

Guidelines for the Blow Molding of Sarlink

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Introduction

Sarlink® thermoplastic vulcanizates (TPV) are based on dynamically vulcanized EPDM rubber particles dispersed in a polypropylene matrix.

Because of this morphology, Sarlink thermoplastic vulcanizates combine the performance characteristics of widely used thermoset rubbers, such as EPDM and polychloroprene, with the ease of plastic processing.

Sarlink offers a wide range of properties valuable to the end user. For instance:

- resistance to high temperature
- resistance to low temperature
- excellent flexural fatigue endurance
- high impact strength
- excellent resistance to chemicals and solvents
- excellent resistance to weathering
- good electrical properties
- high tear resistance
- low tension and compression set
- good resistance to oils (particularly harder grades).

In addition to their superior performance characteristics, Sarlink thermoplastic vulcanizates, which are fully compounded, ready-to-use pellets, offer the following processing advantages compared to thermoset rubber:

- no compounding
- no vulcanization
- low capital investment.
- easy processing on standard thermoplastic equipment for extrusion, injection molding and blow molding
- fast processing (short cycle times)
- thermal stability/wide processing window
- low energy consumption
- recycling of scrap generated during processing
- recycling of parts after service life
- excellent control of product quality and dimensional tolerances
- in-line colorability
- easy weldability (profiles, sheeting...)
- material combinations by co-extrusion, co-injection or co-blow molding to produce hard/soft articles, solid/sponge profiles...

In addition to standard types, a wide range of specialty grades are available, including high flow and UV stabilized grades.

Because of its combination of excellent finished part properties and easy processing, Sarlink thermoplastic vulcanizates have found many applications in a wide range of markets, including: automotive, building and construction, electrical, mechanical rubber goods, medical and leisure.

Sarlink thermoplastic vulcanizates are widely used in many blow molded parts such as rack & pinion steering gear boots, shock absorbers, strut covers, steering column cover, (3D sequential) automotive air ducts, cable ducts and many other applications in all market segments.

This brochure is a guideline for the blow molding of Sarlink and shows an overview of the different blow molding techniques. A checklist for troubleshooting is available on the last pages.

The Principles of Blow Molding

Introduction

Blow molding is the established technique for the production of hollow articles such as bellows and airducts. There are three major techniques for this process:

- extrusion blow molding
- press injection blow molding
- injection blow molding.

Extrusion blow molding is the most widely used technique. Sarlink is very suitable for blow molding because it has excellent melt strength and a high blow ratio. Sarlink gives a significant weight reduction compared to thermoset rubber and Sarlink is fully recyclable. Table 1 shows an overview of application and material combinations.

Continuous extrusion blow molding

The principle of the extrusion blow molding process is that a parison, which is formed by continuous extrusion of material and rotating of the screw in the barrel, is clamped between two halves of a mold, cut-off and inflated with air to fill the mold. The mold is cooled so that the product is frozen into the mold shape, while still under air pressure. The mold is then opened and the part removed. Due to the high melt stability and large blow-ratio (up to 4.5 for the high hardness grades) of Sarlink, large blow molded articles can be made. The processing steps are shown in figure 2.

Multi-layer/sequential co-extrusion blow molding

Several polymers can be extruded in a multi-layer parison. The equipment is based on continuous extrusion or equipment with a melt accumulator. The thickness of each individual layer can be varied. Sarlink can be used in this kind of process to create e.g. a soft touch or rubber-like layer on polypropylene. The principles of the multi-layer extrusion blow molding system are shown in figure 1.

