Guidelines for the Extrusion of Sarlink

Contents

Introduction

Sarlink® thermoplastic elastomers (TPE) based on dynamically vulcanized EPDM rubber particles dispersed in a polypropylene matrix. Because of this morphology, Sarlink thermoplastic elastomers 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 following processing advantages compared to thermoset rubber:

- no compounding
- no vulcanization
- low capital investment
- easy processing on standard thermoplastic equipment for extrusion, injection molding, blow molding
- fast processing (short cycle times)
- thermal stability/wide processing window
- low energy consumption
- recycling of scrap generated during processing
- recycling of part 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....

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

In extruded goods, Sarlink thermoplastic vulcanizates are widely used as automotive sealing profiles, architectural glazing seals, window/door profiles, expansion joints, cable insulation and jacketing, hoses and tubing, and sheeting.

This brochure focuses on the general principles of Sarlink extrusion.

The rheology of Sarlink TPV is similar to the rheology of highly filled polymer systems. Both materials exhibit highly pseudo-plastic behavior, lack of a viscosity plateau at low shear rate and low extrusion swell.
The shear viscosity is moderate at shear rates commonly found in extrusion (100-1000 s-1). It is made more sensitive to changes in shear rate than to temperature changes (see Figures 1 and 2).

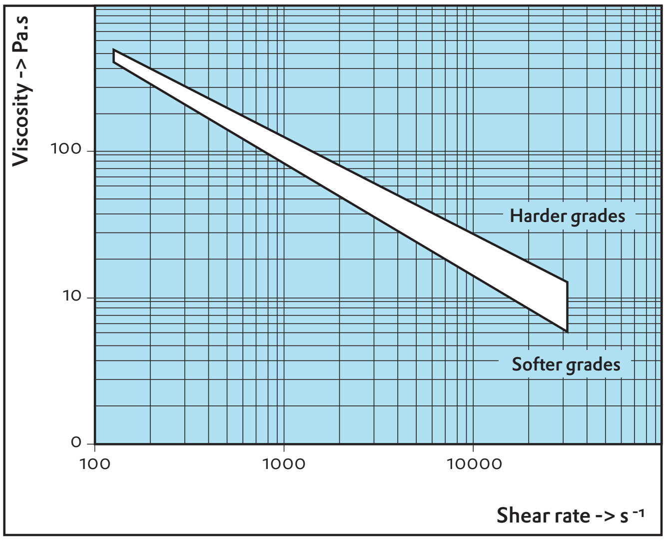

Fig. 1 - Melt viscosity of Sarlink as a function of shear rate at constant temperature. (DIN 54811 - 200 °C)

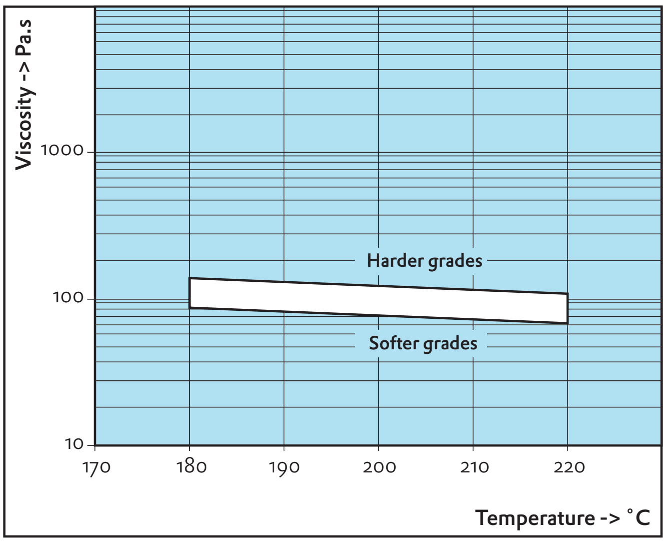

Fig. 2 - Melt viscosity of Sarlink as a function of temperature at constant shear rate. (DIN 54811 - 1000 s^{-1})

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Characteristics of the Optimum Extrusion Equipment for Sarlink

Sarlink can be easily processed on standard polyolefin equipment without further modification. However, in order to obtain best extrusion performance or if dedicated equipment for processing Sarlink is being sought, it is recommended to take the following items into consideration.

Screw:

- single stage, three zone polyolefin type metering screw
- L/D 24:1 or greater (L/D 30:1 preferred)
- compression ratio 3:1 (minimum 2,5:1, maximum 4:1)
- diameter: 25 to 114 mm depending on type of extrudate and desired output
- mixing elements: recommended

Screw

Single stage, three zone polyethylene type metering screw
Figure 3 gives an illustration of a typical three zone screw.

The various sections of the screw fulfill different functions. An optimum screw design for Sarlink consists of:

- Feed Zone: Relatively short, about 25 % of total screw length. A deep feed channel will allow consistent pumping of Sarlink pellets and more uniform compaction when regrind is used.
- Transition Section: About 25 % of total screw length. This will ensure a uniform melt.
- Metering Section: About 50 % of total screw length. Provides adequate shear mixing. Shorter metering sections can also be used, but the quality of the melt is reduced, particularly at high rpms.

Care should be taken to avoid any decompression zone in the screw, as this can lead to irregular output.

L/D 24:1 or greater (30:1 preferred)

This range of L/D (length to diameter) ratios gives adequate shear, optimum melt homogeneity, and high production rates. Lower L/D ratios give lower outputs. Short screws, with a L/D ratio of 20:1 and below, should be avoided.

