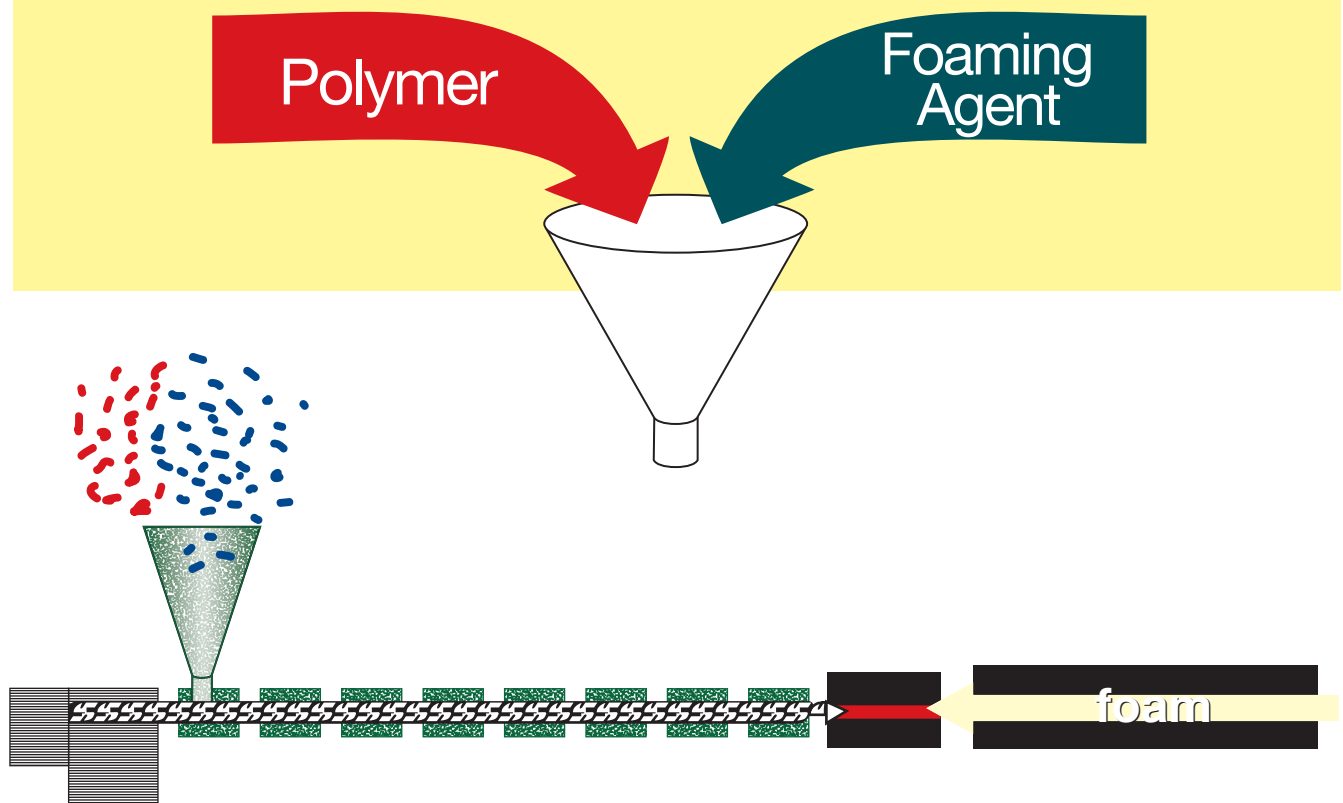


FOAMAZOL™

Chemical Foaming Agents

CHEMICAL FOAM EXTRUSION PROCESSING GUIDE



FOAM EXTRUSION USING CHEMICAL FOAMING AGENTS

Introduction

The basics of foam extrusion consist of mixing a chemical foaming agent with the polymer to be extruded. The heat generated to melt the polymer decomposes the chemical foaming agent resulting in gas being liberated. This gas is dispensed in the polymer melt and expands upon exiting the die.

