown film extrusion process has also advanced. When broken down into the individual elements there are many companies and organizations that specialize in the optimization of their part. In an extrusion system, however, it is the optimization of all the elements that can produce the most cost effective, efficient film extrusion line.

From a simple economic standpoint it is often stated that when an extrusion line is running it is making money and when it is down it is costing money. The assumption behind this statement is that the line is producing film that is of saleable quality. The point here is that quite often we talk about the gross output of an extrusion line or the pounds or kilograms per hour. But the real factor has to be the total net output of a machine that takes into account downtime. Down time factors include maintenance, die cleaning, filter changes, formulation or product changes etc.. The design of control systems and operator functions will also influence significantly how easy it is for the operators to set up each product that has to be run. This paper will explore how the optimization and interaction of the individual blown film extrusion elements influences the production of the final product.

2. Film Extrusion Elements

The main elements of the blown film extrusion process will be discussed and include the following:

Material handling and blending
Extrusion, heating and conveying,
Die forming
Bubble inflation and cooling
Collapsing and web handling
Trimming, slitting and winding.

Other auxiliary functions such as surface treatment also take place but will not be addressed in this paper.

2.1 <u>Material handling and blending</u>

There is a significant increase in the number of gain in weight batch blending systems offered in the market place. The advantages of such systems include ease of use, low cost and the metering of all the materials into a common weigh hopper or chamber. However the dosing of small components and the design of the mixing chamber can impact the uniformity of the blend or batch. For this reason it is sometimes preferred to blend or mix subsequent batches.

In order to avoid de-mixing issues, continuous blenders are frequently mounted directly onto the extruder feed throat. This ensures direct feeding of the materials into the extruder. Accurate auger control for the range of additive rates required is a prerequisite for this type of process.

Each system has its advantages and disadvantages but the accuracy of the blend must be maintained to ensure extrusion stability.

2.2 <u>Extrusion</u>

There is a vast range of polymer materials and additives available today. Each particular material has its own melt density and viscosity at a given temperature. The formulation and pellet geometry also has a significant impact on the coefficient of friction and the conveying efficiency in the extrusion system. The design of the feed section to control friction at the barrel wall has received significant attention over the years. Efficient designs can be produced that optimize the feeding capability for a wide range of materials. Extruder screws are generally designed with a specific melt conveying capability. It is important that the feeding of the material exceeds the melt carrying capability in order to ensure a stable extrusion process and an efficient compaction and compression of the material to compensate for the change in density. If air is not excluded during the compression and compaction of the polymer then the film quality will be affected. Also, during the film extrusion process it is important the variation in extrusion throughput does not vary by more than 1% of the total rate. Efficient extrusion systems will also ensure that there are no temperature variations greater than 1 degree. Consistent feeding is required to achieve this condition.

2.3 Die forming and distribution

The uniform distribution of the polymer melt in a blown film die is an extensive subject beyond the scope of this paper. Multi-layer dies are often designed to run many different materials with different viscosities and often with a range of throughput requirements. The design of each layer is critical to optimize the range of shear stresses and pressure drops that the material will be subjected to. Uniform temperature and pressure drop are just two of the main operating factors in ensuring a uniform distribution of the polymer melt. The temperature control of the different die elements, particularly in multi layer dies is important. Careful consideration has to be given to the position of controlling thermocouples. Each heating element must be kept under very tight control to ensure uniform heating.

Purging times or purging rates? Extrusion and die designers are often asked how long it will take to transition from one material to another. The question should really address the amount of material that has to go through the system to make the complete transition. To answer this fully the viscosity of the materials or blends has to be taken into consideration as this will have a significant effect on the shear stress on the material against the metal wall. The temperature at which the transition has to occur should also be considered. Planning for the most efficient transition times can have a significant impact on the efficiency of the system, particularly on multi-layer blown film lines employed for the production of barrier films.

Why are die gaps adjustable? It is quite interesting that we are often quite happy to adjust the concentricity of a blown film die to correct a film thickness issue. However, one of the first actions that many people take when there is a film thickness issue is to stop the line and measure the die gap to make sure it is uniform. The die gap should not be used to correct or compensate for other factors such as non-uniform heating, polymer flow or ambient effects. If the die gap is used to correct for an external factor to make the thickness uniform there is a very good chance that the stress in the film will not be uniform. If the stress in the film is not uniform, the flatness of the film will be affected after the stress is relaxed.

2.4 Bubble cooling and stability

The cooling function of the blown film process has received a lot of attention over the years, both from an internal and an external perspective. Every new design of cooling ring or cooling process is expected to give significant increases in production output, especially when expressed in direct percentage terms. When such systems become complex in their design it is often at the expense at flexibility and ease of use. However, when expressed in terms of net production it is interesting how even a 4% increase can yield a significant increase in output.

If an extrusion system operates at 1000 lb/h with a 90% efficiency rating then a 4% increase in output equates to more than 290,000 lbs per year. Looking at this another way, imagine the increase in output that would result if an operator has to change product on the same machine twice in 24 hours and that the design of a new cooling or other blown film function reduces the change over time by 30 minutes each time. This can result in more than 330 hours of production each year.

The cooling function is a key component in the blown film process but it is not the only parameter that influences the output of a blown film process.

I think it is worth mentioning a few points about bubble stability and width control. This is strongly linked to web handling, creasing and film flatness. Each blown film line is equipped with a system to control the diameter of the bubble or width of the film. It is worth making the distinction because sometimes the bubble diameter is the final measurement for width control and sometimes it is the width of the collapsed tube. In terms of width stability, the control system gets a lot of attention. However, there are many variables that also influence the stability, such as blending, extrusion stability, air ring design, haul-off control, tension control and frictional effects during collapsing. If any one of these parameters is not controlled or designed correctly, it will be very difficult for any bubble or width control system to function effectively.

2.5 Bubble collapsing and web handling

The geometrical challenges of collapsing a round bubble into a flat tube have been well documented. The concept of articulated collapsing has also been introduced to reduce geometrical differences. In order to achieve an optimized collapsing function the film properties, coefficient of friction, collapsing angle, film temperature and preferential cooling or deformation effects have to be balanced. This can only be achieved if a stable extrusion process is present. However, the frictional effects during the collapsing operation can also have an effect on the stability of the forming bubble below. This can initiate instability that is then exacerbated during the collapsing operation and the situation becomes self perpetuating. Wrinkles and web flatness issues can result and it is important to address the route cause of the instability in order to reestablish a stable process.

Unfortunately the winding operation is at the end of the line so the winding operation is dependent on all of the upstream events to present a flat film to the winder. If there are wrinkles in the web or oscillations in the width of the product, how many trouble shooting guides would point the operator in the direction of the blender? However, if an additive or material component is not metered and mixed correctly and consistently it can result in feed and extrusion instability that may at first not be apparent but can cause subtle changes to the stability of the downstream process.

3. Conclusion

The blown film process, is like many extrusion operations a sequential process. Each subsequent step is dependent on the stability and optimization of the preceding elements. In order to increase the efficiency of the blown film system it is important to understand and optimize each element to have the maximum effect. The individual elements have to be combined appropriately to define an optimized system.