Compression ratio
3:1 (minimum 2.5:1 - maximum 4:1)

A high compression ratio allows for proper control of shear and shear heating, and therefore optimum melt temperature control over a range of shear rates. Higher compression ratios are better for the softer grades of Sarlink. An overly high compression ratio may cause overheating of the material.

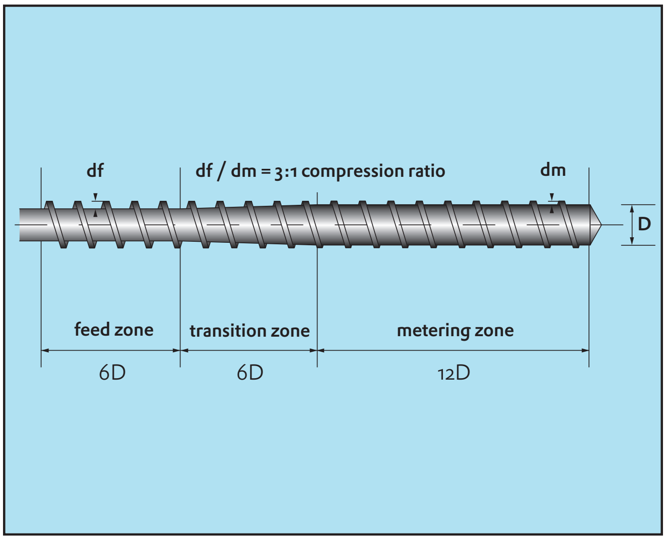

Fig. 3 - Typical screw design for Sarlink (general purpose screw)

Screw diameter
Depends on the type of extrudate and on the desired output (see section "Extruder output" on page 8).

- Small profiles are normally run on smaller machines (25 to 65 mm screw diameter). Linear extrusion speeds of 10 to 30 meters/minute are typical. This speed varies strongly according to the complexity of the extrudate. In order to increase the production capacity, it is possible to carry out duplex or multiple extrusions of simple section profiles.
- For larger extrudates, it is advisable to use bigger extruders, with screw diameters around 65-114 mm. Smaller or larger screw diameters may also be selected if the intended production requires it.

The extruder should be sized appropriately such that a screw speed in the range 25 to 80 rpm is used. If the extrudate cannot be run within this speed range, then a smaller or larger screw diameter should be selected.

To obtain best surface appearance of the extrudate, it is recommended to use a bigger extruder with a lower screw speed rather than a small extruder running at high speed.

Mixing screws and elements

The mixing capacity of standard extruder screws is relatively limited. Therefore, it is advisable to use mixing elements in order to enhance the melt quality. Before selecting a mixing element it is important to determine whether distributive or dispersive mixing is required.

Distributive mixing is easier to achieve than dispersive mixing and is required when Sarlink materials are blended with additives such as color concentrates, UV-stabilizers or different polymers with the viscosities reasonably close together. Well known distributive mixing elements are pin mixing sections. The pins cause disturbances in the velocity profile, thereby improving mixing. Examples of pin mixing elements are Pineapple, Dulmage or Saxon mixing sections.

Dispersive mixing can be achieved with mixing elements or with specially designed dual flighted barrier screws. These devices are used to help homogenize the melt. This is particularly important in small or thin gauge extrusion, e.g. thin film and profile extrusion. In these devices, one or more barrier flights are placed along the screw such that the material must flow over the barrier flights. In the barrier clearance the material is subjected to a high shear rate; the corresponding shear stress should be large enough to break down the particles in the polymer melt. A drawback of this mixing device is that it is pressure consuming and can increase melt temperature. Dispersive mixing elements which have been used to process Sarlink with good results are Maddock, Maillefer, Egan sections and blister rings.

Figure 4 depicts examples of mixing elements: a mixing pin device for distributive mixing, a Maddock device and a barrier screw both for dispersive mixing.

In order to obtain optimum results, it is recommended to place the mixing elements in the head of the screw, as shown above.

Temperature controls

A typical three zone barrel temperature control is adequate for extrusion of all Sarlink grades. Each zone should be equipped with heating and cooling. Digital temperature controllers with thermocouples embedded in the barrel will produce accurate temperature control. It is suggested to place a melt temperature probe at the exit of the screw. These temperature controls will allow the maintenance of the melt temperature of Sarlink at the desired level (see sections 'Temperature settings' and 'Melt temperature' on pages 11 and 12).

Material for screw and barrel

A flame hardened 4140 steel chrome plated screw with a bi-metallic barrel (Wesco 555, Xaloy 306 or equivalent) is suggested for long life and to allow processing of other thermoplastic materials.

Extruder output

Output is an important factor in determining the size of the desired extruder for a given application. Output depends on several variables, among others:

- screw diameter
- screw speed
- screw configuration
- presence of a grooved barrel
- type of extrudate/design of profile
- die back pressure
- temperature profile
- melt viscosity of the Sarlink grade.

