BOY
Spritzgiessautomaten

Liquid - Silicone - Rubber

1+1=1 -
Liquid-Silicone-Rubber

In spite of always improving high-tech thermoplastics or thermoplastic elastomers it has not been possible to substitute curing rubbers in every application. Especially the resulting possible shorter cycle times, made that change economically interesting. Liquid-silicone-rubbers (LSR) are offering a very interesting alternative, concerning their mechanical and processing properties. As a result, there are already up to 2000 different LSR-parts in every new automobile.

LSR units the rubber-elastic properties of well-known elastomers with „thermoplastic“ cycle times. In addition to the substitution of elastomers some other areas of application, which have not been possible yet, are offered now (for example hard-soft combinations of elastomers and thermoplastics).

The following is meant to guide the processor and simplify the debut with these fascinating materials.

raw material

The form of delivery is already special. Depending on the material consumption the processor can select either 20l Hobbocks or 200l containers. A ready-to-process material delivery exists of two containers that include on the one side component A or on the other side component B. Both components already contain all necessary processing additives, inhibitors, curing agents etc.. Hence, the compoundation that has to be done when processing traditional elastomers is not necessary anymore. Possible additives are either included with the both components or can be added from an additional small container in a special mixer (s. auxiliary). From this the processor does not need any other additional compoundation equipment (kneader, rolling mills).

At room temperature the material is process able for 6 month (before mixing) or 3 days (after mixing). Therefore at longer production interruptions those parts of the unit that are in contact with the mixed material have to be „washed“ with one of the main components (A or B). Several raw material suppliers are listed in table 1.

- Bayer
- GE-Plastic
- Wacker
- Dow-Corning

Table 1: LSR-material supplier

material properties

Since LSR is a curing elastomere, the main differences between elastomer and thermoplastic parts are obvious (table 2).

Thermoplastic	LSR
Solidification by heat emission	solidification by heating
source able	limited source able
meltable	not meltable
visco-elastic	rubber-elastic

Table 2: physical differences between thermoplastic & LSR

Moreover there exists a clear distinction to standard elastomers. As an example table 3 shows a comparison between LSR and 1-component hard silicone.

property	HTV	LSR
cycle time		4-5 faster
transparency	not possible	possible
colourability	few colours	as needed
price	100%	200%
accuracy of dimensions	worse	better
possible degree of atomisation	worse	better
curing process	usually peroxide	addition
split products	peroxides, processing additives	very low

Table 3: differences between HTV & LSR

The certain curing reaction is responsible for some of the striking properties. Therefore the chemical methods shall be explained shortly. The most common curing reaction for traditional elastomers, the peroxide vulcanisation, results in more or less toxic split products. In contrast an addition cross linking does not deliberate any split products. Therefore the use of LSR-parts that are in contact with food or living beings can be realized. Additionally the addition curing reaction is much faster.

Figure 1 roughly illustrates the differences. This graph, especially the extreme short time that is available for the filling of the cavity, is very important for the processing of LSR.

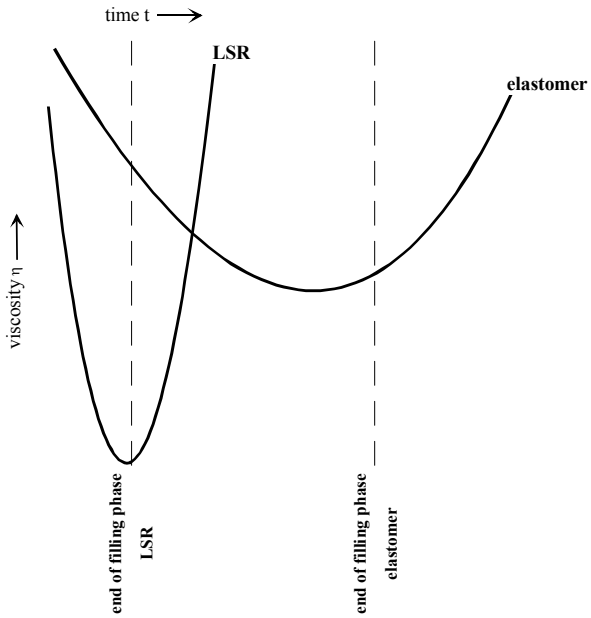


Figure 1: viscosity over time for LSR and standard elastomers

- physiological unobjectionable
- smell and taste neutral
- free of softening additives
- good rubber mechanical properties
- high heat resistance; up to 180 °C
- food approval possible
- ozon- & UV-stabil
- negligible development of toxical gazes when burning
- high dynamical loading (low heating rate)
- good low-temperature-resistance and low-temperature-flexibility

Table 4: striking properties of LSR-products

Tables 4 and 5 sum up the mechanical and general properties that make the material so interesting for the designer.