Basically, all common extruders can be used for foaming if the following requirements are met:

The melt temperature must be high enough to guarantee a total decomposition of the foaming agent.

The pressure of the melt must be kept high enough to keep the gas – generated by the decomposition of the foaming agent – dissolved in the polymer melt until the melt exits the extrusion die.

If the melt temperature is too low, the decomposition of the foaming agent will be incomplete, resulting in an uneconomical process. And, un-decomposed foaming agent particles can lead to agglomerates, which can clog the melt filter or cause voids, poor cell structure, or poor surface appearance.

A pressure profile that is not high enough can lead to “pre-foaming”. Even with a subsequent pressure increase, the gas cannot be “re-dissolved”, resulting in a large irregular cell structure with broken and collapsed cells.

The coarse foam produced this way leads to holes in flat films, while profiles and sheets get a rough surface (shark skin); during blown film production, the blown film tubing can collapse.

The use of “degassing” or vented extruders (used for the extrusion of PS and PMMA) is possible, but the following is recommended:

- The vent opening should be plugged or sealed to prevent escaping of the gas generated by the foaming agent.
- Use of a three-zone screw or a degassing screw, with a not too deep cut screw shaft, and respectively not too high flights in the degassing zone. In the de-volatilizing zone, a higher free volume is available. This can lead to slight pressure decrease, potentially leading to pre-foaming. For thicker screw shafts, this pressure decrease can be compensated by a higher screw speed or by pressure increase in the die.

Foaming Agents

Foamazol™ Chemical Foaming Agent, the foaming agent system developed by Bergen International, is formulated in a way that, when used properly,

Table 1 Foamazol™ CFA Products and Decomposition Temperatures

FOAMAZOL™ CFA	Decomposition Start	Thermoplastic Polymer	Processing Temperature
F-XO-118	~130°C	PVC, LDPE, EVA	> 180°C > 160°C
F-90	~135°C	LDPE, EVA, TPE, TPU	> 180°C
F-50 F-70	~160°C ~145°C	LDPE, EVA, PS, ABS	> 180°C
F-60	~175°C	HDPE, PP, PMMA, PET (A-, C-, G-)	> 200°C > 240°C > 270°C

ensures complete decomposition and a very consistent and fine foam structure, within a well-defined temperature range.

Two forms of foaming agent are commonly used, powders and concentrates or masterbatches in the form of pellets. Although more economical at first glance, powder foaming agent are difficult to meter. When lacking a suitable powder metering system, powder foaming agents are usually blended with the polymer via dry blending. To achieve a good mix, the polymer must usually be coated with a liquid material (primer) in a pre-mixture using suitable mixer. Suitable primers are low viscous paraffin oils, or other liquid additives such as plasticizers, lubricants or antistatic agents. The primer is used in small amounts, usually about 0.5 to 1.0% of the mixture. If too much primer is used, there is danger of melt slip/over-lubrication, which can lead to feeding problems in the extruder.

In general, it is best to feed the foaming agent in the form of a pelletized masterbatch in ways similar to those used for other additives and color masterbatches. Many types of feeders, blenders, and metering devices are available to meter the masterbatch gravimetrically or volumetrically. However, when using masterbatches, the carrier polymer can influence the foaming process.

It is very important to choose a foaming agent masterbatch that is made with a carrier material compatible with the polymer being foamed. For this reason, Bergen International foaming agents are available in different concentrations with a variety of different carrier resins.

Bergen International also offers a full line of products based on exothermic foaming agents as well as a blend of endothermic/exothermic material. These materials are available in powders as well as pelletized masterbatches.

MACHINE PARAMETERS

The Extruder

Most single screw extruders are suitable for chemical foam extrusion. The L:D ratio should be at least 24:1; normally screws with a L:D ratio of 30:1 are used. The temperature in the feeding zone should be lower than the initial decomposition temperature of the used foaming agent to prevent early decomposition of the foaming agent.

The use of a grooved barrel leads to a relatively quick pressure increase in the extruder (See figures 1 & 3). This is very advantageous when using foaming agent masterbatches with low melting temperatures. As the foaming agent masterbatch melts in an early stage

and reaches the decomposition temperature earlier, the resulting gas will dissolve the melt, due to the high pressures present at the beginning, and can be very well distributed in a short period of time.