Application	Material
Rack & pinion steering gear boots	Sarlink 3190B, 3139DB, 4190B, 4139DB, 4149DB
Shock absorber, strut cover	Sarlink 3170B, 3180B, 4190B
Steering column cover	Sarlink 3190B, 4190B
Automotive air ducts 1 dimensional	Sarlink 3180B, 3190B, 4180B, 4190B
Automotive air ducts 3 dimensional	flexible part, PP stiff part
Cable duct	Sarlink 3160B, 3170B

Table 1: Examples for possible Sarlink/application combinations

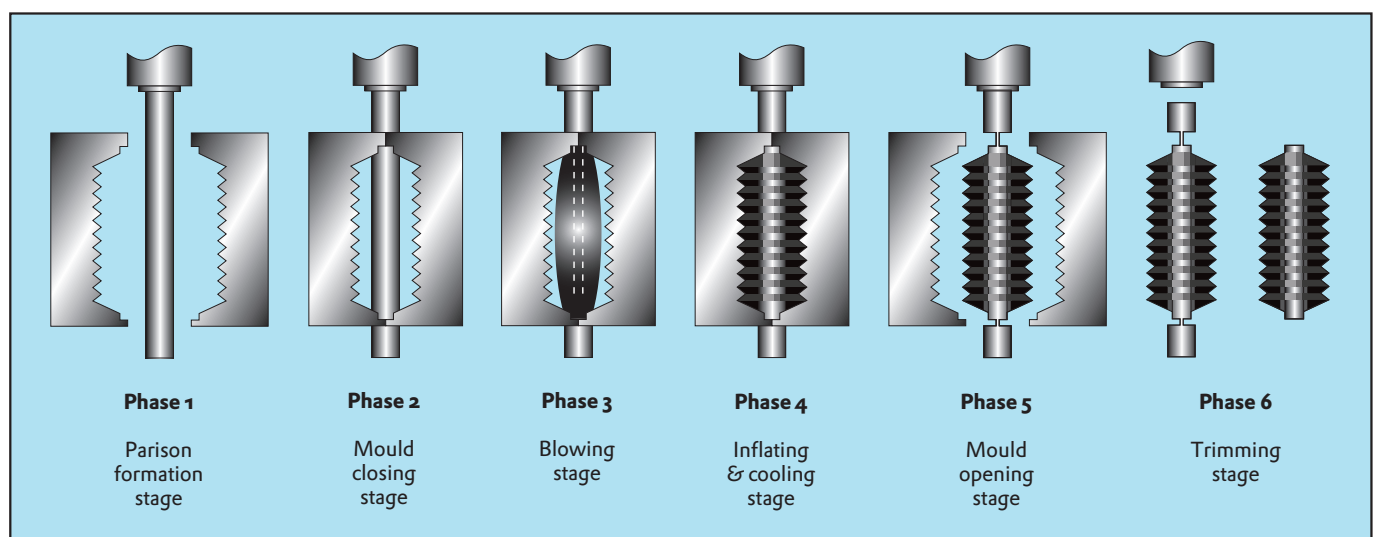


Fig. 2 - Overview of the extrusion blow moulding process

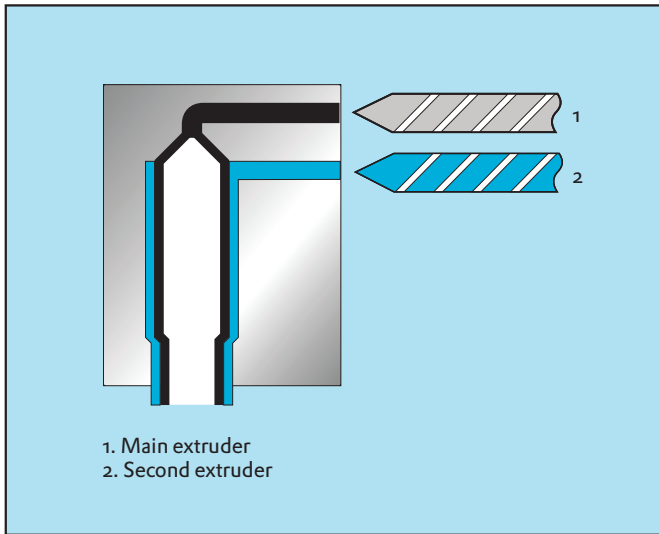


Fig. 1 - Two layer co-extrusion blow moulding

The different materials can also be extruded sequentially. This is accomplished by reducing layer thickness to zero for one layer at a time in an alternating pattern. This technique is used to create hard-soft combinations. Automotive air ducts with flexible ends and rigid pipe sections are produced with this process.