LSR-properties	**value range**
compression set [%]	10-50
elongation at break [%]	300-800
tensile strength [kN]	8-10
hardness [Shore A]	10-80
density [g/cm^3]	1.08-1.2
volume shrinkage [%]	2.7-3.5

Table 5: mechanical and physical properties of LSR-materials

auxiliary

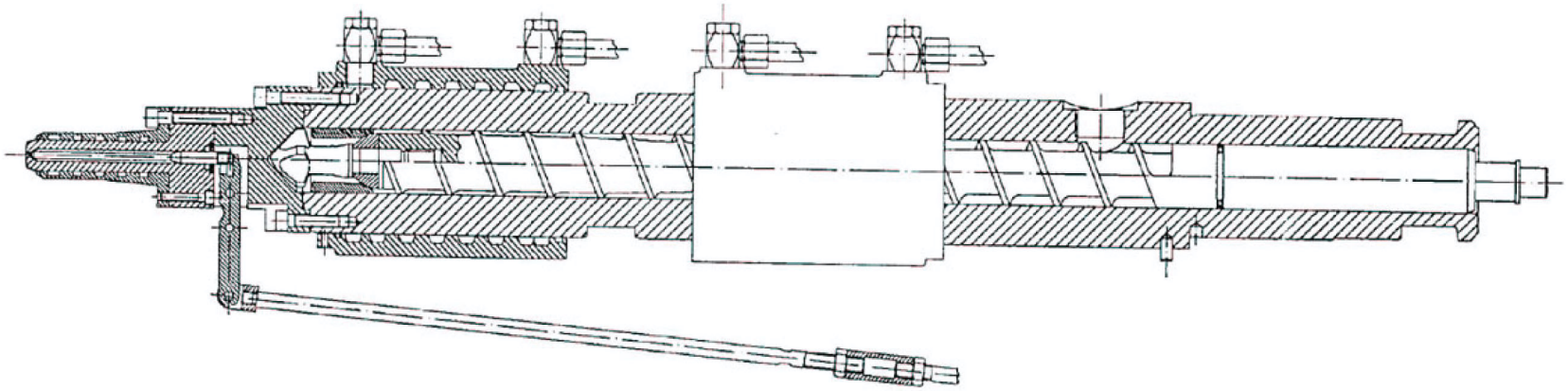
Similar to the processing of thermoplasts, the processing of LSR on BOY-injection moulding machines needs some additional equipment. Depending on the complexity of parts and the focused degree of atomisation the overall cost for the whole unit can exceed the price of the injection moulding machine many times.
The following chapter lists the main perpherical equipment, their function and some of the OEMs (table 6).

device	function	OEM
mixing unit	• dosing the two components A&B (ratio 1:1) • adding colour batches and other additives	• Reinhardt-Technik • 2KM • Hilger & Kern
mixing head (part of the mixing unit)	• brings together the flowing melts: A-component, B-component, additives	
static mixer (part of the mixing unit)	• mixing the different material components	
vacuum pump	• evacuating the cavities ⇒ avoiding air enclosures and burnings due to excessive injection speeds	• Becker • Jet-Form • Fezer
brushing device	• „ejecting“ the parts	• Dahle Geiger

Table 6: Equipment

Due to the fact that the mixing unit makes up an important part of the production unit, we will concentrate on that item. First of all the size of the mixing unit depends on the necessary material output and, hence, on the used material containers (20 or 200 litres). Moreover one mixing unit can provide either one or several machines with LSR. Especially if only one certain type of LSR is processed, bigger mixing units are favourable even for smaller machines. The then used 200 litre containers are distinguished by reduced material losses due to the ventilation of the system and the remaining rest material in the containers (2.5% compared to 10% of 20 litre Hobbocks). In order to further minimize the material residues, some of the OEM offer special options. Another helpful optional equipment is the level-control. This device detects differences in the dosage of the A and the B component. An optimised mixture quality (1:1) is guarantied.

