**Technical article**
2013/05/22

**Series production capability for high-performance fiber composite components with polyurethane matrix**

# Collaboration revolutionizes automotive manufacturing

**Henkel has developed a new polyurethane matrix resin for the resin transfer molding process (RTM) that will speed up the production of composite components in the automotive industry. Henkel's know-how in the field of polyurethane-based composite matrix resins and the expertise of KraussMaffei, one of the world's leading makers of manufacturing and processing machinery for plastics, have proven to be a perfect match. The outcome: Curing times of just one minute are now possible – a significant advance for fast and efficient volume production of fiber composite components.**

Driven by fuel efficiency targets and the resulting need for lightweight solutions, composite components have become an increasingly important factor in the multi-material designs of modern cars. Offering high strength combined with low weight, glass or carbon fiber-reinforced composite materials are especially suited for the manufacture of motor vehicle components. Particularly for mass-produced automobiles, resin injection processes such as RTM now predominate. [1]

Henkel has pooled its expertise in developing composite matrix resins and in fundamental research on adhesives and surface modification to engineer a complete and coherent system for the manufacture and integration of composite components in the automobile.

Compared with the epoxy resins normally used for RTM, Loctite MAX 2 offers a very attractive combination of good mechanical properties and high damage tolerance. Table 1 shows selected characteristics of the pure resin.

| Pure resin properties | Polyurethane matrix resin |
|---|---|
| Tensile modulus [MPa] | 2800 |
| Tensile strength [MPa] | 80 |
| Elongation [%] | 5-10 |
| Glass transition temperature [°C] | 115* |
| Critical stress intensity factor $K_{1c}$ [MPa*$m^{0.5}$] | 1.2 |

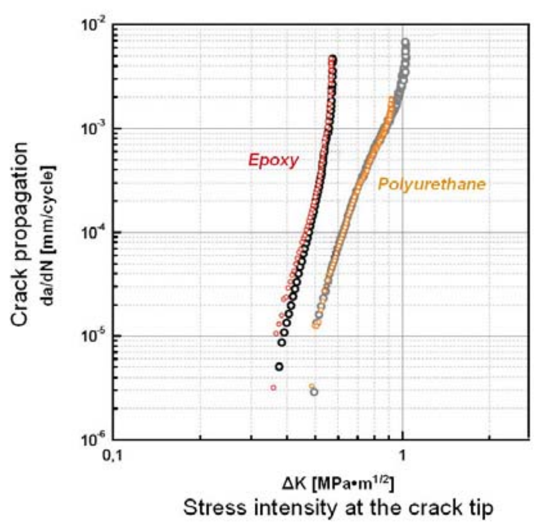
* after tempering

Table 1: Properties of the cured pure resin.

## High toughness for longer life

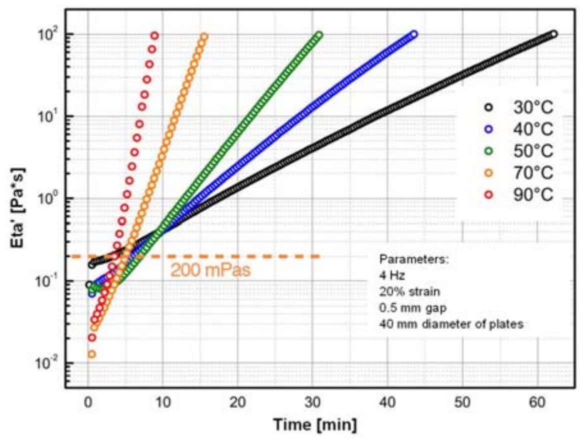
One special feature of the polyurethane matrix resin is its exceptionally high stress intensity factor, which is a measure of toughness. The specific interactions between the polyurethane molecules that take place in addition to chemical cross-linking help to enhance this property.

The excellent toughness of the resin also has a positive effect on the fatigue behavior under load. The high tolerance to stress peaks delays the formation of critical cracks, thus prolonging the part life.[2,3] In automobiles, which are constantly subjected to dynamic loading under driving conditions, materials with a high fatigue tolerance are essential in order to be able to exploit lightweighting potential to its fullest extent.




Graphic 1: Crack propagation test under alternating loads (pure resin). Comparison of a typical reference epoxy resin versus a corresponding polyurethane resin.

