High tear resistance and low compression set

A new prepolymer for cast elastomers with unusual properties

A new MDI-terminated prepolymer based on a polyester has been developed. It cures with 1,4-butanediol to give polyurethane hot-cast elastomers. These are characterized by high tear resistance and low compression set at the same time. Under catalysis, the prepolymer can be economically processed in short to medium pot life. This enables the production of elastomer solutions with hardnesses of 83–87 Shore A, covering a wide range of requirements. The post-curing of the resulting components can be delayed without any loss of mechanical properties.

The prepolymer Vibrathane 7085 is a development of the Urethane Systems business unit of Lanxess. This was established in 2017 following the acquisition of the US company Chemtura, a leading supplier of flame retardant and lubricant additives. Lanxess Urethane Systems sees itself as a systems provider and offers not only prepolymers but also catalysts and curing agents for cast elastomers. The business unit is also a leading supplier of special aqueous polyurethane dispersions (PUD), as well as prepolymers and additives for coatings, adhesives and sealants with special focus on solvent-free and monomer-free systems. It has production facilities and application development centers in all major economic regions, including Brazil, the USA, India, China, Australia, Italy, and England. The focus of its innovation work, which is carried out in the global research, development and innovation center in Naugatuck, CT, USA, includes, for example, new technologies for the production of prepolymers with low free isocyanate contents (low free prepolymers, Adiprene LF grades) and the refinement of blocked systems to improve the ease-of-use of polyurethane systems.

Focus on mechanical performance and economy

The development of the new prepolymer was prompted by inquiries from customers in the mechanical engineering and vehicle construction industries, among others. The requirement was an MDI-terminated polyester material, which can be processed under catalysis in short process times and at high throughputs into components with significantly higher tear strength and lower compression set than, for example, the two standard prepolymers Vibrathane 8585 or 8587 established in series production. In order to meet all these needs, Lanxess Urethane Systems applied both the synthesis and design of the prepolymer and the processing conditions, such as stoichiometry, post-curing temperature and processing time. A further focus was set on the selection of a suitable catalyst and of a prepolymer polyol adapted to the catalyst.

Several hurdles had to be overcome in the development of the new casting prepolymer. Usually a low compression set and a high tear strength are hard to achieve at the same time, because both properties are typically inversely related. High contents of catalyst improve the compression set, but other mechanical properties of the cured elastomer such as modulus of elasticity, rebound resilience or hardness normally deteriorate. Furthermore, the use of a catalyst leads to faster processing, meaning less time remains for tool filling.

High purity and linearity of the prepolymer

The new prepolymer is matched to a catalytic processing. It is manufactured under precisely defined conditions, in such a way that hardly any side reactions occur and a product with higher linearity and purity is produced. This means, among other things, that the prepolymer reacts faster with the chain extender during curing and the cast elastomer shows better mechanical properties.

The processing was optimized with the aid of statistical design of experiments (DoE). This is a method for planning and investigating experiments that aims to describe the influence of important factors on a process with a minimum of effort and tests. In case of the prepolymer processing, stoichiometry (91–105 %), post-curing temperature (85–130 °C) and post-curing time (4–24 h) were selected as factors because they have the greatest influence on tear resistance and compression set. In addition, the effect of the catalyst and delayed post-curing on the properties of the elastomer was analyzed.

High flexural fatigue resistance

Vibrathane 7085 is designed as a general purpose prepolymer. Depending on the processing conditions, it produces casting resins with compression sets from 13 % to 42 % according to ASTM D395 method B (70 °C, 22 h). Tear strength according to

▼ ***Tab. 1:*** *Three elastomer variants based on Vibrathane 7085 in comparison*

Product solutions / Properties	Vibrathane 7085 – Alternative 1 (great compression set, best dynamics)	Vibrathane 7085 (base)	Vibrathane 7085 – Alternative 2 (best tear)
Stoichiometry	95 %	102 %	102 %
Processing conditions	115 °C mold, 115 °C post cure/16 h	100 °C mold, 100 °C post cure/4 h	115 °C mold, 115 °C post cure/16 h
Compression set	15 %	26 %	42 %
Trouser tear	227 pli (39.8 kN/m)	441 pli (77.3 kN/m)	490 pli (85.9kN/m)
Dynamics, tan δ/T_c	0.029/130 °C	0.061/100 °C	0.063/100 °C

ASTM D1938 (tear strength, Trouser), for example, is between 27.2 kN/m and 85.9 kN/m. Compared with standard polyurethane elastomers of similar hardness, the compression set is about 1.7 times lower and the tear resistance up to three times higher. This is precisely the special advantage of the prepolymer. Added to this is the low fatigue tendency of the resulting elastomers under cyclic loading. Thus, the flexural fatigue strength is at a high level. For example, tests according to ASTM D3629-99 (flex fatigue resistance) showed Texus flex values of more than 170,000 cycles at a stoichiometry of 102 % at deformations of 11 %, 18 %, 35 % and 45 %. Furthermore, the elongation at break values of 571 % to 691 % are significantly higher than for comparable standard products.