Plasticizing unit for LSR



	BOY 90	BOY 22			BOY 35				BOY 55		BOY 90	
	129-15	220-52			350-52			350-92	550-79	550-205	900-205	900-370
Screw diameter mm	14	18	22	32	18	22	32	32	32	42	42	48
Max. stroke volume (theoretical) ccm³	6,1	20	30	64	20	30	64	76,5	76,5	166,3	166,3	280,5
Max. spez. injection pressure bar	2413	2587	1732	818	2587	1732	818	1207	1030	1235	1235	1320

machine specification

Basically the fully hydraulic clamping unit of the BOY-injection moulding machines is perfectly suited for the processing of LSR. One main item is that the resulting clamping force is independent from possible heat extensions of the machine and/or the hydraulic oil. From this it works constantly and reproduce able. The platens stay parallel and flash formations are avoided effectively

Nevertheless the processing of LSR needs some modifications of the standard equipment. Due to the fact that these options are always necessary, they are comprised in so called LSR assembly groups. A typical LSR assembly group for BOY-injection moulding machines exists of (table 7):

- shut-off nozzle (with hydraulic & mechanic devices)
- LSR-plasticising unit with cylinder and screw
- dosage signal for mixing unit
- plug for mould heating

Table 7: typical BOY LSR-assembly unit

Additionally some helpful optional equipment is (table 8):

- interface for brushing device
- interface for vacuum pump control
- double air-ejector

Table 8: useful optional equipment

The exact filling of the cavity is an important requirement for the successful production of LSR-parts. Therefore the closed-loop controlled machines with Procan MD / Procan CT provide decisive advantages. Moreover the processor should select the plasticising in a way that the actual shot volume makes up more than 50% of the maximum stroke volume. With a machine equipped with the options mentioned above, the mould can be heated, the plasticising unit can be water-cooled, thus, LSR can be processed.

mould

The basic design of a LSR-mould is different to the one for thermoplast processing. This takes into account the different melt and part properties (see figure 1).

The LSR-“melt“ has a very low viscosity during the injection phase and, therefore, tends to flash even into gaps of as narrow as 0.01 mm. Thus the designer has to concentrate on several mould components, in order to be able to manufacture refinishing-free products (table 9).

- extremely stiff mould design
- stress release after every mould production step
- ejecting by force instead of mould slides or core pulls
- special ejector mechanisms (table 11)

Table 9:how to avoid flashes

Additionally the conception of the runner system can exclude some potential errors. Some important aspects are listed in table 10.

feature	**reason**
• rheologically balanced	• even mould filling
• small, precise runners	• reduced melt viscosity • reduced production scrap
• high flow length possible	• reduced melt viscosity
• cold runner systems recommended	• improved process control • reduced production scrap

Table 10: the LSR-runner system

Moreover we want to recommend the use of cold runner systems that can be either part of the machine or of the certain mould. These systems reduce the production waste to a minimum, hence are very economical when processing this relatively expensive materials. But one has to be aware that very tight tolerances and an exact temperature separation is absolute important. To charge an experienced mould designer is highly recommended. In addition to the mentioned small gaps, one can count on shrinkages of 2.7% of untempered and 3.5% of tempered parts (see refinishing).

The standard ejector pins known from thermoplast processing usually are not used with LSR-moulds. This is due to two reasons: On the one hand the combination of soft materials and ejector pins with small diameters can result in a perforation of the parts. Additionally the inevitable and necessary gap between the pin and its slaving guide favours flashes.

The ejector's function and the part's quality is endangered. Common ejector systems are shown in table 11.

- mushroom ejector
- air ejector
- stripper plate
- brushing device

Table 11: ejector systems

Moreover some passive measures (for example different structures of the two cavity surfaces) can influence the parts adhesion, hence, simplify the ejection phase (table 12).

