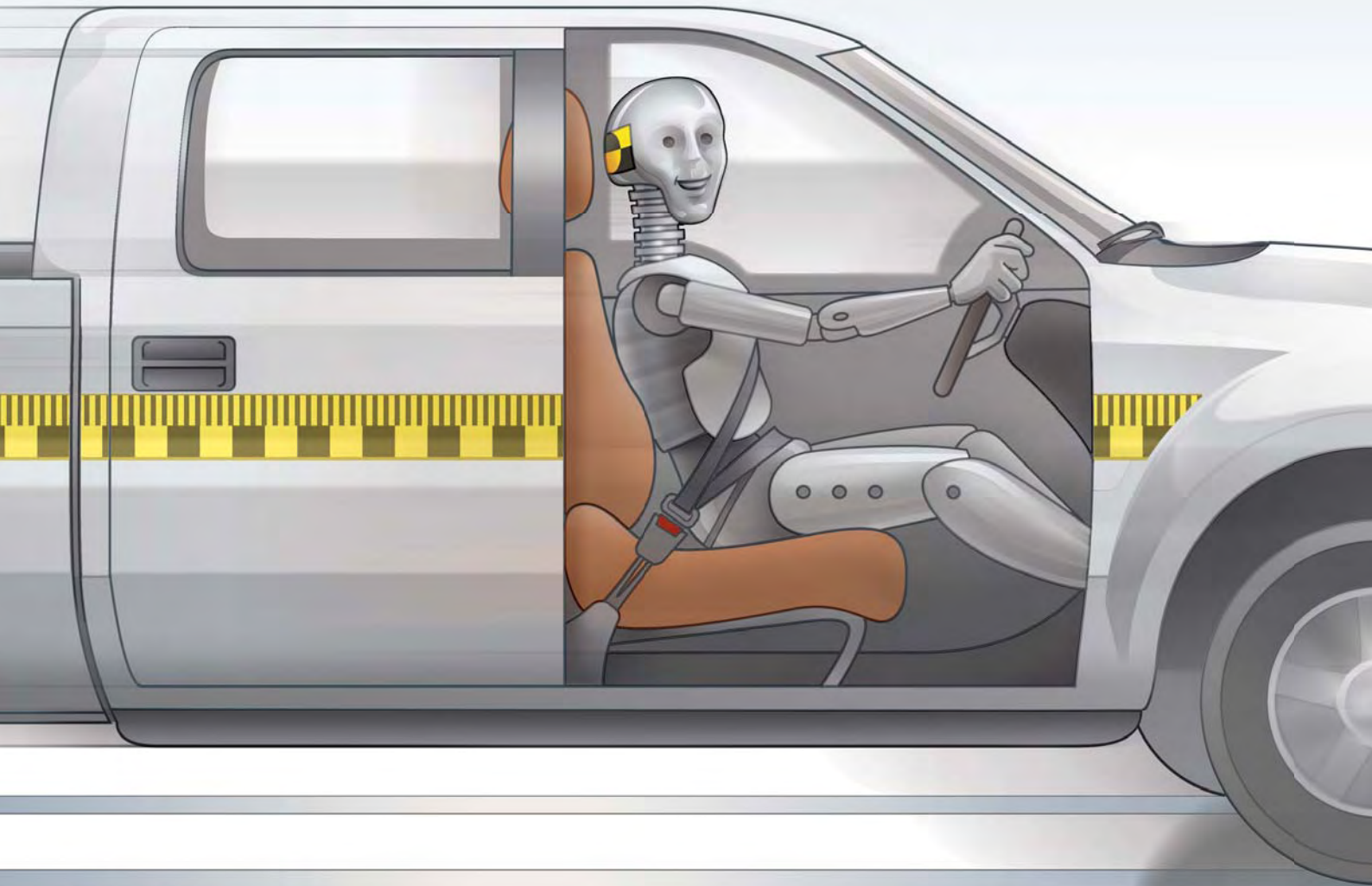


Safe, safer, crash resistant



Henkel researchers develop novel crash-resistant structural adhesives to make tomorrow's cars even safer.





Bonding is common practice in automotive engineering. For 20 years now, car makers have been reinforcing the welds in car bodies with high-performance adhesives. By making the car body considerably stiffer, these reinforcing adhesives have made it possible to use thinner metal panels – making the cars lighter – while improving the vehicle’s driving performance at the same time. Lighter car bodies also mean lower fuel consumption and hence reduced output of climate-damaging carbon dioxide.

Conventional reinforcing adhesives do, however, have one major drawback: “Although reinforcing adhesives easily cope with the mechanical stresses of everyday motoring, they are unable to withstand a serious crash. Because of their brittleness, they tear open like a zipper,” explains Dr. Olaf Lammerschop, head of the Structural Adhesives technology platform at Henkel. “This is why car makers don’t use these adhesives in critical crash-safety components.”