Chart is missing output numbers (Y values)- check original European chart

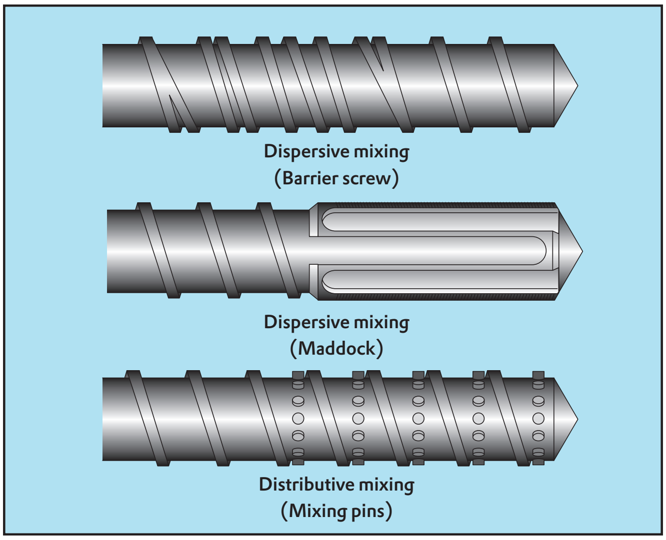

Fig. 4 - Examples of mixing elements

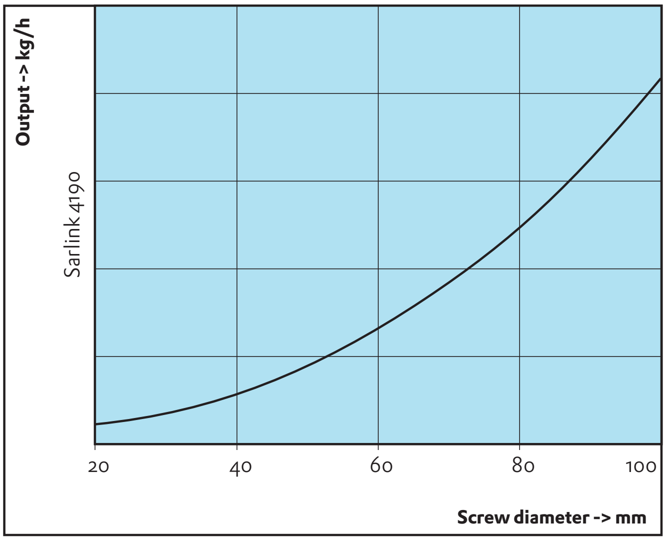

Fig. 5 - Sarlink output as a function of screw diameter

Processing Conditions for Optimum Extrusion of Sarlink

Drying Sarlink

Exposed to air, Sarlink granules may pick up moisture to a slight degree. The presence of moisture in the granules reduces melt strength and throughput, causes die build-up, creates porosity in the extrudate, and impairs surface quality. It is therefore recommended to store Sarlink carefully and to dry both virgin pellets and regrind before extrusion.

Recommended storage conditions:
Sarlink is pre-dried before shipping.
Suggested storage conditions are:

- store Sarlink bags closed and undamaged in a non humid environment
- open bags just before use 3 close the bag securely if the whole content has not been used
- bring cold granules to ambient temperature in the processing room while keeping the bags closed.

Recommended drying conditions:

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

Use of regrind

Sarlink thermoplastic vulcanizates have excellent melt stability, and all scrap generated during processing can be recycled, provided it is kept clean.

As an example, figure 10 shows that there is hardly any variation in physical properties of Sarlink after reprocessing the same material 10 times through an extruder.

As shown on figure 10, the viscosity of Sarlink slightly decreases 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.

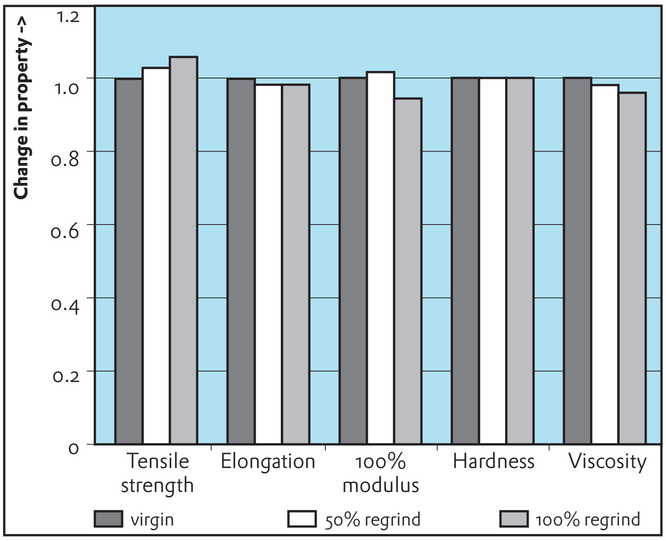

Fig. 10 - Regrind stability of Sarlink

It is also recommended to dry recycled material before reuse.

If feasible, scrap should be ground to a particle size similar to that of the original granules, because too large or too small particles may disturb the material distribution. Regrind can be carried out in a grinder with a rotating knife operating at low rpm. The grinder should be cleaned thoroughly prior to grinding Sarlink in order to prevent cross contamination with other materials.

Coloring Sarlink

Natural color Sarlink rubber can be colored by addition of a suitable color masterbatch. Polypropylene based masterbatches offer best compatibility with Sarlink, but may slightly increase the hardness. Low density polyethylene based masterbatches are also suitable, as they disperse more easily and have less of an impact on hardness. In very critical cases, Sarlink based color masterbatches are advisable.

Recommended melt index for PP/LDPE: 10 to 20.
Recommended level of color masterbatch in Sarlink: 1 to 5 % by weight, to minimize the impact on Sarlink properties.

During extrusion, dispersion of the color masterbatch can be improved if needed by utilizing a higher mesh screen pack and/or a mixing screw.

Screen pack and breaker plate

Screen packs and breaker plate are recommended when extruding Sarlink TPV. They fulfill several different roles:

- create back pressure against the screw to ensure a homogeneous flow of material to the head
- when using regrind, screen out foreign objects in the melt which might damage the die or the extruded part
- help disperse color concentrates.

The screen pack should be placed at the exit of the screw just prior to the die adapter.