- sand-blasted, eroded or etched surfaces ⇒ reduced adhesion
- polished surface ⇒ improved adhesion

Table 12: passive ejection helpers

Additionally we want to emphasize the extremely important temperature separation between, on the hand, mould and machine and, on the other hand, mould and cold runner system. An even temperature profile in the cavity guaranties that the cross-linking process accelerates right after the complete filling of the cavity (and not before!) and the achieved degree of curing in the parts is as even as possible. Due to the separation of the different energies with isolation plates also the needed energy requirement is optimised/minimized for heating the mould.

processing on BOY-injection moulding machines

The processing of LSR is very similar to the processing of standard elastomers. Using the basic set values in table 13, the appendix and the always important sensitivity, the machine setter can find out the optimal operational point quickly. Nevertheless some items should be regarded in a special way.

set-up parameter	value ranges
dosage pressure p_{dos} [bar] (mixing unit)	20-50
back pressure p_{back} [bar]	10
injection speed v_{inj}	very high
injection speed p_{inj} [bar]	120-200
mould temperature T_{mould}[°C]	(140)170-230
material temperature T_{mat}[°C]	20
cold runner temperature T_{CR}[°C]	40
injection volumeV_{inj}	0.92*V_{cavity}
heating time t_{heat} [s/mm]	≈ 4

Table 13: several set-up parameters for LSR-processing

The mixing unit brings together the components A and B in a 1:1 ratio. Additives like colourants have a maximum dosage of 5%. The compounded material is transferred to the plasticising unit with a certain pressure. That pressure should avoid possible differences in the filling volume. The screw fulfils it's usual jobs: to convey and homongeneize. The residence time is not really relevant.

To avoid an early vulcanisation and resulting trouble shots the injection speeds have to be set to high values. But they are limited by possible venting problems that can lead to burns. The cavity should be filled to about 92%. The holding pressure phase is rather used as a last injection step where the cavity is filled absolute exact (pressure controlled!!). The „missed" volume (8%) is just filled by thermal extensions of the LSR during heating time.

Due to the fact that the exact operational point depends on the specific mould, this hints should be sufficient. Additionally the appendix-table „trouble-shooting" can be regarded as a helpful tool for the beginner in the field of LSR-processing.

refinishing

Since one aims on a flash-free and, accordingly refinishing-free production, the final working steps are mostly reduced to a temper process (about 2 h at 200°C). On the one hand this thermal treatment improves the compression set (CS). On the other hand residues of low molecular weights are diffusing. If parts are used in food applications this is peremptory required; on the contrary when used as isolators this diffusion is an important an interesting argument for the use of LSR. The diffusing components build up a water-repellent jacket. Some material provider offer special types for this kind of application.

Applications

The possible fields of application are nearly incalculable; moreover the overview is complicated by newly developed grades with, for example, extremely high vulcanisation speeds. Table 14 tries to conclude some of the most important fields and products.

businesses	product groups
medical technique	• sealings, syringes, pipettes, respiration bellows
automotive industry	• sparking plugs, ignition cables, sealings, cable bushings,
electrical industry	• anode caps, plug-type connectors, isolators
computer and enter-tainment industry	• switching mats, UHV-shieldings, plug-type connectors
food industry	• baby nippels, comforters
sport industry	• scuba diving equipment, snorcles, sealings

Table 14: important LSR-businesses and product groups

market & out views

The material LSR is relatively new. All the same already 15000 tonnes are processed yearly (diagram 1 and 2).

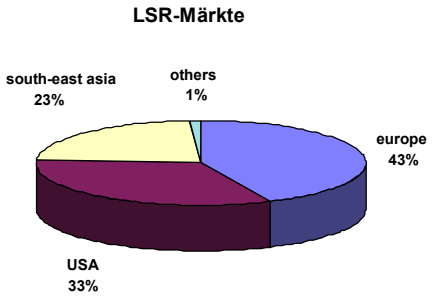


Diagram 2:share of LSR-consumption of different regions

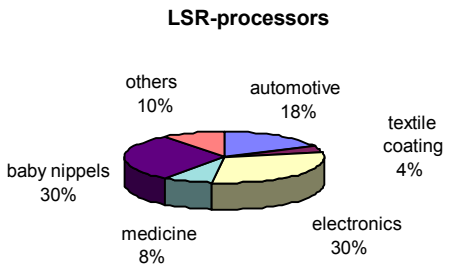


Diagram 1: share of LSR-consumption of different industries (world wide)

Improved machinery techniques and the expanded material types (especially „faster“ grades) will foster the substitution of classic elastomers by LSR. Also the possibility to process LSR and thermoplasts in an one-step-method, is a future-orientated field of application that can be realized due to the faster grades only.
In the future reduced cycle times and growing markets will form the promising development of LSR.

We hope that we have brought this fascinating material -LSR- to your attention and created your interest. If there are any further questions, our process engineering staff are always at your disposal for a discussion or evaluation.