Higher throughput of parts, lower energy consumption

By using the catalyst, the reaction of the prepolymer with the chain-extender speeds up. Therefore, the parts can be demoulded faster and the tools can be refilled earlier, resulting in a higher throughput. In addition, the DoE optimized processing conditions allow to shorten the post cure duration which results in a higher productivity and reduces energy consumption. This improves sustainability of the production and opens up for cost savings. Pot life can be kept very short at 90 s, but can also be extended to around 4.5 min, for example to achieve uniform tool filling for more complex component geometries.

The curing behavior tests also showed that the processor can delay the time between curing and post curing without degradation in tear resistance, compression set and other mechanical properties of the final elastomer product. This allows to collect demoulded parts first and then to cure them together, increasing flexibility and manufacturing efficiency.

Compression set and tear resistance can be individually optimized

One advantage of the new prepolymer is that by varying the stoichiometry and the processing conditions, both the compression set and the tear strength can be individually optimized and thus adapted to specific requirements of an application **(tab. 1).** The other mechanical properties remain largely unaffected. For example, the tear resistance can be increased to 85.9 kN/m (alternative 2), whereby this material variant still has a compression set of 42 %. In contrast to this is an elastomer with a compression set of only 15 % and excellent dynamic properties (alternative 1). Its storage modulus G' is stable over a wide temperature range of 70 – 150 °C. The loss factor tan δ, which represents the ratio of loss modulus to storage modulus and describes the energy conversion into heat during an oscillation, is low at 0.029 at 120 °C to 130 °C. This means less heat generation in the elastomer. The material is therefore particularly suitable for dynamically highly stressed components such as wheels of forklift trucks.

Wide range of applications

The application potential of the new prepolymer ranges from applications in industry and mechanical engineering to vehicle construction, mining and opencast mining to wheels, tires and rollers **(fig. 1, 2).** Elastomers that are particularly tear and cut resistant and exhibit a high resistance to bending cycles could be used, for example, in the production of die-cutting blankets and anvils. On the other hand, there are material variants with low compression set and high tear strength for bushings in torque rods of trucks, buses and trailers. The elastomer materials optimized in their dynamic properties could prove themselves in the production of robust, noise-damping shaking screens for ore processing thanks to their high abrasion resistance.

Outlook

Lanxess Urethane Systems is currently working with customers to make first applications of the new prepolymer ready to series production. The partners are extensively supported in all steps of component development – from the initial concept idea to material selection, design and tool design right through to the start of series production. For example, Lanxess contributes its expertise in customer-specific material formulation, in the processing of hot-casting elastomers and in component design (structural analysis) **(fig. 3).** In addition, the experience gained with Vibrathane 7085 will be used to develop further products, such as a polyurethane prepolymer based on a hybrid polyester system.

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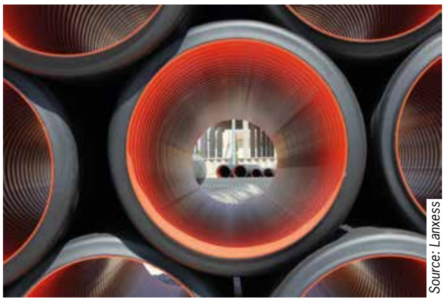
▼ ***Fig. 1:*** *Application example: PU coated pipelines*



▼ ***Fig. 2:*** *Application example: Mining screen*

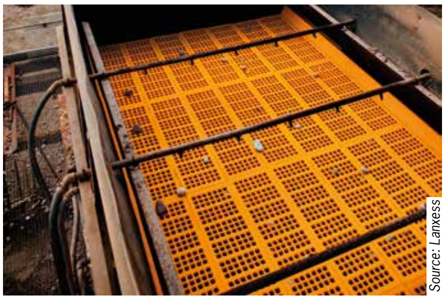


Fig. 3: *Urethane Systems' services include FEA, CAD calculations, thermal and material fatigue analyses.* ▼