Injection blow molding

The injection blow molding process is based on an injection molded preform instead of a directly extruded parison in the extrusion blow molding process. This process has the advantage of producing injection molded

ends which have better control of dimensional tolerances. These machines are typically arranged in 3 or 4 stations that perform individual process steps. In the first station the preform is injection molded. The machine is then indexed to the second position where the preform is inflated into a blow molding cavity. In the third station the parts are ejected off the core rod. In the fourth station the core rods are tempered. This process is typically used to produce high production volume parts such as rack & pinion boots.

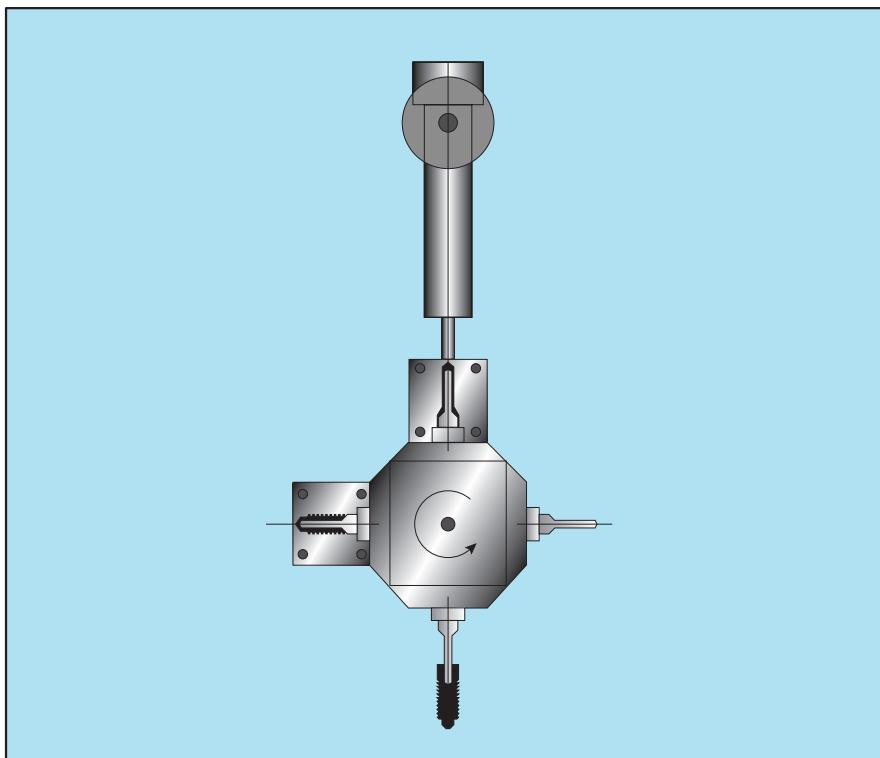


Fig. 3 - Injection blow moulding

3D blow molding

This process is typically used for automotive air intake ducts. An advantage of three dimensional blow molding is that it is possible to make complex parts without generating flash along the edges. There are different techniques to make 3D articles. Figure 4a shows the process with a movable mold; figure 4b shows the movable head system on a fixed mold. The parison can also be put into the mold by manipulating the parison with a robot.