Recommended screen pack:

- material: stainless steel, square weave screens are commonly used
- typical settings: a mirror construction, 20/40/60/40/20 mesh screens, with coarse screens both in front and back of finer screens. Higher mesh screen (up to 200 mesh) can be used to create additional back pressure to aid in dispersing color concentrates and additives, or to protect intricate dies.

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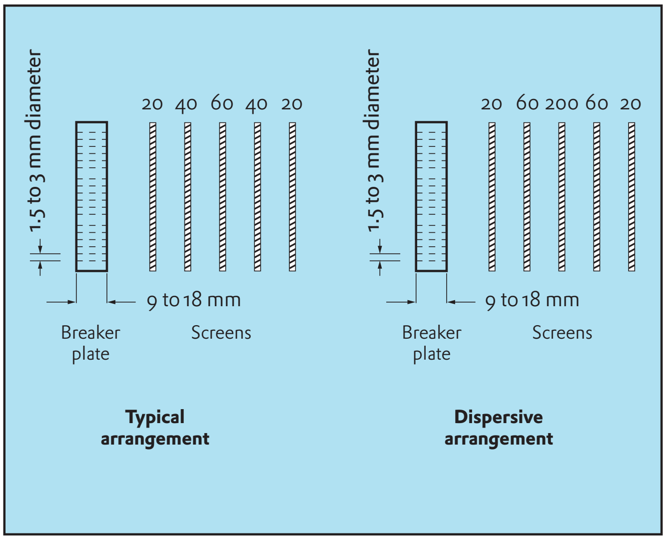

Fig. 11 - Screen pack and breaker plate

Figure 11 shows screen pack and breaker plate arrangements for standard conditions and for improved dispersion.

It is important to always have a coarse screen (20 mesh) away from the flow, in order to support the finer and more fragile screens.

The breaker plate supports the screen pack against the pressure of the melt flow as it goes through. The breaker plate also redirects the flow from the spiral motion in the screw to an uniform parallel flow pattern.

Temperature settings

The feed throat of the extruder should be cooled to avoid agglomeration of the pellets and to facilitate the feed.

The typical temperature settings for the extrusion of Sarlink grades are presented in the table below:

Extruder	Settings* (°C)	Settings* (°F)
Feeding zone	135	275
Compression zone	175 - 185	347 - 365
Metering zone	195 - 200	383 - 392
Head	200	392
Die	210	410

The screw should be neither heated nor cooled. Cooling could provoke hardening of the material on the screw flights.

Melt temperature

Typical melt temperature between 195 and 220 °C is optimum for Sarlink. A too low melt temperature will result in increased die swell and rough surface because of lack of homogeneity of the melt. A too high melt temperature is detrimental to the hot dimensional stability and to the draw down of the extrudate. Melt temperatures above 250 °C should be avoided as they might cause thermal degradation of Sarlink.

Ventilation

It is recommended that local ventilation be provided at the exit of the die. A fume hood located directly above the die will provide the most effective ventilation.

Screw speed

High shear rates are recommended in order to obtain low melt viscosities. Screw speed helps control the shear rate.

- Minimum screw speed: 20 rpm
- Typical screw speed: 25 to 80 rpm, depending on the size of the extruder.

Up to 200 rpm can be used for most screws without generating excessive melt temperature. However, surface quality of the extrudate may deteriorate as screw speed increases. Larger screws tend to operate at lower speed.

Maintenance of the extruder

Cleaning-up of equipment before processing Sarlink

To avoid contamination, the extrusion equipment should be cleaned before processing Sarlink. Polyethylene or polypropylene of low melt index is 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.

Extruder 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 eventual Sarlink fines. Remove the screen pack, breaker plate and die plate. Clean these with brass tools. At this point, the drive motor and heaters can be turned off.

Extrusion Dies

There are several basic types of extrusion dies depending on the shape of the extrudate to be produced. The most common dies, corresponding to the major applications of Sarlink, are: profile, tubing, and sheet. Specific recommendations to design dies for these applications are given, preceded by some general information on the die swell of Sarlink grades. Advice on dies for co-extrusion can be found in the chapter on co-extrusion (see pages 17 and 18).

Die swell

Sarlink thermoplastic elastomers gives less die swell than most conventional thermoset rubbers. Typical die swell values for Sarlink range from 0 to 15 %. Die swell tends to increase with:

- increasing hardness of Sarlink grade
- increasing shear rate
- decreasing extrusion temperature
- decreasing total length of die.

As a result of the low die swell characteristics of Sarlink, profile and tubing dies are designed oversized. Typically, these dies are cut 5 to 10 % larger than the desired profile shape. The profile is then drawn down and its dimensions decreased to the required dimensions by the take off puller. It is highly recommended to make a flat plate die for prototyping and checking of the extrudate dimensions.

General recommendations for die design

- Die must be flow balanced to ensure constant linear exit velocity of all sections of the profile.
- This flow balance can be obtained by varying the land lengths of each die section.
- Parallel land length is recommended.
- Short land length will result in higher die swell caused by elastic recovery.
- Decompression zones in the die should be avoided.
- Diverging channels of more than 30 degrees should be avoided.
- Angles in the die should be minimum 15 degrees to keep shear.
- Sharp angles should be avoided.
- Minimum radius at sharp corners should be: 0.2 mm.
- Air channel should be created through closed die sections to prevent the collapse of the section.

Extrusion dies for profiles

Profile dies are built as either a flat plate or streamlined melt channel design.

Flat plate designs are typically quicker and less expensive to produce than streamlined dies. These dies, however, have dead spots behind the die plate where material can sit and degrade over time. Due to the excellent melt stability of Sarlink, a flat plate design can be used for many applications. This is particularly true for prototyping or short production runs. For longer runs it is recommended that the die plate be removed periodically during production for cleaning.

