# TPV seals for plastic pipes – Innovative fitting solutions

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*New Sarlink thermoplastic vulcanisate materials enable innovative solutions for seals designed to prevent leakage of pipe systems. With these solutions, pipe systems can be produced:*

- *at lower system costs,*
- *with fewer components*
- *with easier installation*
- *in a smaller space, and*
- *with fewer installation mistakes leading to leakage.*

## 1. Introduction

Seals or gaskets are used to prevent leakage of many different pipe systems made of iron, concrete, clay or plastic. This applies not only to leakage of liquids flowing through these pipes but also to leakage of ground water into pipes that are laid underground.

For many years seals have been produced from thermoset rubbers like SBR, polyisoprene, NR, EPDM and NBR. Thermoset pipe seals have a good sealing performance but are in a mature stage of the life cycle with little room for innovation in the pipe market. Sarlink thermoplastic vulcanisates offer possibilities for innovation of pipe seal solutions. It can be processed on traditional injection moulding equipment for thermoplastic materials leading to lower scrap rates, low cycle times and high efficiencies. If the injection moulding process is fully automated, very limited amount of labour is required. More importantly, 2K injection moulding technology offers new production technologies for pipe seals and pipe fittings by creating freedom to design innovative new seal solutions In addition, the possibility of injection moulding a seal onto a fitting gives new ways to attach and to position the seal on a fitting. For larger seals, co-extrusion of hard and soft TPV material allows production of seals which are easier to handle with less scrap and enables the generation of new design solutions for corrugated pipe seals.

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The transition from the more traditional thermoset pipe seals to a new Sarlink solution is not an easy step. New designs are required and they have to be validated. Processing has to be optimised. Sarlink supports customers in this transition process. This already has led to the successful introduction of several innovative seal solutions since 2002.

## 2. Requirements

Materials used for pipe seals have to meet high standards. In Europe the standards for non-pressure waste water TPV pipe seals are described in CEN EN 681-2 **(tab. 1).** The EN 681-2 sets standards for the basic physical properties in combination with requirements to assure long term performance of the final pipe seal. A stress relaxation measurement according to ISO 3384 is the method used to assess the long term seal performance.

To prove the consistency of Sarlink to customers, the material is audited every year by KIWA. KIWA is an independent organisation issuing certifications for water and construction as its core activity. KIWA is measuring the EN 681-2 compliance of a random production lot in order to assure the quality of the TPV pipe seal grade. KIWA is also testing and approving any formulation change. This results in an additional KIWA approval (BRL2020).

## 3. Stress relaxation

The performance of a pipe seal depends on the relaxation of the sealing force in time. Sarlink uses ISO 3384 to study the relaxation behaviour of pipe seals. **Figure 1** shows the stress relaxation of an SBR and a Sarlink pipe seal grade measured at room temperature. The initial stress relaxation of the TPV is a little faster but the curve indicates a cross over point between 5 to 10 years. It shows that stress relaxation is material dependent. This material dependence has an impact on the optimal designs of the pipe seals made from these materials. The curves show that the TPV outperforms thermoset seals in the long term, especially at higher temperatures. It has a superior stress relaxation at higher temperature up to 100 °C due to the absence of sulphur cross-links and unsaturations in the main polymer chain.

## 4. Design and prototyping

To support innovation and development of pipe seal applications with Sarlink, a number of Computer Aided Engineering (CAE) programs are utilised. Finite Element Analyst (FEA), Moldflow, Design of Experiments software (DOE) and Computer Aided Design (CAD) allow designs to be evaluated in-depth without having to make costly prototype moulds for all designs, and reduce the time to market.

FEA for elastomeric material uses mathematical models such as Ogden or Mooney-Rivlin, where data are taken from laboratory testing of the material in different strain states – tension, shear and biaxial. Additionally, due to the temperature sensitivity of polymers it is often required to test strain at a number of different temperatures. Data collected from this testing is fitted against the mathematical models and used to study specific components or designs. The accuracy of the fit between test data and the model can be seen in a graphical format for each strain state and the strain rate. It is important to review the fit carefully as there are often variations between the test data and different mathematical models.

In the initial stages of a design FEA provides an efficient way to evaluate the functional performance of different seal designs. Key performance criteria are pipe insertion force, initial sealing force, and long term sealing force.