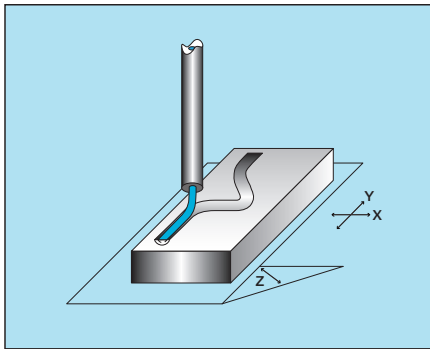


Fig. 4a - Example of 3D blow moulding with movable mould

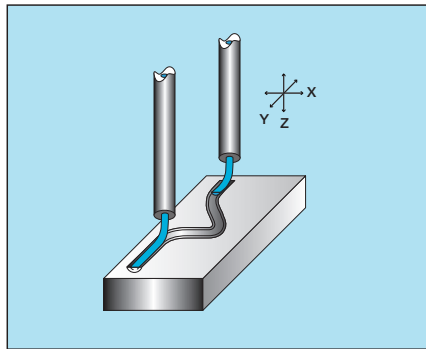


Fig. 4b - Example of 3D blow moulding with movable head

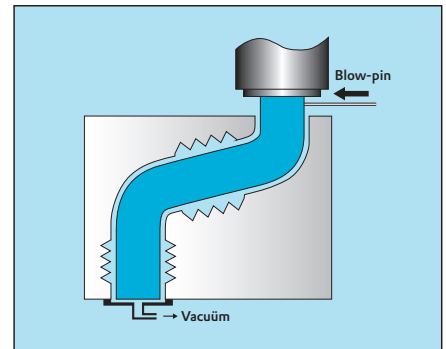


Fig. 5 - Suction blow moulding

Suction blow molding

In this blow molding process the parison is sucked in the (closed) mold by a vacuum pump. This pump is connected to the bottom of the mold. The filling process of the mold takes place very rapidly (typically within a second). When the mold is filled, the parison is inflated via an injected blow needle. This blow needle is injected on the top side of the parison.

The advantage of this blow molding technology is that it is possible to produce 3D blow molded parts on standard extrusion blow molding machines after a (small) change

of the mold and the addition of a vacuum pump. One disadvantage of this system is the impossibility to produce complex 3D geometries. Another disadvantage is that the part diameter is limited. Figure 5 shows a simplified representation of the suction blow molding system.

Press injection blow molding

Sarlink is an excellent material to use in a press injection blow molding system. This process is also known as the Ossberger process®, named after the equipment manufacturer. In this process the extruder initially fills a small

injection mold which produces the end fitting of the part. This mold is then lifted vertically while extruding a parison against the force of gravity. The wall thickness is adjusted during the extrusion process by varying the die gap. The mold closes around the injection mold and the parison, and the parison is blown into the mold cavity. The mold opens and the part is removed for trimming. The principle of this press injection blow-molding system is shown in figure 6.

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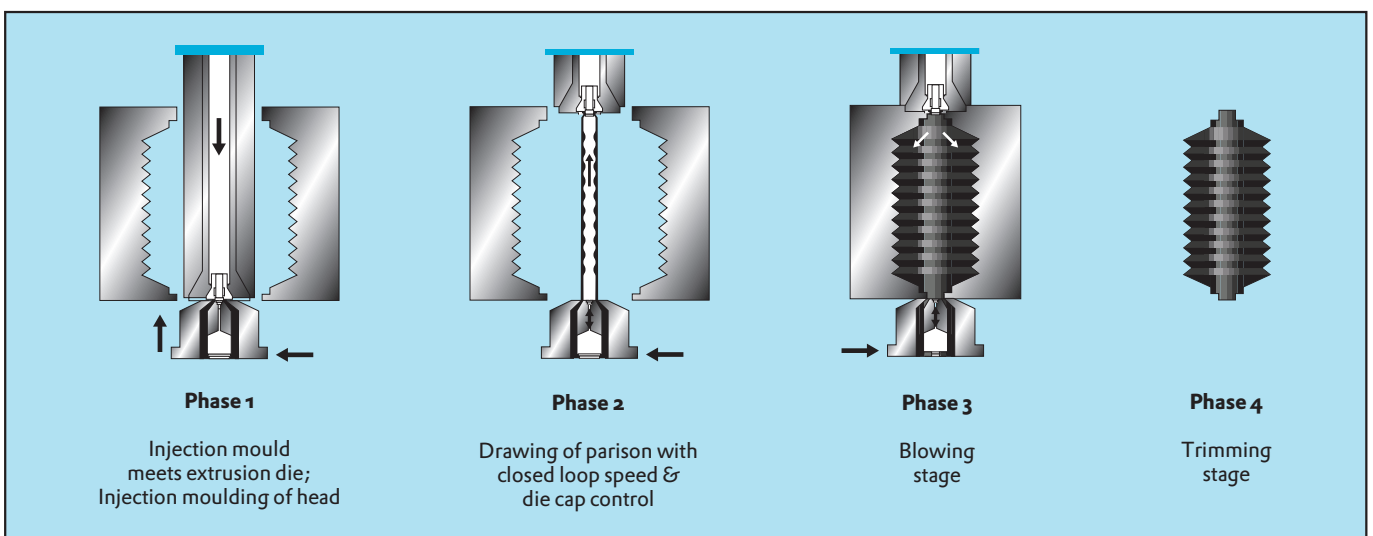


