COMPARISON OF CAST FILM AND BLOWN FILM 9 - LAYER BARRIER FILM

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ABSTRACT

Above-average growth rates in the field of cast film production and stretch film, PP film and barrier film in particular, have promoted the cast film extrusion process. Manufacturers of extrusion equipment have followed this trend and further developed equipment and processes in terms of quality and output.
Being a supplier of blown film and cast film extrusion lines, Windmöller & Hölscher has been asked repeatedly by film producers to present a comparison between the blown and the cast film process for the production of barrier films. So a comparison of both extrusion processes for 9-layer film production is made with the focus on systems engineering, die design, film products and economic considerations.

INTRODUCTION

Prerequisite for an objective comparison of the cast and blown film process is a "comparable" basis in terms of systems engineering. In this way, two different products run on state-of-the-art high-output extrusion lines with similar specification and investment needs can be compared.
Both the cast film and the blown film process show a certain parallelism in their development which is emphasized through the fact that there is a tendency to multi-layer films of up to 9 layers. Both processes are suitable for the production of barrier films and assuming identical applications for the two film types, a technical and economic comparison is extremely interesting. Major applications of barrier films produced by the blown and cast film process are: laminating films, lid films, and tray film for thermoforming for use by the food industry.
By the example of a 9-layer blown and cast film line and two characteristic film products, the significant differences between the two processes are outlined. This includes systems engineering, film product, and economic efficiency.

SYSTEMS ENGINEERING

Since the main differences between the two processes are widely known, there is no need for a detailed comparison of the systems engineering of the two production lines. Figure 1 shows a blown film and a cast film line. The significant differences relate to the extrusion tool – the die – the film cooling and sizing techniques used, and to the layout and dimensioning of the extruders. These machine specific technical features are decisive for product quality and performance of the equipment.

Extruder

Blown film extrusion line:
There is one extruder provided for each layer and the 9 extruders are installed around the die head in satellite arrangement.
One essential feature of state-of-the-art extruders is their universality as far as the processing of most different resin grades (PE, PP, PA, EVOH) is concerned, this gives high flexibility of the production line. The extruders – this applies for both the blown and the cast film line – are equipped with barrier screws and highly effective shearing and mixing sections (see figure 2).

Cast film line:
Owing to the special design of the feedblock, individual extruders can be used to feed one or several layers of the composite structure at a time. Usually, 9-layer extrusion lines are equipped with 6 – 9 extruders. Contrary to blown film lines, cast film lines normally have one high-output "master extruder" for polyolefines (PE, PP); this master extruder is designed for the processing of recycled material and, depending on the layout of the feedblock, used to feed one or several layers.

Cooling Process and Polymers

Different polymers with different viscosities are used in the two processes which is due to the extrusion process proper and the cooling techniques used, i.e. air cooling vs chill roll.
In blown film extrusion, polyolefins (PE, PP) with high viscosity are primarily processed to ensure high bubble

stability which is tantamount to high production output. Preferably, homo PP, CoPA and EVOH with a high contents of ethylene are used (fig. 3).
Another striking difference results from the cooling technique. The chill roll technique used in the cast sector is almost independent of the polymers used and gives, due to the strong and quick cooling down of the melt, excellent product properties such as high transparency and gloss, excellent thermoforming properties, etc. For blown film extrusion mainly amorphous to semi-crystalline polymers are used which are extremely well suited for the slow cooling and bubble forming process.
The thermal forming and sizing of the melt results in different film elongation and strength values. While the blown film process allows for orientation in both machine and transverse direction, the cast film process involves machine direction orientation only. This essential difference affects the mechanical film properties. Blown films stand out for a well balanced strength behaviour in both machine and transverse direction which can, however, take effect only when high blow-up ratios are involved. As far as barrier films are concerned, this applies for 'thin films' run with a blow-up ratio between 1.1 and 3.0 only.

