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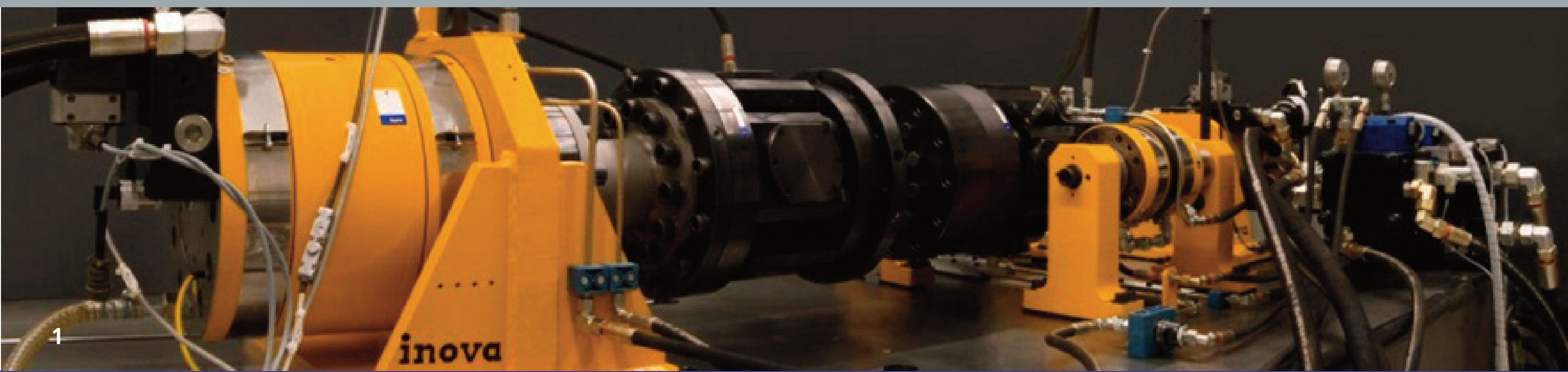

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ADHESIVE BONDING OF POWERTRAIN COMPONENTS WITH HIGH-STRESS CAPACITY

for automotive applications

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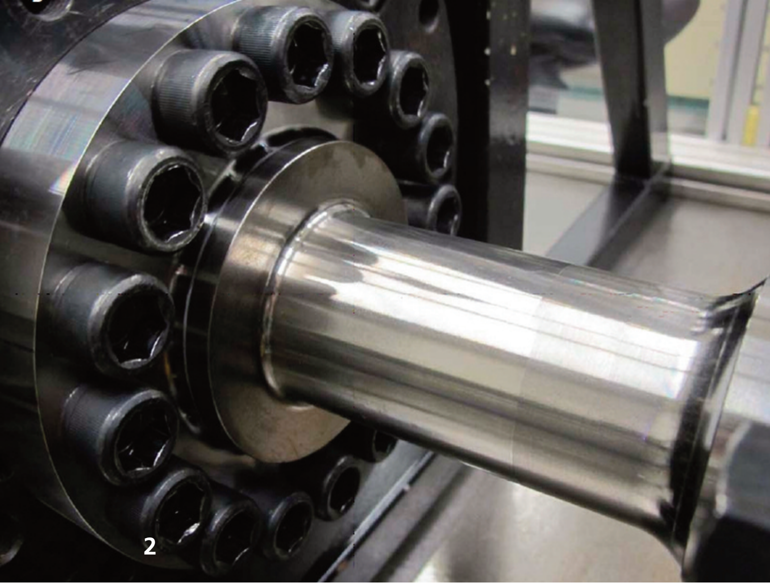
The problem

Welded hybrid joints consisting of grey cast iron and carburizing steel have been the standard for automotive gearbox manufacturers worldwide for more than 15 years. These hybrid joints take the place of the previous time-consuming and expensive alternative of screwing and riveting joints, mainly in differential gears, and they reduce weight and simply manufacturing as well.

Driven by the constant general pressure to reduce cost and improve quality, more and more case-hardened components with enhanced mechanical-technological properties, as well as design materials with limited welding capability, such as sintered materials, black malleable iron etc., are in use. Innovative manufacturing techniques are required to make them usable for advanced vehicle designs.