Fig. 6 - Press injection blow moulding system of Ossberger

Characteristics of the Typical Blow Molding Equipment for Sarlink

Sarlink can be processed on existing blow-molding equipment without further modification. However, in order to obtain the best blow molding performance, or if dedicated equipment for processing Sarlink has to be purchased, it is recommended to take the following items into consideration.

Screw design

General purpose screws

For the processing of Sarlink a single stage, three zone polyolefin type metering screw is adequate. The optimum general purpose screw design is as follows:

- feed zone: this zone should be relatively short, about 25 % of the total screw length
- transition section: recommended is a transition section with a length of about 25 % of the total
- metering section: about 50 % of the total screw length is recommended, in order to provide adequate shear mixing
- L/D ratio of 24:1 to 32:1 is recommended. Shorter screws should be avoided
- compression ratio of 3:1 is recommended.

Mixing pins or shear segments are often used with general purpose screws to improve melt homogeneity and dispersion of colorants and additives.

Barrier screws

The use of a low shear barrier screw will provide the higher throughput and improved melt quality. A generous barrier clearance is used (typically 1.5 to 2.0 mm). The barrier section should be followed with a Maddock mixing section to further homogenize the melt. Consult DSM for further design recommendations regarding barrier screws.

Head and die design for continuous extrusion blow molding

Head design. Polyolefin head designs are also recommended for Sarlink. Important factors in head design are:

- streamlined design
- uniform temperature control
- programmable die parison wall thickness control.

In cases where large parisons are necessary an accumulator head is preferred. The principle of this head design is that the molten material will be stored in the head, prior to the formation of the parison. The parison will be formed by pressing the material out of the head (melt ram). The minimum accumulator capacity should be greater than

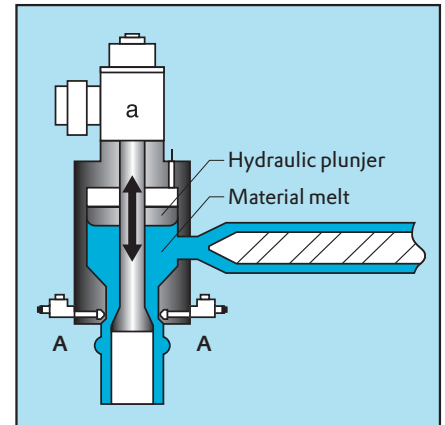


Fig. 7 - Accumulator head design

the part weight plus the flash. The maximum accumulator capacity should not be greater than 3 times the part weight plus flash. The accumulator head design is shown in figure 7.

Die design

The die can be converging or diverging, depending on head design and on required parison diameter. Smaller parts are typically run with diverging head tooling. Figure 8a and 8b shows the difference between a diverging and converging die.