When using smooth barrels, a sufficient melt pressure is reached more slowly (See figures 2 & 3). Foaming agent masterbatches with a low melting point can melt too early at the barrel wall, and the resulting gas can partially or completely escape through the hopper. In this case the temperature of the feeding zone should be adjusted to a lower temperature, to prevent the premature decomposition of the foaming agent.

Figure 1: Grooved Barrel Extruder

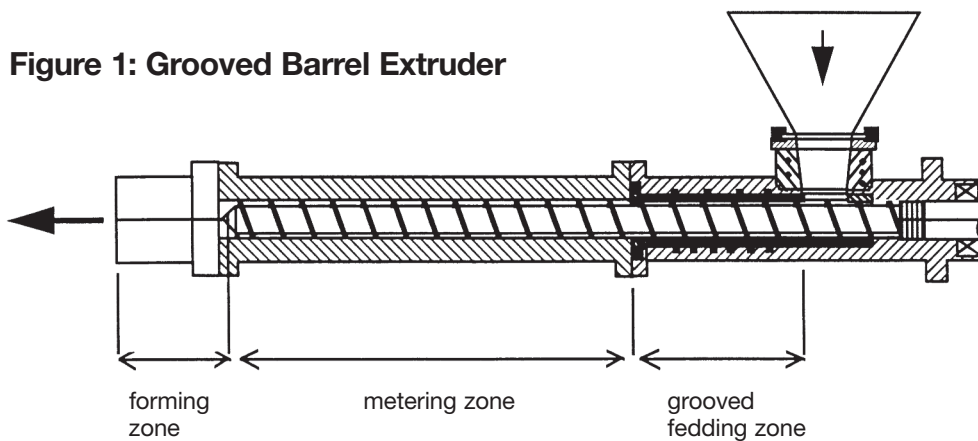
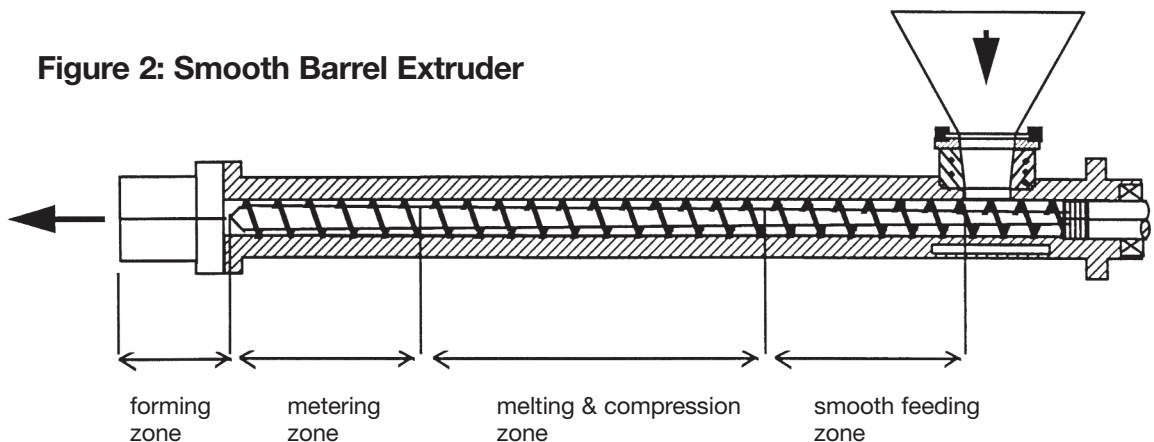


