Quality in the first row: Quick curable adhesives with integrated state monitoring

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Introduction

For the production of safe products with controlled life span it is crucial to control and document design and production. For adhesive bonding the organizational requirements originated from ISO 9001 are described in the new DIN 2304 “Klebtechnik – Qualitätsanforderungen an Klebprozesse” (Bonding Technology – Quality requirements for bonding processes). For realization in practice measurement methods are required to control all important steps during the production process of adhesive bonds including the state of the adhesive. In general it is easier to measure and control the course of slow processes then that of quick processes and often production rate is restricted by the possibilities to control the process. In principle the curing rate of all adhesives can be increased by increasing the curing temperature but time is needed to warm up the construction. Numerous methods were developed in the past to heat up assembled adhesive bonds quickly but it is up to now not possible to measure the real adhesive temperature in production lines as quick as heating is possible. In addition most adhesives are not sufficient for really quick curing within minutes or even in a few seconds as the resulting mechanical properties deteriorate. For increasing productivity in adhesive bonding leading to durable bonds with reproducible properties it is therefore necessary to develop adhesives really sufficient for quick curing and methods to measure and control the temperature course during production.

Quick curing

Long shelf life of adhesives is a precondition so that the adhesive is not expired at the time of bonding. Furthermore, this gives enough time for assembling and processing. On the other hand curing should be as quick as possible from the productivity point of view. In an ideal case the conflicting properties could be combined. This is the case if photocuring is applied but unfortunately this is of limited applicability in adhesive bonding as most parts are not transparent for the light required for curing on demand. Therefore, we focus in the following on thermal curing and show how to circumvent the contradiction between long shelf life and the desire of quick cure. Quick heating is a prerequisite for a quick curing. Methods like induction, microwave, IR radiation, hot stamps are in use but need a proper process control as otherwise it cannot be guaranteed that the adhesive is fully cured but not decomposed due to overheating. As quicker the curing should be for high productivity as better the temperature measurement and control must be. As it is not possible to measure the temperature quickly direct in the adhesive bond with common methods we present in the following two methodologies which enable to do so. In addition the adhesives need to be sufficient for quick cure. This includes that no volatile compounds evaporate during the cure reactions as this would lead to bubbles but it is also necessary that the chemical structure and morphology is reproducible and lead to good properties. For the later most often special formulations are required as most common adhesives are brittle if cured within seconds instead of long term oven processes.

E-FAST®

E-FAST® means electrical fastening. For this a metal film with sufficiently high electrical resistance is inside the adhesive bond. It is electrically connected whereas it heats and changes resistivity. As the data are instantaneously available and can be adjusted rapidly, heating can be carried out very quick including a very controlled hold time at a distinct temperature. This works with paste like adhesives but better with solid and tack free adhesives pre-applied on the metal film (PASA®). In this case the combined heating-sensor element bears already the adhesive with a controlled thickness which enables fast automatized bonding.

IRIS

Not only the resistance of metals is temperature dependent but also the interaction with high frequency radiation. If particles with strong and known temperature dependence of the HF interaction are part of the adhesive they can directly be used for the contact less temperature measurement and control of the adhesive bond. This requires at least one non-metallic part and one has the freedom to use this in combination with paste adhesives as well as with pre-applied solid adhesives. Already from the beginning the sensor particles should be part of the filler package used in the formulation. Heating can be carried out by inductive heating via the particles or with almost all other available heating methods like IR irradiation.

Curing indicators

A possibility to control the state of an adhesive for quality assurance is the visual inspection. For this an indicator sensitive to the cure state is added and the color is observed visually or by color metrics using the RGB values. The sufficient indicator depends strongly on the cure reaction and applied initiators and catalysts. If selected properly the color changes if the shelf life is expired (e.g. doubling the viscosity) and in a next step at the adhesives full cure. Often even overheating can be observed in a next color change so that an automatized color detection is a proper method to check the state of the adhesives over the full production process.

Conclusions

Quick adhesive cure combined with long adhesives shelf life can be realized on numerous ways although these are conflicting requirements. First the adhesive must be sufficient for quick cure which means that the mechanical properties are independent on the cure rate and temperature. Different methods exist to heat the adhesive quickly to a temperature at which curing is finished within seconds. But it is extremely difficult to measure the adhesives temperature quick enough for a proper process control and not just the surface temperature of the bonded parts. For this two methods were developed. The first one is the resistive heating of the adhesive bond and the resistance of the metal film gives information on the temperature inside the bond. This enables controlled adhesive cure within seconds. The second method is a method for temperature control inside the bond for any heating process. It is named IRIS and is based on the temperature dependence of the interaction of sensor particles inside the adhesive with high frequency radiation. The application of this contact less method for temperature control requires just one non-metallic part of the adhesive bond. Temperature control during cure is one important requirement for quick thermal cure but controlling the adhesives state is another one. By a color reaction it can be detected if the adhesive is fresh, expired, fully cured or destroyed by overheating. All these methods are in line with DIN 2304 and allow the controlled and well documented quick cure of adhesive bonds and by this high productivity or in other word cost efficient production.