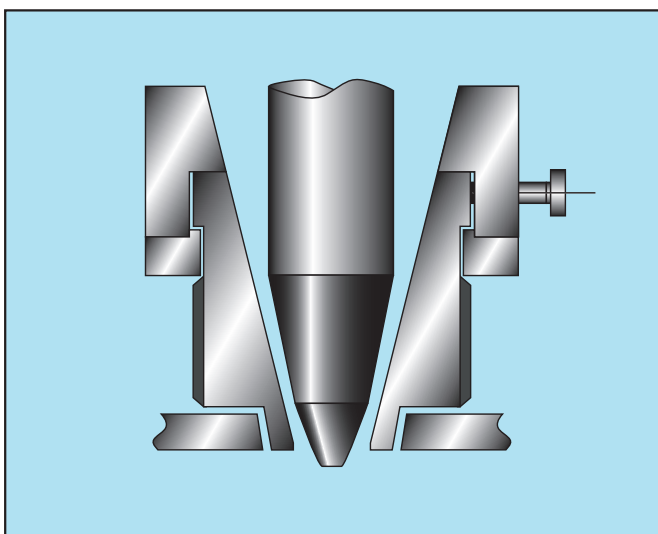


Fig. 8b - Converging die design

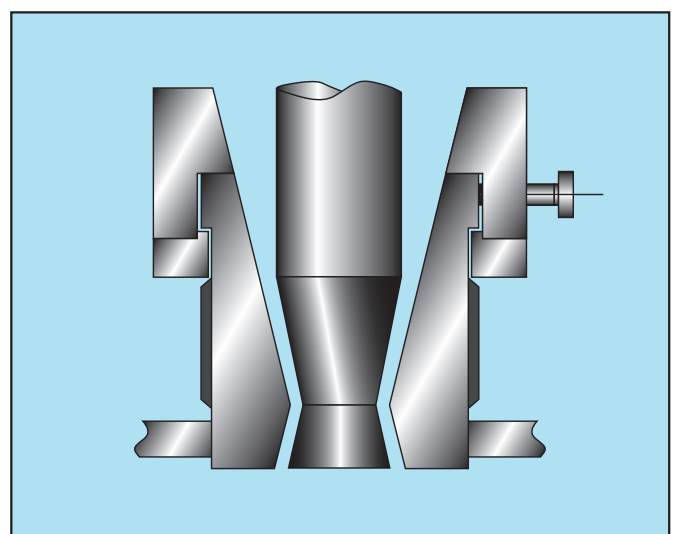


Fig. 8a - Diverging die design

The use of equipment with programmable parison wall thickness control is preferred. This will allow for compensation of parison sagging due to the forces of gravity: if a long, or heavy parison is extruded with constant thickness, it will be thicker at the bottom end, and thinner at the top. Consequently the bend of the finished part will be thinner and constitute a weak point. To correct this, it is possible to vary the wall thickness of the parison during the extrusion by moving either the internal or external part of the die.

Die dimensions

The outer diameter of the extrusion die (d_{die}) is equal to the outer diameter of the requested parison ($d_{extrudate}$) divided by 1 plus the die swell divided by 100.

$$d_{die} = \frac{d_{extrudate}}{\frac{(1 + \text{die swell})}{100}}$$

The minimum parison outer diameter is the ratio of the finished part outer diameter divided by the blow-ratio of the used Sarlink grade.

The parison diameter should be chosen so that the parison enters easily into the mold and minimizes the required blow ratio.

Die swell

Die swell for Sarlink products ranges from 0 to 15 %. The die swell is low for low hardness grades. Die swell is also influenced by the shear rate through the die. As the flow rate increases the die swell will increase. Lower melt temperatures will increase the die swell.

Mold design

Blow mold cavity material

Aluminum materials are typically used for Sarlink. Machined molds are often more expensive to produce but are more durable. Pre-hardened steel material can be used for high volume production to reduce wear.

Venting of the mold

Venting of the mold is necessary in order to allow for escape of air and optimally following the shape of the mold. For Sarlink parting line vents are recommended, with a depth of 0.05 to 0.08 mm. Vents to the outside can be much deeper from 0.25 mm to 0.40 mm. Incavity vent plugs are used for convoluted molds or for larger parts which require more air flow to vent.

Cooling of the mold

For large molds, it is advisable to have several cooling zones. Most intensive cooling should be located in the pinch relief section, where the material is the thickest. Small molds should have a single cooling circuit. Recommended mold temperatures are 10 to 40 °C.

Shrinkage

The approximate shrinkage of Sarlink in a blow molding process for a wall thickness of a part, up to 2 mm, will be 1.5 % for the soft grades, below 75 Shore A and 2 % for the high hardness grades.

Processing Conditions for Optimal Blow Molding of Sarlink

Drying and storage of Sarlink

In exposure to air Sarlink granules may pick up moisture to a slight degree. The presence of moisture in the granules produces porosity in the parison, leading to parison failure during the blowing stage. It is therefore recommended to store Sarlink carefully and to dry both virgin pellets and regrind before blow molding.

