Heat Management Concepts for a Precision Assembly of Micro Components Using Hot Melt Joining

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Abstract

Nowadays, the production of 3D MEMS and MOEMS is carried out by using hybrid integration of single components, for which batch production is normally preferred. In this field, adhesive technology is one of the major joining techniques. At the Collaboration Research Center 516, a batch process based on a joining technique which uses hot melt adhesives was developed. This technique allows the coating of micro components with hot melt in a batch. The coating process is followed by the joining process. Due to this, the time between coating and joining can be designed variably. Because of the short set times of hot melt adhesives, short joining times are possible. For this assembly process adapted heat management is necessary. This paper presents adapted heating management concepts and gripping systems which allow a fast and accurate assembly of hybrid micro systems with hot melt coated components. Therefore, the chosen gripping system depends on the process and heat management concept as well as the thermal properties of the components. Furthermore, the simulative and experimental results of the heat management concepts will be discussed.

1 Introduction

The continuous miniaturization of hybrid micro systems requires joining processes which are suitable for batch production [1]. The most important technology is the adhesive joining technique [2]. Mostly, viscous adhesives are used. Disadvantages of viscous adhesives are long set times and the low suitability for batch processes. A new approach is the usage of hot melt adhesives. The main advantages are extremely short set cycles, the possibility of pre-applying the adhesive and the time-delayed joining procedure [3]. Therefore, the use of hot melt adhesives can be an interesting alternative for the assembly of hybrid micro systems. To establish this technology, adhesive and application technologies as well as the assembly process must be developed, and the process parameters must be deter-mined. A very important aspect for the process design is the kind of heating technology. Therefore, special process components, such as fixtures and grippers as well as the heat management concepts should be developed. One project at the Collaborative Research Center 516 "Design and Manufacturing of Active Micro-systems" is concerned with the development and modification of hot melt adhesives and coating concepts and also with the development of the special assembly process with hot melt coated micro components.

Joining Technology

The listed limitations of viscous adhesives in the micro system engineering are to be compensated by using hot melts. These hot melts are thermoplastics, physical setting adhesives, which are single-component, non-viscous and non-solvent at room temperature. One of the most important advantages of hot melts in comparison to viscous adhesive systems is the possibility of pre-applying hot melt systems in a batch process, e.g. as powder or adhesive spheres, as dispersion or as an adhesive foil. The joining procedure does not have to take place directly after the adhesive has been applied to the substrate; this can happen at any time later on, i.e. hot melts possess no pot life time [4]. The adhesive is only melted during the bonding process by a thermal impulse and moistens the surface of the other substrate. The heating can be accomplished directly by heating the adhesive itself or indirectly by heating the substrate. The adhesive sets, once the temperature of the adhesive has fallen below the melting temperature. If an appropriate heat management concept is used, the hot melts sets very fast, which means that the handling strength (usually the ultimate strength) can be achieved in less than one second as experiments have shown.

2 Adaptive Heat Management Concepts

Heat management is an integral part for the selection and the design of an assembly process using hot melt adhesives. Since the volume of the hot melt is quite small, the thermal capacity is rather low, which is why heating the hot melt itself is not very practical. Contrarily, the thermal capacity of the component and the gripping system is much higher. Hence, the characteristics of the grippers and the components such as their volume, their thermal capacity as well as their thermal conductivity must be taken into consideration when designing the assembly process. Besides, the heating source is another crucial factor for the process design. The following heat sources can be used to heat up the gripping unit: heating plates, infrared heaters, lasers, heating foils and Peltier elements as well as a combination of these heat sources. In general, there are two different kinds of heat management concepts – a passive and an active one. The passive heat management concept makes use of the principle of heat storage to supply the energy for the joining process. The solid line in Figure 1 shows the typical temperature history of a component according to the passive heat management concept. Before the actual joining process, the gripper and the component inside it are heated up by a heat source until the working temperature T_{Hp} has been reached. The time needed until T_{Hp} has been reached determines the process time to a large extent. If neither handling nor measuring operations have to take place right after the gripper has picked up the component, the gripper should be heated up before the grip-ping process. Besides, the working temperature T_V must be much higher than the melting temperature of the adhesive to provide enough time to position and join the components until the temperature falls below the working temperature, which is marked by t_{Kp}. The time span between t_{Hp} and t_{Kp} is referred to as the processing time. Contrary to the setting, the process time marks the time span during which the position of the components can still be measured and adjusted. The processing time depends mostly on the material of the components and the gripper. Once the joining component comes into contact with its joining partner, the temperature drops substantially, whereupon the hot melt sets and reaches its final strength. In general, the assembly time is less than a second. As Figure 1 shows, the working temperature is much higher than the melting temperature, as a result of which the components are exposed to very high thermal load. Under certain circumstances, this load will lead to a deterioration of the accuracy of the assembly process. Nonetheless, the fact that the passive heat management concept can be easily integrated into already existing assembly systems is a major advantage of this concept. Disadvantages are the long heating times, the inflexibility of the process design, the high thermal load of the components as well as the immense efforts to monitor the assembly process. In particular, the controlling process of the temperature variation is rather complex.