Car drivers naturally expect maximum safety. They want a vehicle that gives its occupants optimal protection in the event of an accident. For the safety-critical areas in the car body, car manufacturers therefore need structural adhesives that are so tough that

they won’t rupture in a crash – and still perform equally well in all other respects. These crash-resistant structural adhesives greatly improve the vehicle’s passive safety.

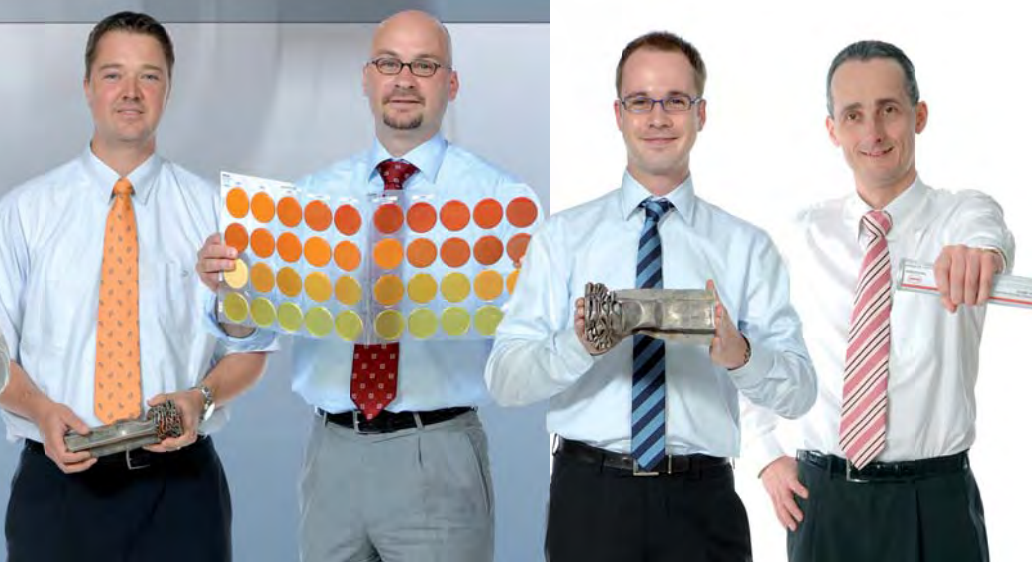
Morphology-controlled crash resistance

Henkel therefore launched a development project to deepen the understanding of the crash resistance of structural adhesives beyond the current state of the art. An interdisciplinary team of scientists and product developers from Henkel sites in Germany, the USA and Ireland systematically investigated the relationship between the chemical composition of the adhesives, their internal structure (technically referred to as morphology), and the resultant mechanical properties.

Structural adhesives usually consist of a brittle adhesive matrix with spherical islands of soft, rubber-like polymers. These islands only begin to form when the adhesive is curing (hardening), a process in which the originally uniform mix of the two constituents separates more or less completely. The experts use the term ‘conventional rubber-toughened’ for this kind of morphology. Crash-resistant adhesives, however, call for a much more complex structure.

Dr. Rainer Schönfeld, in charge of Corporate Research/Polymer Chemistry at Henkel, explains: “The key to crash resistance is the morphology of the cured adhesive. We have developed a method of distributing soft particles, only a →→

They control crash resistance by modifying the inner structure of adhesives (left to right): Dr. Thomas Engels, Dr. Olaf Lammerschop, Dr. Rainer Schönfeld, Martin Renkel, Dr. Bernd Mayer.

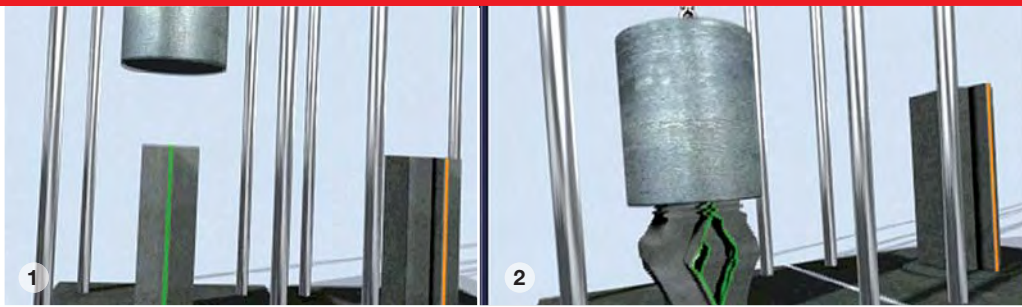


Drop tower tests to determine crash resistance

In the drop tower test, a roughly 500 kilogram weight is dropped from a height of about two meters onto the test specimen. Henkel experts use this method to investigate the crash behavior of test specimens produced by bonding or spot welding two sheet-steel panels with a top-hat profile.