Streamlined dies are an excellent choice for high volume applications where the die will be run for weeks at a time. These designs eliminate the need to interrupt production for cleaning. A streamlined die should also be used for high throughput extrusions. This will prevent flow disturbances caused by sharp edges on the back side of the die.

Flow balancing

If the profile produced has uniform wall thickness throughout the part, flow balancing may not be needed. On the contrary, profiles which exhibit a varying wall thickness in their section require good flow balancing. Flow balancing is accomplished by reducing the die land for the thinner areas of the die to allow the exit velocity of all sections to be the same. By machining a taper into the back of the plate the die land is reduced thus allowing more material to flow through the thinner sections of the profile. This is illustrated in figures 12 and 13.

Die land length

Profile dies are typically sized based on two factors:

- the wall thickness of the profile and
- the depth required to flow balance thin sections.

For profiles with uniform wall thickness, the die land should be in the range of 2 to 5 times the wall thickness. For profiles requiring flow balancing, a plate thickness of 25 to 50 mm is normally used.

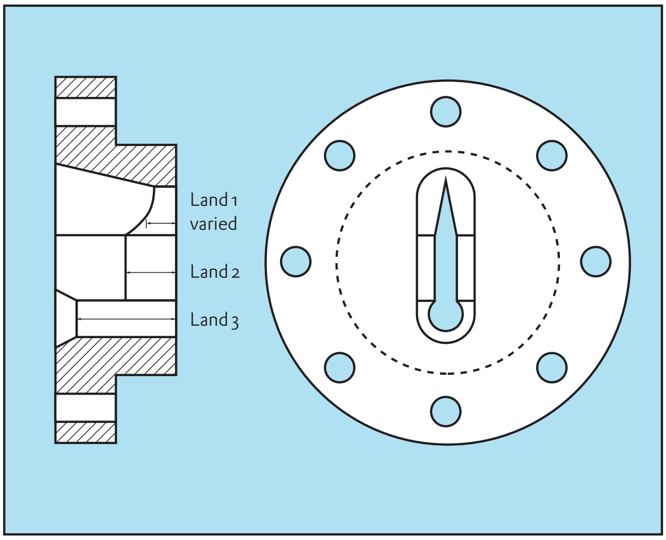

Fig. 12 - Profile extrusion die

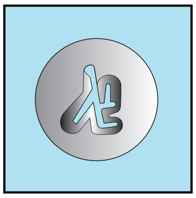

Fig. 13 - Profile extrusion die

Extrusion dies for tubes

Tubing is easily extruded from Sarlink thermoplastic vulcanizates using a polyolefin die assembly. Such an assembly consists of a die pin and an outer bushing, as shown on figure 14.

The inner diameter of the tube is created by the die pin, and is supported by three or four streamlined "spider" legs. An air hole is machined through one of these legs to prevent a vacuum from forming inside the tube, causing it to collapse. The end of the pin is cylindrical, and is used to create a die land when assembled with the bushing.

The outer diameter of the tube is formed by an adjustable bushing, maintained in place by means of four screws which are used to make the tubing concentric with the inner diameter.

Pre-production runs are usually required to achieve the desired tube dimensions and tolerances. The bushing is frequently modified to produce the required wall thickness once the inner diameter is achieved. Die lands of 12 to 25 mm are typically used. For small tubes, of outer diameter below 6 mm, use a die land of 2 times the outer diameter.

Extrusion dies for sheets

A standard polyolefin coat hanger style sheet die is preferred for producing Sarlink TPV sheets, as shown in figure 15. Other styles of melt distribution such as a fishtail, diagonal groove and T types can also be used.

A choker bar with thickness adjustments along the die width can help to prevent excess flow through the center of the die and flow starvation from the die edges. A flexible upper die lip should be used to make final sheet thickness adjustments. This lip should be adjustable in approximately 25 mm increments along the entire width of the die. The lower lip can be fixed or arranged as an insert to allow a greater range of sheet thicknesses to be extruded.

Small dies will typically have one temperature zone. It is important to design the heaters in a manner which provides uniform temperature distribution throughout the die. Thermocouple placement should be in the center of the die close to the melt channel. Large sheet dies can be used to produce sheet up to 1.6 m wide. These dies typically have 3 to 6 temperature zones across the width.

Die temperature controls

Accurate temperature control of the die is essential to produce high quality extrusions. It is important to have uniform temperatures throughout the adapter and the die body.

Dies are typically heated externally with mica or ceramic insulated electric heater bands or cartridges. External bands are the easiest method for heating smaller cylindrical die bodies. Large or more complex dies may require a combination of cartridges and bands with varying watt densities to produce uniform heating.

Proportional (PID) temperature controllers should be used with thermocouples for temperature feedback. Simple dies require a single temperature zone. The zone should utilize a thermocouple embedded in the die body close to the melt channel. Wide sheet dies may have several heater zones across the width of the die.

A separate temperature controller should be used for the adapter.

Die material

Extrusion dies can be produced from hardened stainless steels or carbon tool steels. Carbon steels should be hard chrome plated.

In Appendix 2 the recommended types of pre-hardened steels and fully hardenable steels are listed. Pre-hardened steels are typically used for prototyping and short production runs.