In contrast to the passive heat management concept, the heat source of the active heat management concept is integrated into the gripping or clamping unit. Therefore, heat can be continuously transmitted into the component during the handling process. As another result, the temperature- and material-dependent processing time of the passive heat management concept can be omitted, which is why the processing temperature can be set at a lower level. In most cases the processing temperature can be set right above the melting point. This results in a lower thermal load of the components. Due to the continuous heat input, the processing time of the active heat management concept can be variably chosen. Thus, the assembly process can be designed very flexibly. By actively cooling the components, the joining time can be further shortened. The typical temperature profile of the active heat management concept is illustrated by the dashed line in Figure 1.

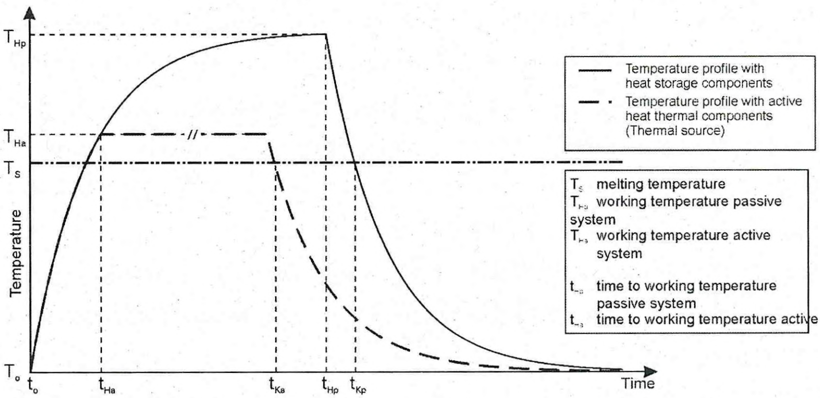

Figure 1. Temperature profiles on different heat managements

The advantage of the active heat management concept is the independence of the assembly process from the heat capacity of components which leads to a flexible process design. The complex design and the integration of active heating components is a disadvantage of the active management concept, mainly, if small and accurate assembly systems are used. In contrast, the integration of heat storage components is easier to handle. However, the control and monitoring of the passive concept, especially the control and monitoring of the temperature, are quite more difficult than with the active heat management concept. The described heat management concepts allow a variable design of the assembly processes. However, not only the active or the passive heat management concept can be used, but also a combination of both is possible.

3 Conclusion and Outlook

In this paper an alternative joining process for hybrid micro systems based on hot melt adhesives was presented. In particular, the process design of the joining process in combination with different heat management concepts was described. In this context, an active and a passive heat management concept were discussed. The objective of this work is to determine the expedient parameters to design the assembly process. The disadvantage of the passive management concept, i.e. the long heating time, can be reduced by using the active concept. The first steps for an active heat management concept have been done by developing an active gripper system. Next steps will be the integration of the assembly system and experimental investigations. In the active management concept has to be investigated. In addition, the combination of the active and passive heat management concept seems to be expedient for a joining technology in micro assembly using hot melt adhesives.

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