Die Design

It goes without saying that when comparing the two processes with each other, the extrusion die is in addition to the cooling technique also a decisive factor.

Blown film: Die
One of the characteristic features of a 9-layer blown film die is that each melt chamber and each annular die has a distribution system (e.g. spiral mandrel distributors) of its own by means of which the melt streams are centrally fed into a joint annular gap where the thermal forming of the melt takes place. In this way, excellent film gauge tolerances of the individual layers are ensured (fig. 4).
The thermal forming of the melt is via an annular die which, in state-of-the-art extrusion lines, is equipped with automatic film gauge control. Changing over to different film structures and polymers is by simply feeding the desired polymers into the extruders and setting the production parameters.
I do not want to fail to mention that the statement that gauge tolerances of blown film will never reach the high level of cast film gauge tolerances, no longer holds because of the very successful introduction of automatically controlled dies.

Cast film: Feedblock and sheet die
Fed by separate chambers, the feedblock joins the melt streams and conveys the composite to a sheet die (fig. 5). Any necessary correction of the melt streams is done by means of mechanical, externally adjustable and/or fully automatic self-adjusting elements. This gives the machine operator the opportunity to selectively influence the distribution of the individual layer thickness.
Forming of the film structure is by means of a rheologically optimized single-channel sheet die featuring an automatically controlled flexible die lip (Flex-lip) to smoothen the gauge profile.
Change-over and adjustment to a new product is usually accomplished by the feedblock which defines the number of layers and their configuration in relation to each other.
State-of-the-art feedblocks are equipped with a special polymer distribution system which ensures minimum down time and fast start-up after product changes. Such a product change-over can be completed in less than 1 hour.

PRODUCT

The significant differences between the two processes in terms of systems and die engineering have already made it quite clear: A direction comparison is possible to a limited extent only. It is nevertheless worth giving these two processes a closer look by comparing two 9-layer films for high barrier applications.
On the occasion of a in-house exhibition, the two 9-layer films described below have been run on two high-output extrusion lines:

1) 9-Layer blown film: Laminating film 30 µm with sealing layer

	LD+mLL	HD +mLL	Tie	CoPA	EVOH	CoPA	Tie	HD+mLL	EVA
(µm)	5,5	5,0	2	1,5	1	1,5	2	5,5	6,0

Production data: Film width 2400 mm double lay flat
Output: 600 kg/h
Film thickness tolerance: < +/-2 % (2 Sigma)

2) 9-Layer cast film: Laminating film / lid film 50 µm with sealing layer

	CoPP	Tie	PA	EVOH	PA	Tie	HomoPP	CoPP
(µm)	12	3	4	3	4	3	20	5

Production data:		
	Film width	2250 mm
	Output gross	1100 kg/h
	Film thickness tolerance: < +/- 2 % (2 Sigma)	

ECONOMIC EFFICIENCY

Something should be said right away:
The question of economic efficiency of the two processes cannot be answered conclusively, since apples compare badly with pears. But in order to be able to better deal with this question, the factors outlined below might be helpful.

Width variability:
Years ago, width variability of the blown film process represented a considerable and even economic advantage. Through the development of dies featuring socalled 'deckling systems', this drawback inherent in the cast process could be largely compensated for. Width variations of +/- 500 mm on either side are feasible now and usually meet the requirements.

Film thickness tolerances, layer thickness distribution:
Uniformity of individual layer structure and film gauge tolerances is of course an important criterion for commercial efficiency. To give just one typical example: PA or EVOH layers serving as barrier material.
While state-of-the-art extrusion lines of both sectors allow for film structures with excellent thickness tolerances to be produced, there are considerable differences as regards the uniformity of individual layer thickness.
Annular dies give a high uniformity of all layers.
The feedblock technology may cause 'slightly deformed' edges which can, however, be compensated for by matching the viscosities of the resins used and by means of mechanical control elements.