Pipe insertion forces are important to consider as they determine how easy the assembly process will be for the installer in the field. Due to complex behaviour of an elastomeric material and the influence of factors such as friction and fixation points in the model, absolute values are difficult to predict with FEA. However, when used as a comparison tool between designs, results are extremely informative. The design of the seal obviously has a direct effect on the insertion force. A good seal design should allow the assembly of the pipe without too much resistance while ensuring the adequate sealing force on the pipe to prevent leakage. In addition, it should compensate for tolerances found in the pipe without excessive changes to the insertion force and sealing pressure. **Figure 2** shows a FEA calculation used to evaluate the insertion forces. In this design there is a cor-

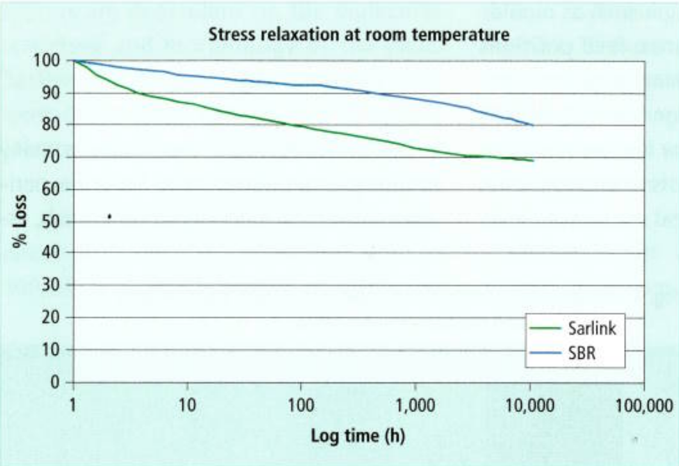
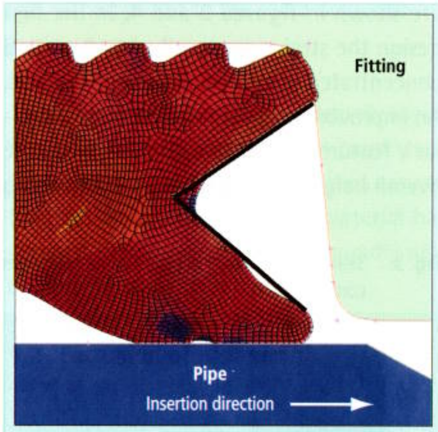



**Fig. 1:** Stress relaxation of a SBR and a Sarlink pipe seal grade at room temperature

**Fig. 2:** FEA study used to calculate pipe insertion force




**Tab. 1:** CEN EN 681-2 (extended with additional KIWA BRL 2020 requirements)

| Properties | Test method | Units | Requirements | Test results |
|---|---|---|---|---|
| Tensile strength perpendicular to flow direction (⊥) | ISO 37 type 2 | Mpa | ≥ 4 | 4.7 |
| Tensile strength in flow direction | ISO 37 type 2 | MPa | > 3.3 | 3.9 |
| Elongation at break prependicular to flow direction (⊥) | ISO 37 type 2 | % | ≥ 300 | 399 |
| Elongation at break in flow direction | ISO 37 type 2 | % | >124 | 215 |
| Hardness nominal | ISO 48 | Micro IRHD | 60 ± 5 | 60 |
| Changes after heat ageing | | | | |
| 14 x 24 h. at 80 °C prependicular to flow direction (⊥) | | | | |
| Tensile strength | ISO 188 | % | ≤ 20 | 2 |
| Elongation at break | ISO 188 | % | ≤ 30 | 3 |
| Hardness | ISO 48 | Micro IRHD | ≤ 7 | – 4 |
| Changes after heat ageing | | | | |
| 14 x 24 h. at 80 °C in flow direction | | | | |
| Tensile strength | ISO 188 | % | ≤ 20 | 3 |
| Elongation at break | ISO 188 | % | ≤ 30 | 4 |
| Compression set after | | | | |
| 72 h at 23 °C 25 % deformation | ISO 815 | % | ≤ 25 | 14 |
| 72 h at 70 °C 25 % deformation | ISO 815 | % | ≤ 40 | 21 |
| 72 h at -10 °C 25 % deformation | ISO 815 | % | ≤ 65 | 35 |
| Change of volume after 168 h exposition in water of 70 °C | ISO 1817 | % | 8/-1 | +3 |
| Stress relaxion at compression (100 days) | ISO 3384 | % | ≤ 32 | 26 |
| Stress relaxion at compression (7 days) | ISO 3384 | % | ≤ 22 | 21 |
| Stress fall | ISO 6914 (method A) | % | ≤ 25 | 22 |
| Resistance to ozone | ISO 1431-1 | – | no cracking | no cracks |

rugation against the fitting and the V shape compression zone has been implemented. Both these features allow reduced insertion forces while compensating for pipe tolerances.