Recommended storage conditions

Suggested storage conditions for Sarlink are:

- store Sarlink bags closed and undamaged in a non-humid environment
- open bags just before use close the bags securely when the whole content has not been used completely
- bring cold granules to ambient temperature in the processing room while keeping the bags closed.

Recommended drying conditions

- dry minimal 3-4 hours at 80 °C using a desiccant dryer with a dew point of -40°C

Use of regrind

Sarlink 3000 and 4000 thermoplastic vulcanizates have excellent melt stability, and all scrap generated during processing can be recycled provided it is kept clean. High levels of regrind can be used.

The viscosity of Sarlink decreases slightly after reprocessing. For this reason, it is recommended during production to blend a constant level of less than 20% regrind within the virgin material in order to keep processing conditions constant. Addition of regrind has no negative influence on surface quality, as mentioned in the 'drying' paragraph.

It is recommended to dry recycled material before reuse to avoid porosity in the parison.

Coloring of Sarlink

Natural Sarlink can be colored by addition of a suitable masterbatch. Polypropylene based masterbatches offer the best compatibility with Sarlink, but may slightly increase the hardness. Low density polyethylene based masterbatches are also suitable. Recommended level of color Masterbatch in Sarlink: 1 to 5 % by weight, to minimize the impact on Sarlink properties.

During blow molding, dispersion of the color Masterbatch can be improved if needed, by utilizing a mixing screw.

Temperature settings

Material melt temperature

A melt temperature in the range of 185 °C to 220 °C is optimal for blow molding of Sarlink. If the temperature is too low a rough surface will appear, parison stability will be improved but blow-ratio will be reduced. A high melt temperature will result in a lower stability of the parison due to lower melt strength, which will result in less control of wall thickness of the blow molded part.

Barrel temperatures

For blow molding of Sarlink the material should be processed in the range of 185 °C to 220 °C. For soft grades low temperatures are recommended. Wide variations in cylinder temperatures should be avoided. Typical barrel temperatures for Sarlink are shown in table 2.

Processing temperatures (°C)		
Hardness	40A	- 50D
Barrel zone 1	180	- 195
Barrel zone 2	190	- 200
Barrel zone 3	195	- 210
Head	200	- 215
Die	200	- 215
Mould	10/40	- 10/40

Table 2: Recommended temperature settings for blow moulding Sarlink

If possible the feed throat of the barrel should be cooled with water to avoid agglomeration of the pellets and to facilitate the feeding. If cooling is not available, it is recommended to keep the first zone of the barrel below 190 °C. Fine-tuning of the temperature settings is dependent on the blow-ratio, parison length and grade used.

Screw temperature control

Internal heating or cooling of the screw is not recommended.

Mold temperature

Blow molds are typically cooled with water. Recommended mold temperatures range from 10 °C to 40 °C. Higher mold temperatures will improve surface quality but will increase the cooling time.

Internal part cooling

For large parts with a lengthy cooling cycle the part can be cooled by circulating air through the part. This is accomplished by means of two blow pins, one for air supply and the other to vent.

Blowing parameters

Pre-blowing

Pre-blowing may be necessary to prevent collapsing of the parison during closing of the mold or by gravity.

Blowing pressure/time

Rapid blowing into the mold is preferred. Actual blow speed should be defined experimentally. The optimal blow speed is influenced by parison, part design, wall-thickness, temperature settings and blow-ratio. Blowing pressure of 0.3 to 0.7 MPa is recommended for maximum part definition and adequate heat transfer. The volume and pressure of the air should be maintained throughout the cooling cycle prior to mold opening.

Blow-ratio

From the hollow parison the product is formed by expansion of air. The blow-ratio (maximum part finished outer diameter divided by die outer diameter) of the parison is dependent on:

- the parison temperature
- the parison thickness
- the hardness of the Sarlink grade used.

An overview of the blow-ratio of Sarlink is shown in table 3.