Our solution

Together with industry partners, we have developed an adhesive bonding process to join parts made of several materials with limited or no welding suitability. This process is capable of joining the parts reliably so that they withstand high stresses. The adhesive bonding technique is not only profitable, but can also avoid crack-sensitive structure zones, such as those that may occur in the extremely hard ledeburite, in the heat affected zone caused by casting during welding.



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Transient thermal stresses and deformations can be completely avoided due to the low energy input during adhesive curing. Welding seams or bolted connections are characterized by local stress peaks, whereas the homogeneous stress distribution spread over the entire adhesively bonded area positively affects the static and dynamic strength values to be achieved.

In a series of adhesive bonding tests carried out on test components made of black malleable iron (GJMB) and carburizing steel, both component design and dimensioning for adhesive bonding, as well as the adhesive's suitability and the pre-treatment parameterization, were investigated.

The results

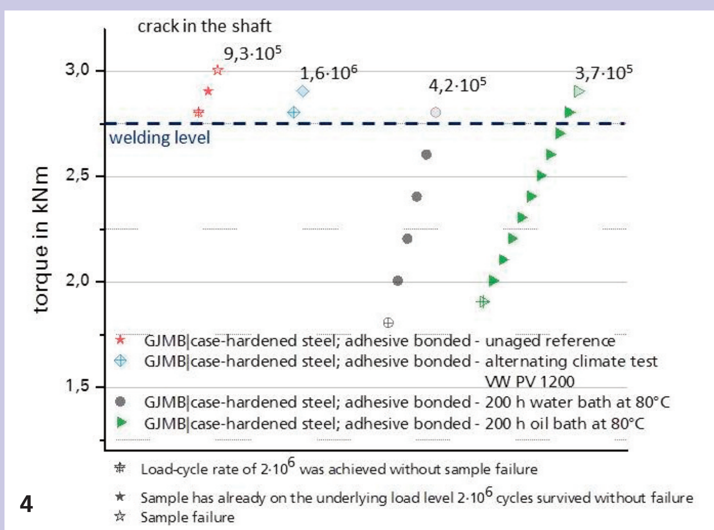
With an eye toward finding parameters that might be used to optimize component dimensioning, structural components joined by adhesive bonding were tested for their cyclic stress resistance on a servo-hydraulic axial-torsion test machine at the Fraunhofer IWS Dresden (Fig. 1). The test specimens were stressed using 13 Hz test frequency, for which a torque was introduced as a function of time as a reverse stress test. The test was performed according to the comparative stress hypothesis by Mises with the stress case assumed to be typical for the differential gear - a combination of bending and torsion in the ratio of 1:12.

The adhesively bonded hybrid joints whose joining parts are made of GJMB and carburizing steel (Fig. 2) achieved fatigue limits at a stress level comparable to that of the hybrid joints (parts are made of spherulitic graphite cast iron (GJS) and carburizing steel) widely in use in the automotive industry and welded with conventional processing lasers and filler metals. Selected results of the torsion vibration tests are shown in Fig. 4. Each symbol represents a series of load cycles of a test specimen, which was tested either up to its fracture or up to the end of the test after $2 \cdot 10^6$ cycles without specimen failure and then further tested at the next higher stress level.

The tests executed on the test specimens show that the adhesive bonding joints achieve a combined axial-torsion alternate strength, which can be represented by a twisting moment of approximately 2,8 kNm, with an axial force of 34 kN.

To assure that the structural properties of the adhesive bonding joint are maintained and that the joint has excellent resistance to media, the joints must exhibit a combination of tight and structural adhesive bonding (Fig. 3), which can be successfully shown without any reduction in strength in diverse ageing simulations.

Diagrammatic representation of the results of the axial-torsion alternate tests



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1 Servo-hydraulic axial-torsion test machine

2 Adhesively bonded test specimens made of GJMB (black malleable iron) and carburizing steel subjected to cyclic axial-torsion testing

3 Environmental cycle test (cycles of climatic ageing) according to the Volkswagen test requirements VW PV 1200