Sealing pressure for a particular design can be calculated using FEA helping to predict the stress relaxation and subsequent lower sealing pressures over time. Designs with high stain levels and high instantaneous stress give increase sealing pressure on assembly. However the decay, or stress relaxation, is significantly higher than in designs with lower strain levels. Two such designs are shown in **figures 3** and **4.** In the first design the strains are locally very high and concentrated over a small area of the seal. An improved design is to incorporate a similar V feature that while still having the same overall height has lower strain levels. Using this type of design leads to improved long-term performance. Utilising FEA, the strains in each design can be evaluated for their short and long term performance. Finally FEA gives you the opportunity to understand the shape of the seal, dynamically while the pipe is being inserted, and in its assembled position showing visually the effect on specific design features.

In combination with FEA studies, Moldflow analysis is used. Moldflow software simulates the injection moulding process based on extensive testing of the polymer melt. It allows information such as moulding conditions, cycle times, feed positions and flow patterns to be simulated for a specific design. In seal design it is critical that functional sealing face or lips are free from defects such as short shots or entrapped air. Weld lines in a round seal are unavoidable, however by using Moldflow analysis. The fill pattern and melt temperature, which is dependant on a number of factors, such as flow length, injection speed (shear), melt and tool temperature, can be chosen to give the best weld line strength and allow for vents, or inserts, to be placed correctly. **Figure 5** shows how Moldflow analysis can be used to predict weld lines and entrapped air. For two-component moulding, venting can be a problem and the ability to predict fill patterns is particularly beneficial as entrapped air at the PP interface can cause weak points in the seal.

## 5. Processing

Due to the history of their business, many seal or pipe producers have limited experience converting thermoplastic materials, es-