In the test, the bonded test specimens crumple accordion-like over a certain distance, starting at the top. The impact energy is absorbed well, and the bond line holds (a).

By comparison, the exclusively spot-welded test bodies show greater deformation, and energy absorption is less effective (b).



Computer simulation of a drop tower experiment:

1) The weight falls on the top-hat profile with the welded seam. 2+3) Upon impact, the two halves that have been joined exclusively by welding tear apart at once (marked in green).

few hundred nanometers in size, uniformly throughout the matrix before curing of the adhesive. This is an entirely novel technology." Using this method, the experts can precisely control the adhesive's morphology and internal interfaces. They can also tell exactly how the interfaces between the hard and soft constituents will affect the mechanical properties of the adhesive.

With this technology, the Henkel specialists have created a new generation of crash-resistant structural adhesives with especially high thermal stability and a crash resistance that is more than ten times better than that of reinforcing adhesives. This has been demonstrated in various ways, including drop tower experiments in which the experts test the mechanical strength of metal-to-metal bonds (see box at left).

Henkel has been marketing these adhesives since 2004 as part of the Terokal product line under its Teroson umbrella brand. "Car manufacturers can now obtain adhesives geared precisely to

their requirements and their production processes," reports Mike Flener, responsible at Henkel for the international marketing of structural adhesives. "We launched the first crash-resistant Terokal structural adhesive in the USA in 2004. With this adhesive, the Ford F-150 pickup was given the highest crash resistance rating in its class by the U.S. Insurance Institute for Highway Safety." This was also the first crash-resistant adhesive in the North American market that could be applied without use of heated pumps, as demanded for standard automotive adhesives. A little later, Henkel introduced a similar adhesive to the European market.

Goal: Simulating crash behavior

Despite these advances, vehicle manufacturers are not yet exploiting the full potential of crash-resistant adhesives. While welding has been widely accepted for decades and is a highly developed technique, engineers have been slow to adopt adhesive bonding technologies.





3) Unlike the specimen joined exclusively by welding, the specimen joined with a crash-resistant adhesive folds up like an accordion (marked in orange). 4) The bonded seam remains intact.

5) After the experiment: The test specimen with the crash-resistant adhesive has folded up and not torn apart.

Yet bonded joints are in fact capable of almost entirely replacing the classical spot welds – just a few spot welds would be sufficient to fix the bonded body components until the adhesive has cured. In addition to enhanced safety, this also generates considerable potential for savings.

Today, it is already standard practice for engineers to design and develop new car bodies on the computer and simulate their mechanical properties. However, the thinness of adhesive bond lines still represents a major challenge for conventional numerical modeling techniques like the finite element method (see box at right).

Henkel therefore initiated a project in 2005 to improve the acceptance of adhesive bonding. Also involved are vehicle manufacturers Opel and Schmitz Cargobull and the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research (IFAM) in Bremen, Germany, one of the leading European scientific institutes in the

field of adhesive bonding technologies. By 2010, the experts aim to further develop the finite element method and other techniques for these applications in order to be able to provide the desired computational support for the reliability of bonding.

Transferable action mechanism

The next generation of structural adhesives will open up new applications. Adhesives that stay crash resistant even at temperatures as low as – 40 degrees Celsius are already available now. In addition, the Terokal structural adhesives of the future will display especially high heat resistance. This means that the car makers will be able to use them even closer to the hot engine block than before. Henkel experts are also using their findings to apply the action mechanism to the matrix resins of fiber-reinforced plastics – so that these modern lightweight materials may one day also be able to resist crashes.

Modeling with finite element methods

Design engineers model vehicle bodies on the computer with the aid of finite element methods that permit virtual tests and optimizations. This is done by laying a mesh over the image of the car body and breaking the structure down into many small segments – the finite elements. Bonded car bodies pose a dilemma for the engineers. To model the behavior of thin bond lines, they require an extra-fine mesh. However, this increases the number of finite elements to such an extent that even high-performance computers are pushed beyond their limits. If, on the other hand, they select a coarse mesh, the adhesive bonds slip through the net. The experts involved in the joint project with the Fraunhofer Institute for Manufacturing Technology and Applied Materials Research (IFAM) are working hard to overcome these challenges.



Members of the international development team for crash-resistant adhesives (left to right): Rajat Agarwal, Mike Flener, Dr. Matthew Holloway, Dr. Barry Burns, Dr. Ray Tully.