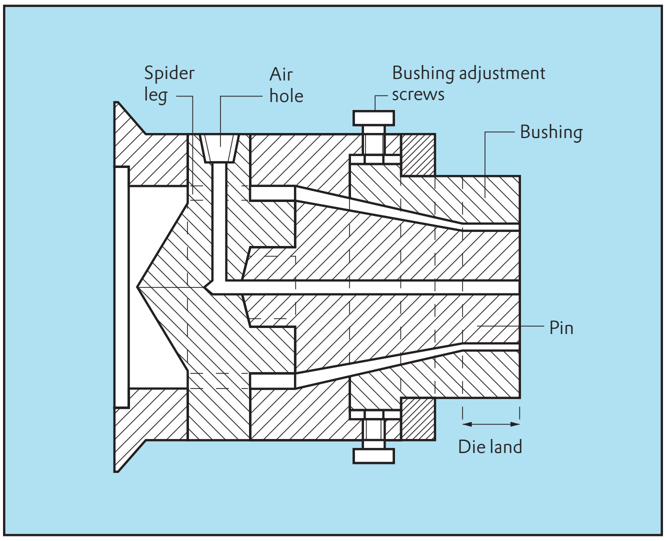

Fig. 14 - Tubing extrusion die

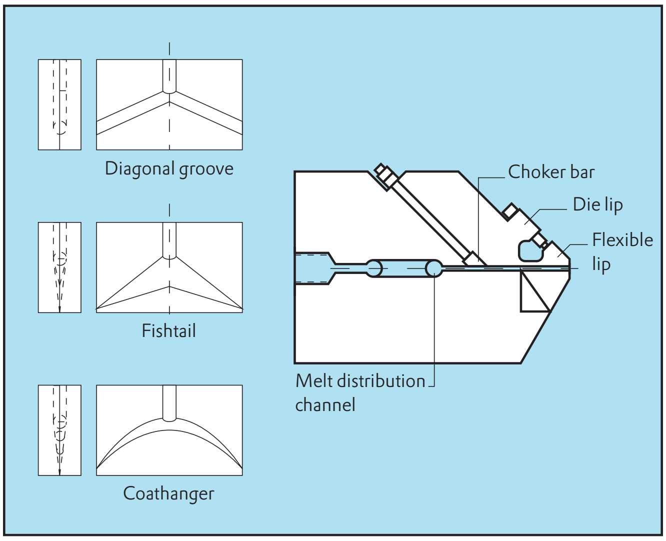

Fig. 15 - Extrusion dies for sheets

Co-Extrusion

Co-extruding Sarlink

Co-extrusion, triple or multiple extrusions are easy to achieve with Sarlink. The material can be coextruded on itself, for instance in hard/soft combinations, or in profiles/ tubings of different colors to create interesting cosmetic effects. Sarlink can also be easily co-extruded on melt compatible plastics such as polypropylene, polyethylene, etc.

Very strong melt bonds can be achieved using PP, PE, and TPOs. Slightly lower bond strengths are obtained with glass reinforced and mineral filled polyolefins. For non-melt compatible polymers, it is possible to use adhesives in order to obtain adequate bonding. Specific recommendations on adhesives types according to the type of polymers and the performance required can be obtained on request.

Co-extrusion is easily achieved by arranging portable extruder(s) alongside of the main extruder. The extruders can be linked together by a manifold block, which feeds each melt stream into the die body. Alternatively, extruders can be linked directly into the die body.

Recommendations for optimum results: polymers should be at the same melt temperature during interface welding lowest viscosity material should be fed first into the die for proper flow balancing.

Designing dies for co-extruded profiles

These dies are designed to bring together two materials in the melt within the die as shown on figure 16. Both materials are joined under pressure within the die body to achieve a permanent and durable melt bond.

The combined layers pass through the final section of die land to provide the final shape required prior to exiting into a water bath. The die land should be a minimum of 9.5 mm long to promote good adhesion.

It is also possible to split the flow of any of the incoming layers to create more complex profiles as shown on figure 17.

Adjustment of the side feeder rpm then determines the exact location of the interface between the hard and soft segments. These dies are flow balanced in the same way a single layer die is, except that the side feed rpm can be used to correct for differences in viscosity of the two materials.