Scrap rate
Nowadays, the scrap rate is one of the decisive criteria when it comes to productivity analyses. This includes both start-up and change-over waste, but also edge trim waste during production. In general it can be said that less edge trim waste is produced by the blown film process, although new technologies allowing for a considerable reduction of edge trim waste in the cast sector have been developed. Depending on the layer configuration, about 50 % of the edge trim waste produced on modern cast film lines can be refed into the production process. The 'encapsulation' technology (fig. 6) developed to this end is a highly useful instrument.
A comparison of the gross and net output depending on the layer configuration, the polymers used, and the line width gives the following results

Blown film: approx. 100 - 95 % of the gross output
Cast film: approx. 95 - 92 % of the gross output

Seen from the edge trimming point of view especially in the cast process, the use of 'wider' lines is strongly recommended since this helps reduce scrap (in kg/h) considerably.

Energy consumption
Another essential cost factor influencing the productivity of a line is the energy consumption. Blown film lines offer, without doubt, certain advantages in this regard since the cooling medium 'air' usually does not need to be cooled, only the unwanted heating up of the factory hall has to be considered, while cold water of 8-13°C is used for the cast film line.

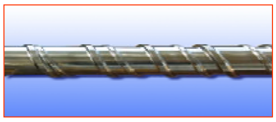
CONCLUSION

Both processes for the production of barrier film will continue to exist in parallel in the market place in the long run and develop continuously.
The selection of the most suitable production process based on mainly economic aspects is of course possible but necessitates detailed discussions between machine manufacturers and film producers.
The demand for an even greater number of layers shows the limits inherent in the blown film die technology, highlighting at the same time the cast film process and its feedblock technology. Already today lines for 18-layer films and more – even for barrier film applications – are available.

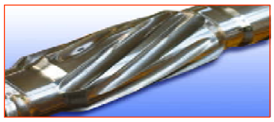
Abb. 1

Barrier Screw

- **Barrier zone:**
  - **smooth transition from „solid“ to „liquid“**
  - **rheologically optimized melt flow**



- **Advanced shearing element:**
  - **no pressure loss**
  - **self-cleaning**



- **Advanced mixing elements:**
  - **for excellent melt and temperature homogenity**

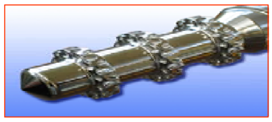


Abb. 2

Polymer Selection Preference

....no rule without exception

	Blown Film	Cast Film
LDPE, LLDPE	MFI 0,7 – 2 (4)	MFI 2 - 4
PP	CoPP MFI < 5	Co and HomoPP MFI 5 - 12
PA	CoPA Rel.Visc. ca. 3,5	Homo PA Rel.Visc. 3,5 - 4
EVOH (Ethylen)	38% ⟶ 29%	32% ⟶ 29%