But material properties are not the only important factors: In the mass-production of automobiles, speed is paramount, and RTM is a process that enables short cycle times to be applied.
Graphic 2 shows the viscosity behavior of Loctite MAX 2. Its extremely low viscosity, even at low temperatures, permits very fast resin injection without distorting the fibers while also achieving good wetting even with high fiber volumes. [4]




Graphic 2: Rheological behavior of Loctite MAX 2 during curing at different temperatures.

## Fast curing even with thick parts

Furthermore, the polyurethane chemistry makes it possible to control the curing reaction more reliably, either by adjusting the temperature or adding an accelerator. The generally low heat generation during curing allows fast curing even of thick parts with many layers of fibers and reduces the risk of local overheating and resulting defects.

Henkel and KraussMaffei joined forces with the declared aim of improving the speed and reliability with which composite components can be manufactured.

Through their work, they have demonstrated that using the new resin system on high-pressure RTM equipment can significantly reduce manufacturing cycle times. Loctite MAX 2 cures much faster than the comparable epoxy resins that are mainly used in the RTM process today. This was exemplified by achieving a cure time of just one minute with a real-life three-dimensional component. The machine settings are listed in Table 2.

| Injection parameters | Polyurethane matrix resin |
|---|---|
| Fibers | 4 layers of CF fabric 300 g/m² |
| Mold temperature | 120℃ |
| Injection time | 4 s |
| Resin injection rate | 70 g/s |
| Time to demolding | 1 min |

Table 2: RTM process parameters for manufacturing the polyurethane composite component

The resin is injected into the preheated mold under vacuum and removed after one minute. The fiber volume was approximately 50 percent, with no fiber distortion being detected regardless of the laminate structure. Milling to the final shape was performed directly after cooling of the components.

Fig. 1: Open mold of Ningbo Huaxiang (CN) with the unmachined part before demolding (KraussMaffei in Munich, Germany).

Fig. 2: The component: a lightweight cover section for central consoles, manufactured with carbon fibers from Zoltek and impregnated with Loctite MAX 2.

## Machine technology adapted for polyurethane RTM

Even though high-pressure polyurethane processing and high-pressure RTM are already state of the art, the machine technology does require some adaptation for the polyurethane RTM process. Building on Henkel's processing expertise, KraussMaffei's engineers further optimized the proven mixing and dispensing stations and the mixing heads in order to improve the high-precision dispensing technology and thus the controllability in high temperature processes. The results can be seen on the part itself. Excellent mixing of the resin components under high pressure ensures homogeneous product properties without any air pockets. As a result, suitable and proven systems are now available for mass-production. [5, 6]

However, no application solution for the automotive industry is ever complete if it cannot be integrated into an overall package. Henkel therefore offers individually formulated adhesives to ensure reliable integration of the different component materials in modern multi-material designs.

| Adhesive | Curing time [min] | System/Curing temperature | Application | Shear strength [MPa] | Elongation [%] |
|---|---|---|---|---|---|
| Terokal 5055 | 240 | 2P Epoxy/RT | structural bonding | 18 – 22 | 3 |
| Terostat MS 9399 | 90 – 180 | 2P SMP/RT | elastic bonding | 2 | 150 |
| Terolan 1510 | 0,5 | 1P PUR/> 85 °C | structural bonding, fast-curing | 10 – 14 | 120 |
| Terolan 1103 | 2 | 1P PUR/> 95 °C | flange sealing | 4 | 200 |
| Teromix 6700 | 120 | 2P PUR/RT | structural bonding | 13 | < 10 |

Table 3: Henkel's adhesives portfolio for bonding composites

## New opportunities for volume production

The polyurethane-based matrix resin technology Loctite MAX 2 offers a very attractive properties profile tuned to the requirements of the automotive industry. Good handling capability in the RTM process combined with low injection viscosity and controllable cure speed permits short cycle times (< 5 min) in composite component manufacture. The excellent intrinsic toughness of the resin results in higher resistance to dynamic loading and greater fatigue tolerance.

Combining Loctite MAX 2 with glass or carbon fibers opens up new opportunities for cost-efficient mass production of lightweight components in the automotive industry. The first applications are already in the commercialization phase.