**Fig. 3:** Seal design leading to high strains, high insertion force and poor tolerance compensation

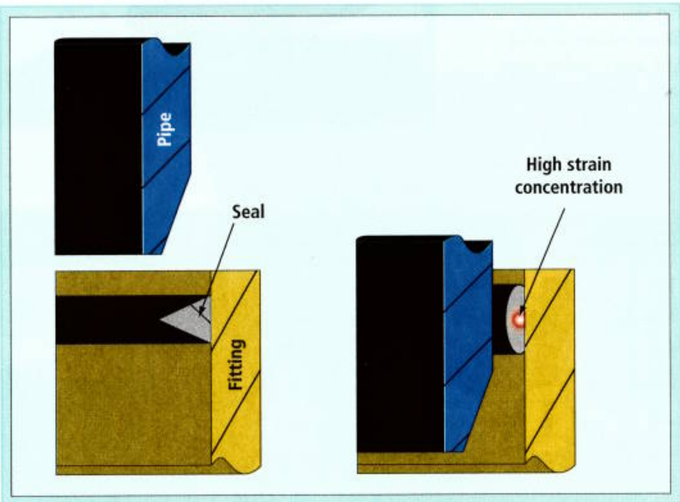



**Fig. 4:** Improved seal design with lower strain, lower insertion force and improved tolerance compensation

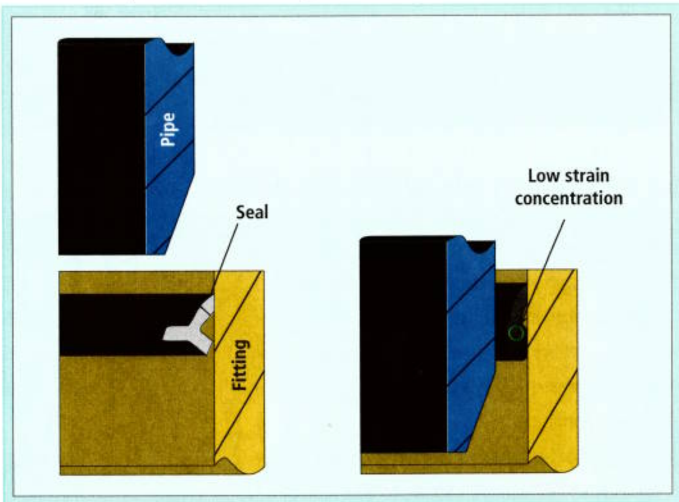



**Fig. 5:** Moldflow used to predict weld lines and gas traps

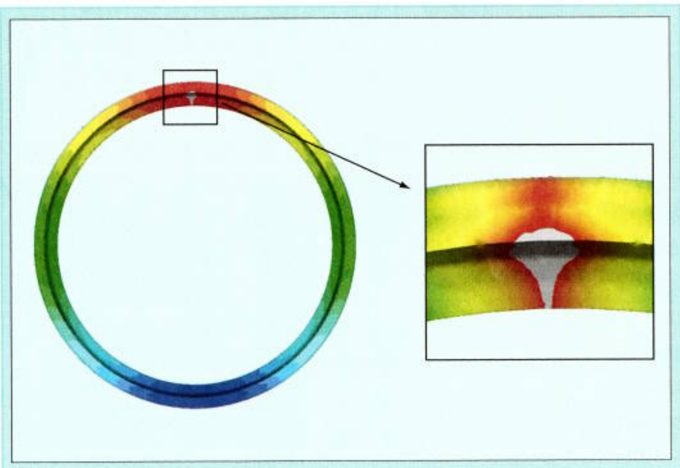
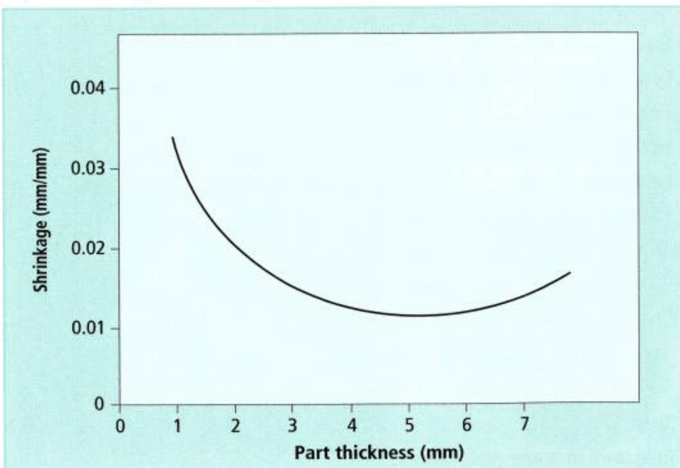


**Fig. 6:** Shrinkage is affected by part thickness



pecially when it comes to TPE and TPV. The melt behaviour and processing of TPV are quite different from thermoset rubber. Sarlink's support to its customers to switch to TPV has proven to be crucial.

DOE software allows the complex interactions of the moulding operation to be compared, understood and utilised. It can be used to collect data from a prototype tool or to fine tune quality and cycle times on a production tool.

With all polymers, the processing conditions are dependant on the molecular structure and morphology of the melt. Sarlink TPV consists of very small highly cross-linked EPDM particles in a PP matrix. This morphological structure results in the melt viscosity being particular dependant on shear thinning. At shear rates experienced with injection moulding, 1000 to 100,000 $sec^{-1}$, the viscosity is relatively low and suitable for filling thin sections and relatively long flow paths. At low shear rates, such as those found in extrusion, the viscosity increases significantly giving high melt strength.

### 5.1 Injection moulding of pipe seals

Part design, gate size and feed system play important roles in the processing. Thick sections and sudden changes in part geometry should be avoided. Gates are generally slightly smaller than those for PP parts, Valve gate technology can be used and results in improved gate vestige and prevents cold flow of material. Hot runner flow bores are also typically smaller, to encourage shear thinning, than normal and should have no major changes in section to prevent shot to shot inconsistency.

Shrinkage can vary considerably with process conditions, and part geometry. For 2K moulding, the shrinkage is mostly governed by the rigid material, however, for seals made from only TPV; particular attention needs to be paid to the wall thickness of the part and injection speed. **Figure 6** shows the shrinkage behaviour for a typical seal hardness of 55 Shore A. The curve is U-shaped with more shrinkage being experienced on thinner and thicker parts. Injection speed greatly affects shrinkage, as shown in **figure 7.** It shows that by using DOE software, that for parts with a wall thickness of about 1mm shrinkage can vary greatly with injection speed alone. Increasing the melt temperature reduces the amount of shrinkage, although not to the same degree as injection speed.

Holding pressure is usually relatively short. Excessive holding pressures can cause cold flow of material causing deformities around the gate, in addition once the material has stopped flowing viscosity rises rapidly and holding pressure is ineffective.