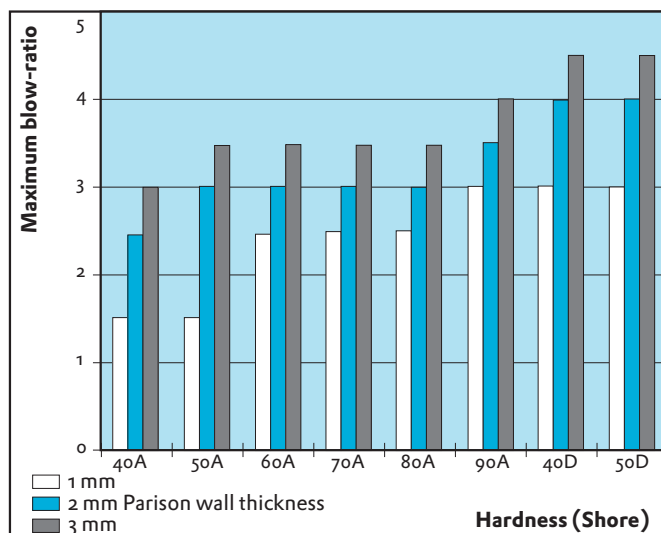


Table 3: Maximum blow-ratio of Sarlink, as function of the parison wall thickness

Maintenance of the equipment

Purging of equipment before processing Sarlink

To avoid contamination, the blow molding equipment should be cleaned before processing Sarlink. Polyethylene or polypropylene of low melt index are recommended. Purge at a temperature of 200 °C. This cleaning operation is particularly important if the equipment has been used previously for PVC or POM/acetals.

Equipment shut down and cleaning

At the end of the production, run the hopper and screw empty of Sarlink. Purge the extruder thoroughly with polyethylene or polypropylene if change over to another material is anticipated. The use of high viscosity polyolefins will speed up the purging process.

Perform a general clean up of the hopper and any pneumatic conveying lines to remove residual fines. Clean the mold and protect the mold for corrosion.

Ancillary equipment

Equipment typically used for PE or PP, such as toothed circular saws, may not be suitable for soft Sarlink grades, because of its rubber-like nature. Sarlink parts are best trimmed with razor blades. For the lower durometer grades, hot knives are recommended in order to get an optimal surface. These soft parts should be supported during cutting to avoid distortion. Rotating knife systems are typically used to trim ends of cylindrical parts.

Appendix 1

Troubleshooting Table for the Extrusion Blow Molding of Sarlink

Problem	Cause	Solution/corrective action
Unstable parison	Melt temperature too high	Decrease cylinder temperatures Decrease head/die temperatures
	Die not central	Centre die and pin
	Die/head dirty	Clean die
Parison is running to one side	Pressure differences of the parison as it leaves the die or circumference temperature differences in the melt when the parison is formed and leaves the die	Centre die and pin
		Check head and die heaterbands
Rough mouldings/surface	Material too cold	Raise cylinder temperatures (check heater-bands)
		Raise head/die temperatures (check heater-bands)
		Decrease extrusion speed; longer heating period
	Mould too cold	Increase mould temperature
Head/die dirty	Dismantle pin and die and clean; polish if necessary	
Dispersion problem	Use screw with more compression	
	Decrease hopper-side temperature	
Blown parts contain unmolten particles	Inhomogeneous temperature distribution in the melt or material is in general too cold	Increase cylinder temperatures
		Increase die/head temperatures for melting
		Decrease extrusion speed
		Increase back pressure if possible
	Mixing elements	
Dispersion problem	Use screw with more compression	
	Add mixing element to screw	
Blow problems	Impossible to blow parison	Dry granulates
		Dry regrind
		Increase or decrease blow pressure
	Blow ratio too low	Change to higher hardness
		Increase parison wall thickness
		Decrease or increase material melt temperature
Change die tooling to increase the parison diameter		

Problem	Cause	
Weld lines	Weld lines visible or cracks on part and parison formed in spider	Increase melt temperature
		Increase die temperature
		Purging or cleaning of head/spider/die
Flashing	Flash of material on part	Decrease blow pressure
		Increase clamp force
		Decrease melt temperature
Contamination in parison/part	Dirt in equipment	Purge to remove degraded material
	Dirt in regrind	Decrease barrel/head temperature
	Burned/degraded material	Reduce overall cycle time
Silver streaks or voids in parison	Water vapour enclosure, material contains moisture	Use dry material; pre-dry material
		Dry regrind if used