Figure 2: Smooth Barrel Extruder



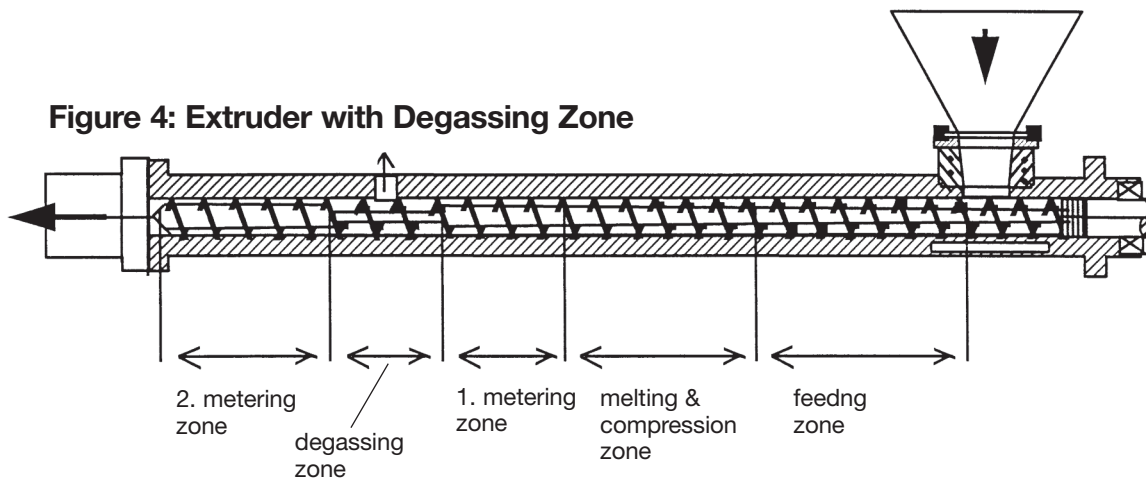
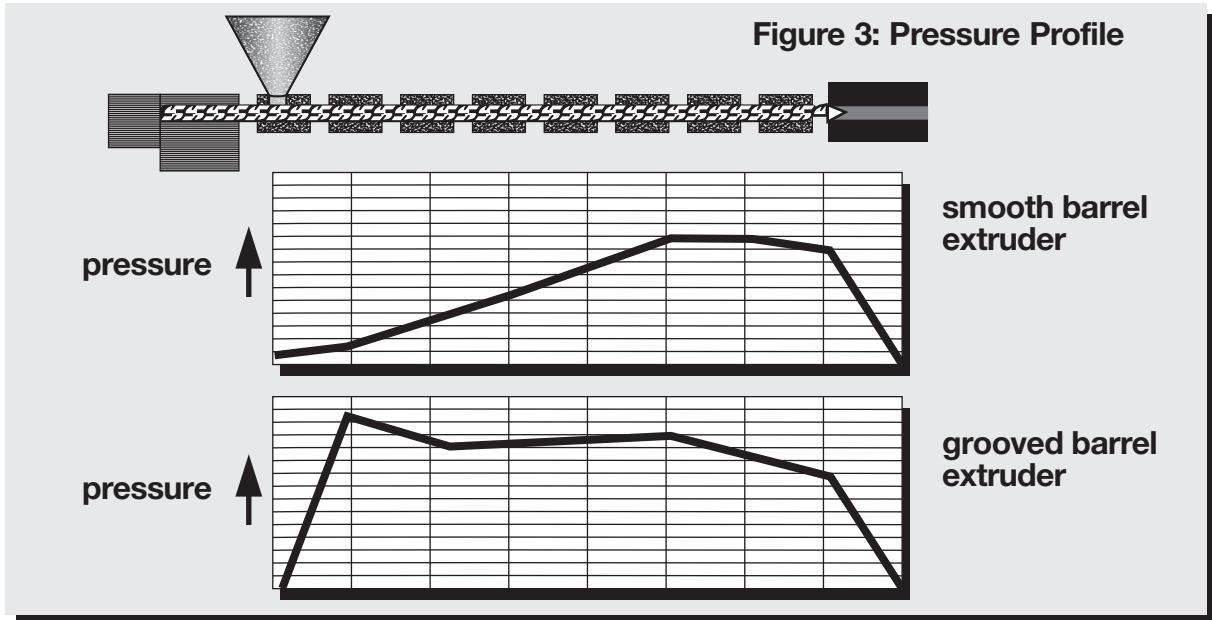
SCREW GEOMETRY

Basically, all common screws can be used for foam extrusion, as long as there is no large pressure decrease in the single zones of the screw, which leads to unwanted pre-foaming in the melt.