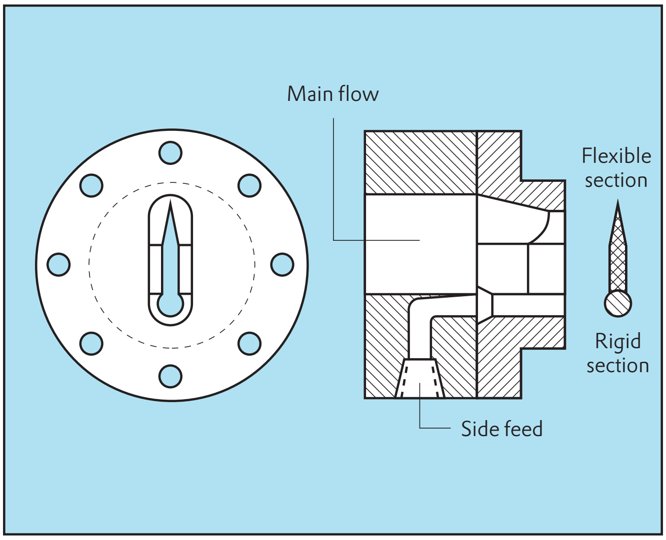

Fig. 16 - Co-extrusion profile die

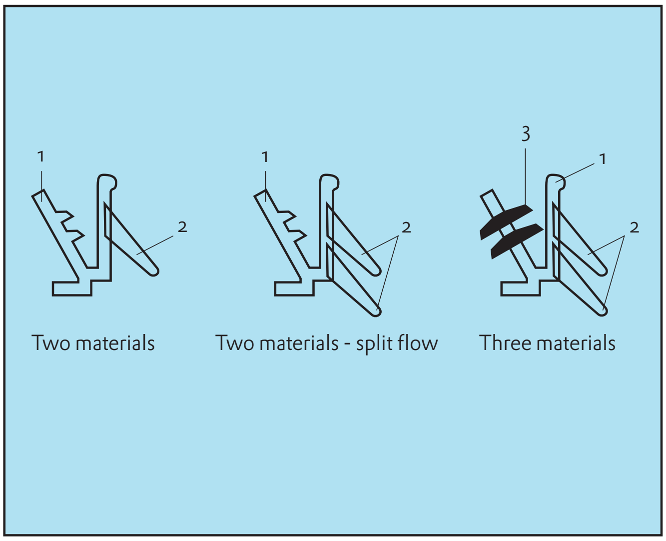

Fig. 17 - Examples of multiple extrusions

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Ancillary Equipment

Take-off equipment

For profiles and tubes: a water bath and a belt puller combination is the most common take-off technique.
For sheets: Sarlink sheet can be extruded with common types of thermoplastic sheet extrusion equipment.

The three rolls are typically operated at a temperature of 40 to 70 °C. It is possible with high durometer grades to create a glossy surface appearance by increasing temperatures to 85 °C. Low hardness grades will produce a dull matte surface appearance regardless of roll temperature.

Sarlink can also be run under a single roll submerged in water. This technique will not achieve the same thickness uniformity of a three roll stack but may be adequate for many applications.

Cooling bath

Water bath length depends on part thickness, extrusion rate and part design, such as the presence of closed sections, internal ribs, etc. Generally, bath length ranges from 2.5 m to 10 m. Very cold water should be sprayed on the profile at the entrance in the bath in order to shorten cooling time and to avoid potential distortion of the hot profile.

Water at the entrance of the bath will quickly warm in contact with the hot profile. Consequently, good circulation of cool water is recommended. In order to cool faster, extrudates should pass under water, guided by pulley wheels. It is also possible to use a conveyor with water spray for flat bottomed profiles.

Tubing can be pulled through a vacuum water bath tank to provide the best concentricity. For small profiles and tubes, a pulley arrangement will allow three passes through a single water bath.

Calibration

Calibration devices are normally not necessary for standard extrusion. However, they may be recommended in special cases, for instance:

- to maintain the shape of complex profiles, pipes or tubes
- to avoid collapse or distortion of the hot extrudate at the exit of the extruder
- to ensure tight dimensional control of the extrudate when required.

There are several types of calibration devices:

for pipes and tubes:

- sizing rings located at the entrance of the bath

for profiles:

- A support to hold just a few critical sections of the extrudate.
- A series of plates with an oversize profile cut in them, as shown in figure 21 can be used for simple shapes our dual durometer TPV shapes.
- Blocks with water and vacuum are used for more complex shapes and co extrusion which involves PP and other rigid polymers

These calibration devices are normally located at the entrance of the water bath, but they can also be placed between the die and the water bath entrance. This is typically done for profiles of difficult shapes which need to be supported just after extrusion.

Draw down

The draw down ratio is the ratio of the profile dimensions just at the exit of the extruder and at a certain distance. It is recommended to choose a low draw down for Sarlink, particularly for the softer grades. Higher hardness grades have higher draw down capability.

Profiles and tubing are typically drawn down 5 to 20 % for all grades. Sheets can be drawn down up to 3:1 ratio to produce thicknesses from 0.1 to 0.5 mm.

A precision belt puller is the preferred method for controlling the draw down of Sarlink profiles. Use of a DC motor with PID controls will ensure tight dimensional controls. A long belt (10 cm wide, 50 cm long) is suggested for small precision profiles. A wider belt can be used for larger profiles.

The use of a closed face sponge rubber belt is recommended to achieve good grip. Large, flat profiles may also be pulled using a long single belt conveyor with water spray from above.

Fig. 21 -Calibrator plate

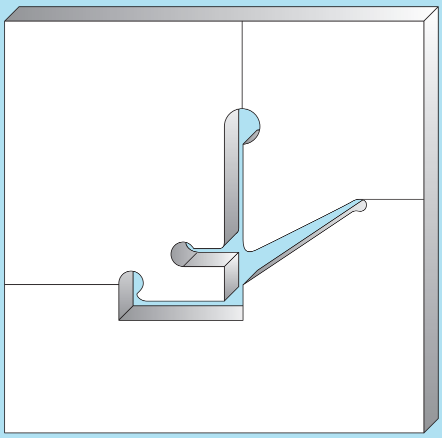
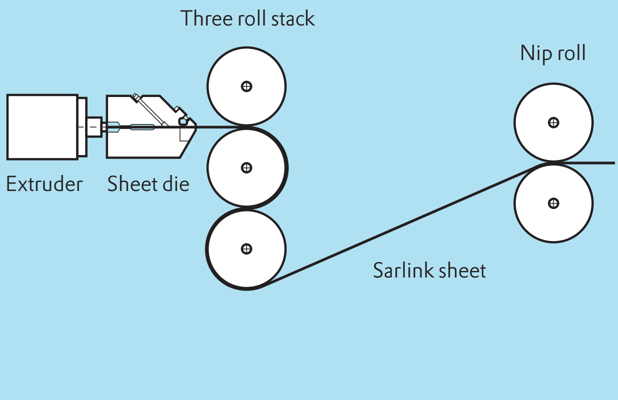


