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The influence of adhesive-specific internal stress and damage states on the strength and resistance of metal bonding joints

Abstract

Limitations and uncertainties in the use of adhesive techniques arise due to the fact that over time, the strength of bonded connections can be reduced under the influence of mechanical and climatic / corrosive stresses and also internal stresses that are induced during hardening or in the event of temperature or temperature change stresses in the bonding joint. Of central importance here is the cross-linkage behaviour in the bonding joint. These processes have so far not been examined in a co-ordinated way.

The aim of this work was therefore to investigate the relationships between the adhesive-specific internal stress and damage states and their influence on the strength and resistance behaviour or metal bonds.

First of all, the effects on the mechanical properties of differences in the contraction and shrinkage possibilities during cross-linkage and cooling of heat-hardened adhesives and bondlines were examined. The results show that the properties and material values during the hardening of bondlines that are prevented from shrinking and are therefore subject to stresses differ significantly from those determined on adhesive substance samples which can be regarded as being largely free of internal stresses thanks to the possibility of shrinkage on all sides.

Starting with the conclusion drawn from these investigations that thin bondlines experience anisotropic structuring during hardening compared with substance bodies, the hardening behaviour of adhesives were examined. To do this, two measuring devices were developed as part of the work, with which it is possible to continuously record firstly the expansion and contraction behaviour during hardening and secondly the corresponding stresses that build up in the bondline thickening direction.

In conjunction with other examination methods, the measuring units help towards a better understanding of the adhesive-specific mechanisms during cross-linkage and cooling, as well as their effects on the bondline structure and properties. It is apparent that the thermal contraction of thin cross-linked bondlines in the thickening direction is in some cases way above the values expected from the thermal expansion coefficient of the adhesive substance, which in the final analysis is attributable to the anisotropic structure of the bondlines, as it was then shown.

In order to be able to assess the stress state in hardened bondlines with regard to stress distribution and relaxation, the decomposition principle was adapted to use on adhesive bonds and tested. The results show that this method is in principle suitable in thicker bondlines for identifying local differences in the stress state and for assessing the relaxation behaviour of adhesives on a comparative basis.

By examining the structure of bondlines along with their density and moisture absorption compared with the adhesive substance sample, it is shown that as a consequence of the shrinkage related to cross-linkage and cooling and its three-dimensional prevention, a lamella-type bondline structure arises that is wider-meshed in the vicinity of the joint part and is denser and more branched towards the middle bondline layers.

To assess the effects of the internal stress state, also in combination with wider damage mechanisms such as moisture and temperature change, the strength and resistance behaviour was examined on single-shear overlapped combined tension and shear samples. It was possible to show that the prevention of shrinkage during hardening and the internal stresses that build up as a result act clearly in conjunction with thicker adhesive layers and in particular reduce strength when the bonded joint has been subjected to vibration stress. This applies to bonded connections both before and after ageing. The influence of the internal stresses in the initial state was also recognisable under quasi-static stress. However, after three months of climate corrosion testing and twelve months of intensified weathering outdoors, there was no longer any measurable influence of the internal stress state on the bonded connections examined.