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Electrical capacitance tomography as a method for inline monitoring the homogeneity of adhesive flows

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Robust bonding processes are essential for industrial applications. Especially the industrial processing of two-component (2K) adhesive systems has high requirements in ensuring the specified mixing ratio and adhesive homogeneity. Today there is no adequate technique to measure the mixing quality directly at mixed adhesives. Common systems only measure the volume flow of the individual components and calculate the current mixing ratio. A proper measurement and quality monitoring system would enable the possibility of an immediate intervention in case of mixing failures. This work documents the development of a concept to visualize adhesive flow homogeneity and monitor the mixing ration during the manufacturing process by using the non-invasive method of Electrical Capacitance Tomography (ECT). The system allows a two-dimensional analysis of flow and mixing processes. The adhesive flows through a tube-shaped sensor while the capacity between different electrodes is measured. Using different reconstruction algorithms, the mixing quality is illustrated in a two-dimensional tomogram. The focus of the entire work lies on the adaptation of hardware and software for monitoring homogeneity in bonding technology. This includes particularly the development of adapted computation models for the evaluation of measurement data as well as solutions to protect the sensor against reactive adhesives. In addition, analyses of process-relevant parameters, such as the permittivity of uncured adhesives, are carried out. This extended abstract deals with the challenges of sensor miniaturization.

Keywords: adhesive flow visualization, mixing ratio, quality assurance

Introduction

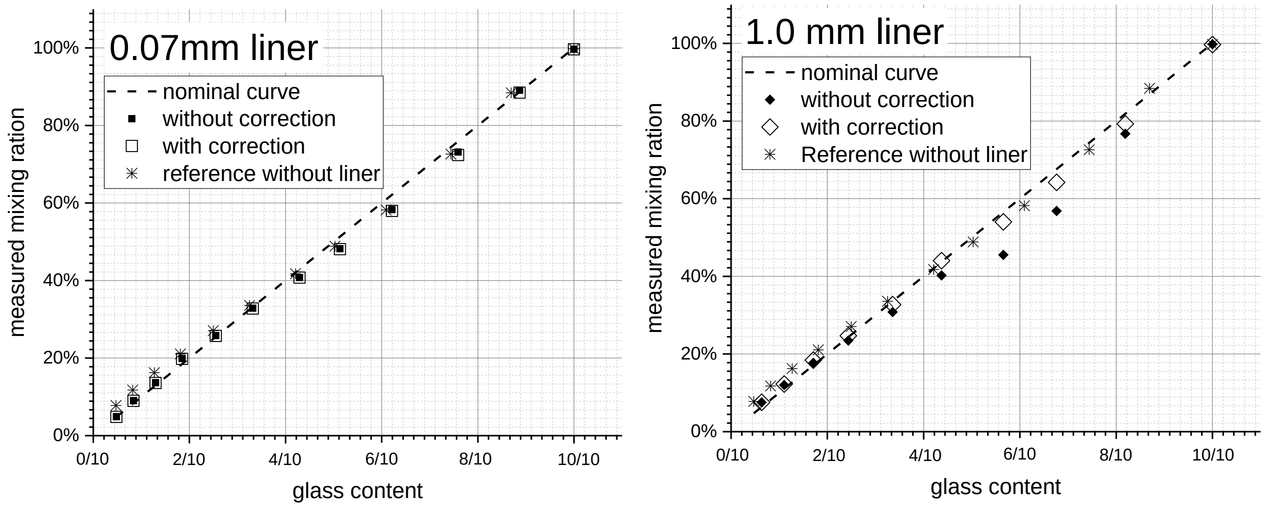
The ECT is a non-invasive inline measurement method for determining the homogeneity of mixtures. Today ECT-systems are used for process analysis in the field of mixing technology and flow analysis [1]. The system consists of the measuring electronic device, a computer with reconstruction software and a cylindrical sensor with eight integrated electrodes. The electrodes are arranged in an insulated ring around the measuring chamber. Due to the usually low flow rates in bonding technology, the internal diameter of the sensor has to be very small compared to other applications. In this work, a sensor with a 14 mm inner diameter is used. The sensor and the electrodes inside have to be protected against reactive adhesives. The use of a replaceable plastic tube (liner) with a wall thickness less than 1.0 mm has proven successfully. The liner gets simply inserted into the sensor. Due to the small internal diameter of the sensor, the liner occupies a relevant part of the measuring chamber. This leads to a negative influence on the measurement result. The influence of liners to measurement of capacities by using a sensor with an inner diameter of 149 mm is described in “The design of an electrical capacitance tomography sensor for use with media of high dielectric permittivity” [2]. Especially the capacitance measurements of adjacent electrodes are strongly affected. A common method to compensate undesirable effects of adjacent electrodes is to truncate capacity values of them [3]. This significantly reduces the number of measurements that can be used for reconstruction methods.

Approach

One way to minimize the influence of the liner is the reduction of the liner wall thickness. The disadvantage of thin liners lies in their low mechanical stability. Another approach is the mathematical compensation. In order to characterize the liner influence, an air-filled sensor (component A) filled with glass rods of defined diameters inside (component B) is measured. The glass rods generate a known ratio of glass and air in the sensor. This approach allows a comparison between measurements without liner, with a thin liner (0.07 mm), standard liner (1.0 mm) and a test of a mathematical compensation algorithm. The compensation algorithm is based on the usual reconstruction method *Linear Backprojection* (LBP). The developed compensation method uses additional information about areas of known permittivity (where the liner is) and recalculates the measured capacitances by using the known parameters inner sensor diameter, liner wall thickness and permittivity of the liner.

Results

Figure 1 shows a comparison of the glass content inside the sensor and the measured mixing ration by using no liner (reference), a thin liner 0.07 mm (A) and a standard liner 1.0 mm (B). It can be seen that the 0.07 mm liner has nearly no influence on the measurement result. By using the 1.0 mm liner the measured mixing ratio deviates in order to the real mixing ratio. Deviations of about 4 % to 11 % absolute between the measured and the real mixing ratio occur from 4/10 up to 9/10 glass content. The correction algorithm has no influence on the measurements with thin liner as expected. The divergences in case (B) are successfully compensated.



(A) **(B)**

Figure 1: comparison of the real mixing ratio and the measured mixing ratio with and without correction algorithm by using (A) a liner with 0,07 mm wall thickness and (B) a liner with 1,0 mm wall thickness

1 Conclusion and recommendations

This extended abstract shows investigations on the liner influence on measured mixing ratios. The liner is still necessary for applications in the field of adhesive bonding. It is shown that a thin liner with a wall thickness of 0.07 mm has no influence on measurements by using a sensor with an inner diameter of 14 mm. The use of thicker liners is advantageous in terms of mechanical properties. A standard liner with a wall thickness of 1.0 mm has a negative influence on the measured mixing ratio. The glass content will be underestimated up to 11 % divagation. The measured capacitance values and calculated mixing ratios are a result of different materials permittivity ε between two electrodes. The permittivity of the liner (ε_L = 2,1) is still lower than the permittivity of glass (ε_G 4,6). While the content of glass increases, the measured capacity is reduced by the liner. The liner significantly determines the measured capacities of adjacent electrodes. The influence of the liner decreases while the distance between the electrodes increase. This correlation can be compensated by using additional parameters in the reconstruction method LBP. It is shown that the method is suitable to compensate the influence of the liner by measuring solid glass rods.

The method has to be adapted and tested for use with mixed liquid adhesives to make ECT systems usable for bonding technology and to open up the possibility of using a more robust liner.

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