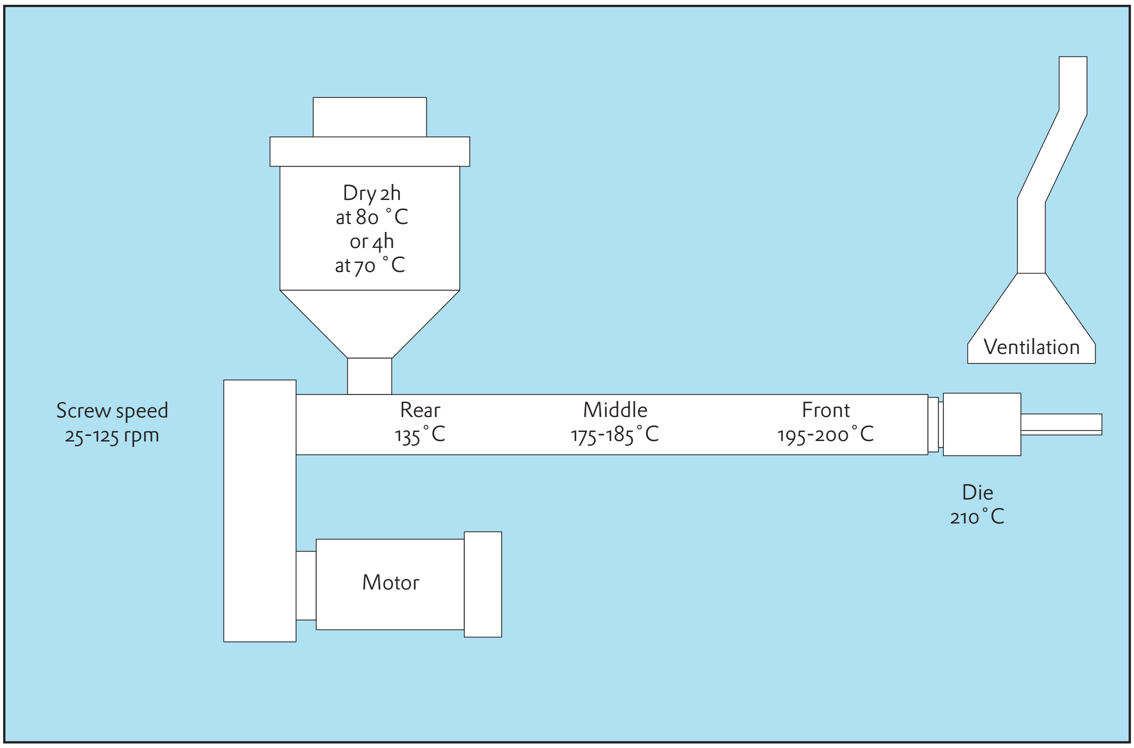
Fig. 20 - Sheet take-off



Appendix 1

Summary of Optimum Processing Conditions
for Extrusion of Sarlink

Drying	3 - 4 h at 80 °C	
Screen pack	20/40/60/40/20	
Feed throat	water cooling	
Feeding zone	135 °C	360 - 400 °F
Compression zone	175 - 185 °C	360 - 400 °F
Metering zone	195 - 200 °C	370 - 410 °F
Head	200 °C	380 - 420 °F
Die	210 °C	380 - 420 °F
Melt	195 - 220 °C	380 - 420 °F
Screw	no heating - no cooling	
Screw speed	25 - 125 rpm	



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Appendix 2

Steel Types for Extrusion Dies

	A prehardened NI-Cr-Mo steel, supplied at 200-330 Brinell, with excellent polishing and photo-etching properties. Suitable for a wide range of injection moulds, blow moulds, extrusion dies	A prehardened stainless holder steel with excellent machinebility, high tensile strength end good corrosion resistance	A through-hardening stainless steel with good corrosion resistance and very good polishability	A versatile through-hardening 5% Cr-mould and die steel with good wear resistance and polishability
Properties[1)]	**I 45NI-Cr6**	**II X36CrMo17**	**III X40Cr13**	**IV X40CrMo51**
Normal hardness [2)]	**(-310)**	**(-340)**	**52**	**52**
Wear resistance	■■■□□□□□□□	■■■■□□□□□□	■■■■■■■□□□	■■■■■■■□□□
Toughness	■■■■■■■■■□	■■■■■■■□□□	■■■■■□□□□□	■■■■■■□□□□
Compressive strength	■■■■□□□□□□	■■■■■□□□□□	■■■■■■■□□□	■■■■■■■□□□
Corrosion resistance	■■□□□□□□□□	■■■■■■■■□□	■■■■■■■■■□	■■■□□□□□□□
Machining [3)]	■■■■■□□□□□	■■■■■■□□□□	■■■■■■■■□□	■■■■■■■■■□
Polishability	■■■■■■■■□□	■■■■□□□□□□	■■■■■■■■■□	■■■■■■■■□□
Weldability	■■■■□□□□□□	■■■■□□□□□□	■■■■□□□□□□	■■■■□□□□□□
Nitriding	■■■■■■□□□□	□□□□□□□□□□	□□□□□□□□□□	■■■■■■■■■■
Photo-etchability	■■■■■■■■■□	■■■■□□□□□□	■■■■■■■■□□ [4)]	■■■■■■■■□□ [4)]
Norms				
DIN	**(1.2710)**	**(1.2316)**	**(1.2083)**	**(1.2344)**
USA AISI	**P20**	**420F**	**420**	**(H13)**
Delivery HB	**~310**	**340**	**215**	**175**
Analysis (3/4)				
C	**0.37**	**0.36**	**0.38**	**0.40**
Cr	**2.0**	**17.0**	**13.6**	**5.2**