Established screws for processing are three-zone screws (Feeding-Compression-Metering/Mixing). Good results have also been achieved with degassing screws (PS), as long as you keep in mind the

conditions mentioned at the beginning of this report (See figure 4).

Some new problems developed with the introduction of barrier screws. One of them is an increased tendency to pre-foam, caused by a high pressure decrease between the barrier flight and the driving pitch. When using short barrier segments, the pressure decrease can be compensated by higher screw speeds.



MELT FILTERS and MELT PUMP

The use of fine mesh screen and screen changers are generally not necessary in foam extrusion. Due to foam structure, impurities, gels or additive agglomerates are usually not visible and do not affect the foam product.

If melt filters are used it is important to use screens that are rather coarse. This can help prevent pressure drop after the screens, which can possibly result in pre-foaming.

The use of melt pumps can improve the extrusion process in the following ways:

- the mass flow is stabilized
- the pressure in the barrel can be increased
- less work-intensive material must be transported in the barrel

For foam extrusion it is very important to place a pressure gauge where the melt enters the melt pump. The pressure reading of this gauge is used to control the screw speed, insuring a uniform melt output at the end of the extruder.

If the pressure setting is too low, pre-foaming may occur. In this case, it is necessary to increase the pressure setting.

Experiments have shown that the following minimum pressures can be used as a guideline to yield acceptable foam extruded products:

Melt Temperature:	Lowest Permissible Pressure:
160°C	40 bar / 580 psi
180°C	50 bar / 725 psi
200°C	60 bar / 870 psi
>200°C	> 80 bar / > 1160 psi

EXTRUSION DIES

Slot Die

Slot dies are used for the production of thin films (with a chill-roll calendar stack), or thicker films such as sheets (with a calendar). When using slot dies with a restrictor bar (for a better dispersion of the melt), the restrictor bar should not be closed too much. If the restrictor bar is closed too much, a pressure drop can occur right after the restrictor bar, which can result in pre-foaming.

It is best to be able to detect a slight area in the melt just exiting the die that is free of foam bubbles. Just after this, the expansion of the gas can be seen. This is referred to as a "halo". When a "halo" can be seen, you can be certain that there is no foaming or expansion occurring in the die or equipment.

During the cooling process of the foamed melt, the following problems can commonly be encountered:

- Foam formation time is not sufficient – the distance between the die and the cooling roll may be too short.
- The foam structure is crushed – the distance between the rolls of the chill-roll system may be too short.
- When producing a thinner film, the foam bubbles become highly stretched and as a result foam film density may increase – the haul-off speed can be too high. However, for some processes this stretch or orientation is wanted, e.g. decorative ribbons or packaging tapes.

When adjusting the distance of the opening in the slot die, the weight reduction has to be considered. For 30% weight reduction, the opening should be reduced by roughly 30% compared to a compact film of the same thickness (to compensate for the expansion of the foam).

PROFILE DIE, TUBULAR NOZZLE

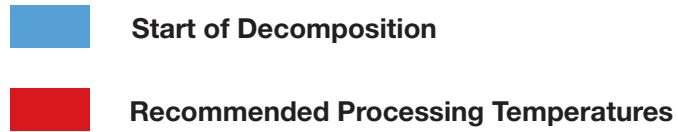
Compared with the cross section of a slot die, the cross sections of profile dies generally cannot be changed or adjusted. When designing and machining the die, the desired foam product needs to be considered. Generally, it is the best to design dies with short land lengths to maintain high melt pressure right up to the die lip. This is also valid for the production of foamed blown film. It must also be noted, that the pressure characteristics of a given die can be affected by many factors, such as resin, resin viscosity, temperature, desired density reduction, output rate, and actual product cross section.