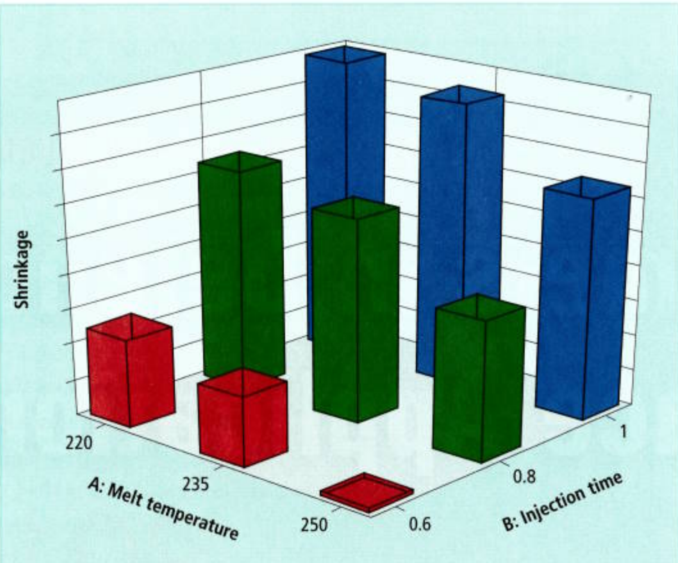



**Fig. 7:**
Injection speed has a significant effect on shrinkage

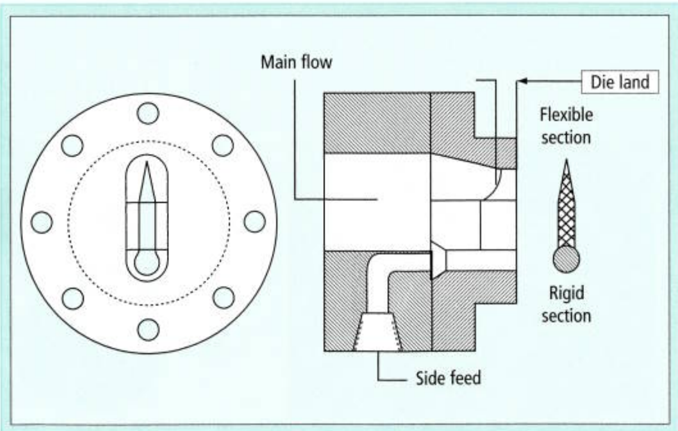



**Fig. 8:**
Co-extrusion profile die

### 5.2 Extrusion of pipe seals

Sarlink TPV can be easily processed on standard polyolefin equipment without further modification. The rheology of TPV is similar to the rheology of highly filled polymer systems. Both materials exhibit highly pseudo-plastic behaviour, 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 (100-1,000 $s^{-1}$). It is more sensitive to changes in shear rate than to temperature changes. Typical melt temperature between 195 and 220 °C is optimum for TPV. When the melt temperature is too low, this will result in an increased die swell and rough surface because of lack of homogeneity of the melt. When the melt temperature is too high, this is detrimental to the hot dimensional stability and to the drawdown of the extrudate.

Co-extrusion, triple or multiple extrusions are easy to achieve with Sarlink. The material can be coextruded onto itself, for instance in hard/soft combinations, or in profiles/tubings of different colours. (This can be useful for corrugated pipe applications where a seal may have to be assembled in a certain direction and colours can be used to ensure proper assembly.) The extruded material can be then cut to length and joined by techniques such as hot plate welding.

Co-extrusion dies are designed to bring together two materials in the melt within the die as shown on **figure 8.** Both materials are joined under pressure within the die body to achieve a permanent melt bond. The combined layers pass through the end section of the die land to provide the final shape required prior to exiting into a water bath. This technique is also used for the application of slip coats as described below.

### 5.3 No lubricant needed

For the assembly of most pipe systems, lubricants are used. Without lubrication, the assembly forces are significantly higher, risking improper installation or damage to the seal, resulting in leakage. In addition the application of the lubricant is labour intensive. By co-extrusion of Sarlink with a slip coat, similarly to how low friction coatings are added in automotive window sealing systems, it is possible to produce seals with a low friction coefficient that remove the need for lubrication. The slip coat is added in a very thin layer as the seal profiles are extruded and results in no added production time.

## 6. Future

Building on the recent successes in developing TPV solutions for the pipe seal industry, Sarlink engineers continuously work on new Sarlink grades, designs and applications in combination with modern simulation technologies, to bring innovation and new developments to sealing applications. Because of the advantages of Sarlink TPV over other traditional materials, further replacement and expansion is foreseen.