Abb. 3

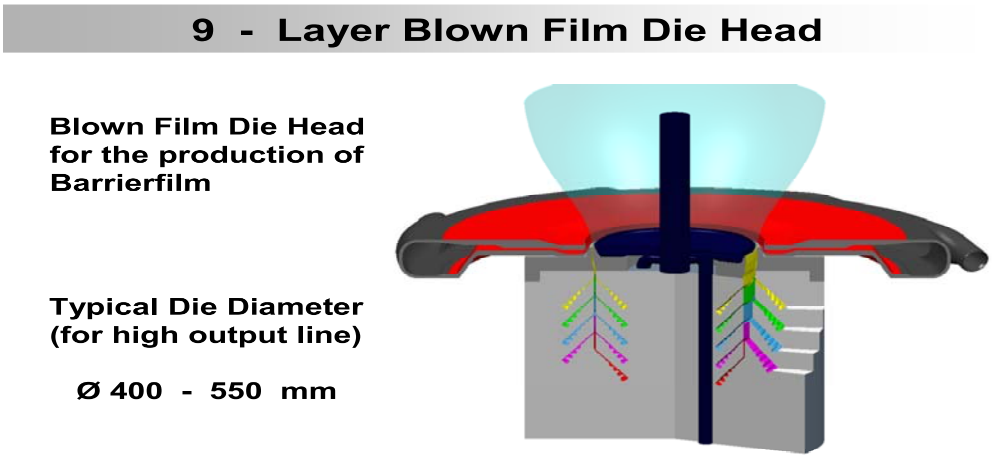


Abb. 4

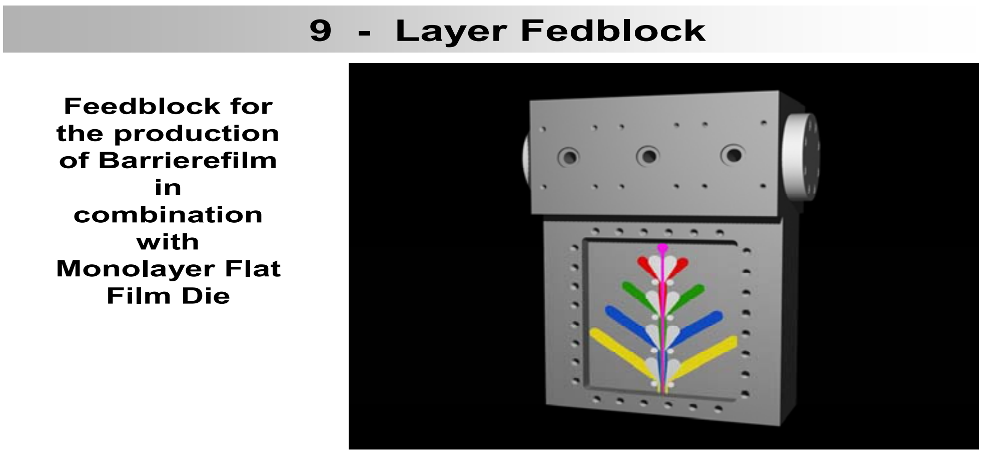


Abb. 5 Typ CLOEREN

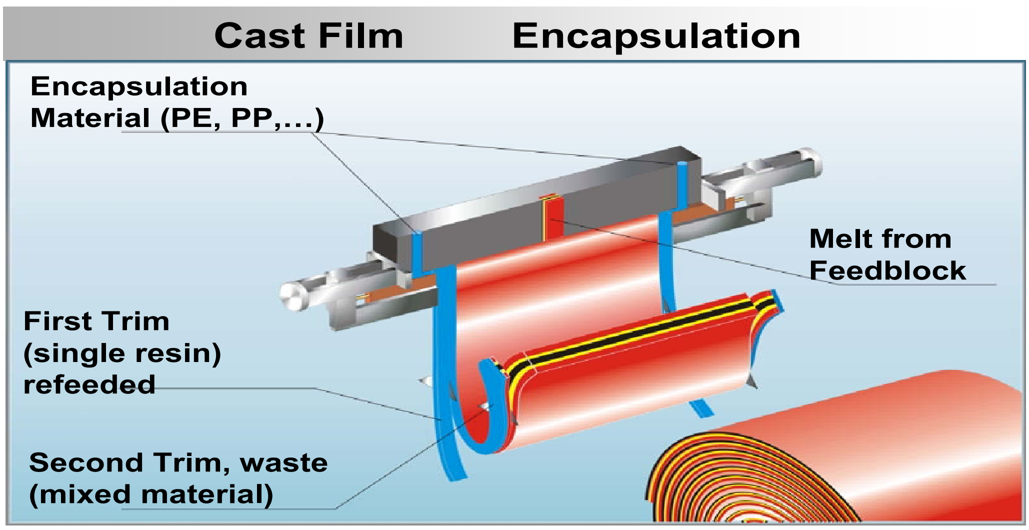


Abb. 6