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## Literature:

1. K. Potter, “Resin transfer moulding”, Chapman & Hall, London, (1997).

2. W.J. Cantwell; J. Morton, ”The impact resistance of composite materials – a review”, Composites 22 (5), 347-362, (1991).

3. M. Kempf; S. Schwaegele; A. Ferencz; V. Altstaedt, “Effect of impact damage on the compression fatigue performance of glass and carbon fibre reinforced composites”, 18th International Conference on Composite Materials, Jeju, Korea, (2011).

4. J. Summerscales, “A model for the effect of fibre clustering on the flow rate in resin transfer moulding”, Composites Manufacturing 4 (1), 27–31, (1993).

5. E. Fries; J. Renkl; S. Schmidhuber, „Mit vernetzter Kompetenz zum Hochleistungsbauteil“, Kunststoffe 9 (2011).

6. E. Fries; J. Renkl; S. Schmidhuber; M. Betsche, „Effiziente Fertigungskonzepte für Leichtbaustrukturen“, Lightweight Design 5 (2011).

**Photo material is available at http://www.henkel.com/press**

**For more information on KraussMaffei’s machine technology, visit: www.kraussmaffei.com**



Henkel operates worldwide with leading brands and technologies in three business areas: Laundry & Home Care, Beauty Care and Adhesive Technologies. Founded in 1876, Henkel holds globally leading market positions both in the consumer and industrial businesses with well-known brands such as Persil, Schwarzkopf and Loctite. Henkel employs about 47,000 people and reported sales of 16,510 million euros and adjusted operating profit of 2,335 million euros in fiscal 2012. Henkel’s preferred shares are listed in the German stock index DAX.

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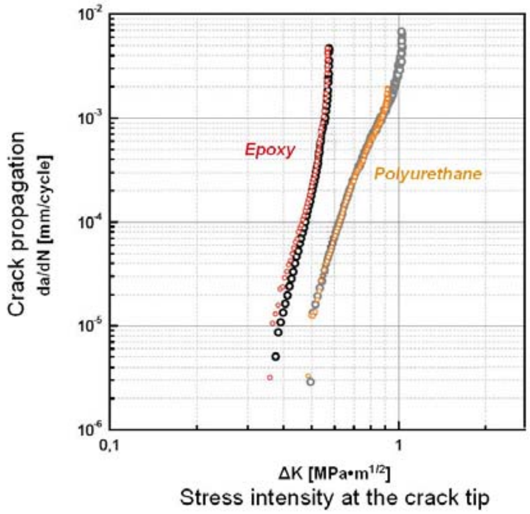
**The following material is available:**

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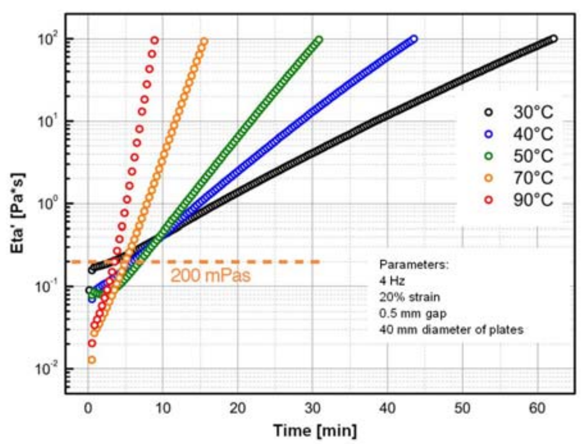
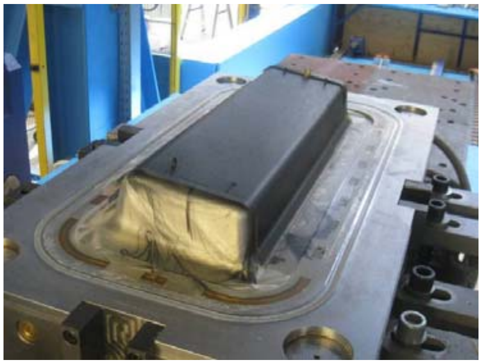



Rheological behavior of Loctite MAX 2 during curing at different temperatures.



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Henkel's adhesives portfolio for joining composite components in the automobile