COEXTRUSION

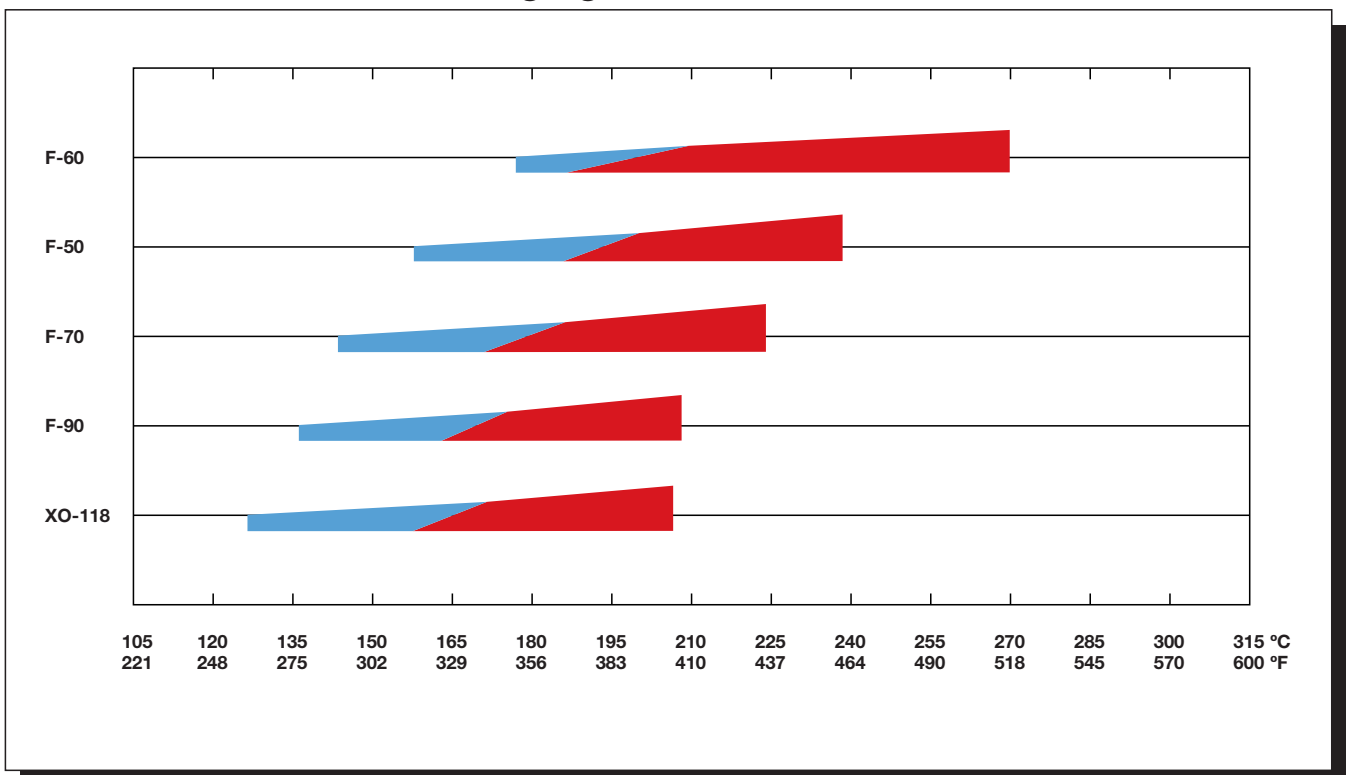
Many coextruded foam products are produced with a foamed inner layer, and solid, unfoamed outer layers. In this case, it is very important, to select the right material. For the outer layer, a "softer" material is recommended, while a material that is somewhat harder is recommended for the inner, foamed layer. This type of structure is suggested due to the fact, that a foamable melt has better flow characteristics (lower apparent viscosity) compared to a solid melt of the same resin. If the layers differ in viscosity, it can result in poor or destroyed foam structure.

Tests have shown that the solid layers can utilize resin with a 2 – 3 times higher MFI-value than the foam layer to give good foam structure.

START OF DECOMPOSITION/ RECOMMENDED TEMPERATURES



Foamazol™ Chemical Foaming Agents



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