Automated micro forming of MST-parts for small electric motors

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Abstract

By the combination of manufacturing steps from the field of microsystems technology (MST) and micro forming a new class of micro sized products can be efficiently produced. As an example the manufacturing chain of an electric micro motor is illustrated: Micro coils made from copper are embedded in an isolating polymer by combining UV-LIGA and galvanic processes. To enable these micro coil arrangements to work as stator windings of a small synchronous motor, they need to be formed to small cylinders. Therefore the MST production process is expanded with a subsequent micro forming process. This process chain has been successfully realised to build up micro motors with an outer diameter of 4 mm. This paper describes the optimization and automation of the mechanical micro forming processes to increase its economic efficiency and to ensure high production quality. Additionally, investigations are described for further downscaling of the motor to diameters of only 1 mm.

1 Automated micro forming machine

The automated machine for the forming of the coil arrangements performs 4 basic process steps: feeding of the pre-product to the machine, forming of the pre-product to the desired cylindrical shape, assembly of formed coil and motor housing and the measurement of the ohmic resistance of the fully assembled coils. These processes steps are illustrated in the following chapters.

Feeding of the MST pre-products

The coils for the micro motor are made from copper that is embedded in an isolating polymer. They are generated by mico-systems-technologies. As last manufacturing

step of the coil arrangements in the clean room they are removed from the wafer and manually placed on stackable magazine trays.

The tray is positioned on the cross-table of the automated forming machine. The location and orientation of the individual MST-parts is fixed within 100 µm tolerance, Fig. 1. An arm with attached vacuum gripper, which can perform a rotation of 180°, takes a system and places it onto the horizontal part of the thin metal belt of the forming mechanism, Fig. 1 right.

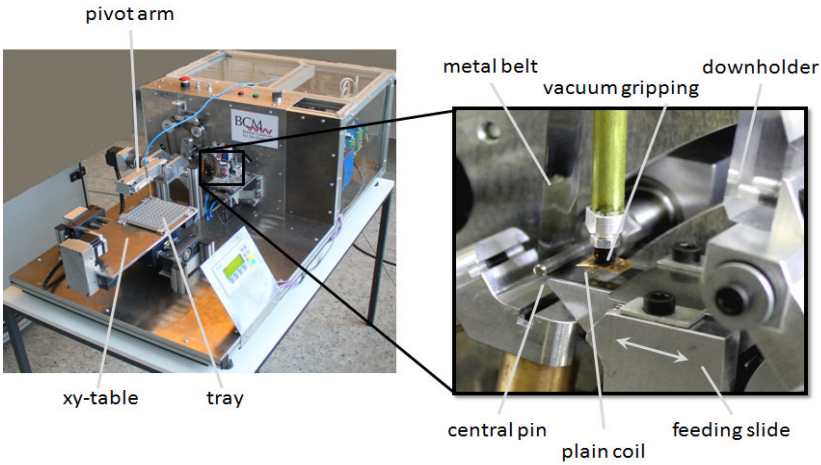

Figure 1: Forming machine with crosstable and vacuum gripper

2 Forming into cylindrical shape

The forming of the planar coil into a cylindrical shape is carried out by winding it around a central pin, s. Fig. 2. The pin is heated to 180°C to support the bending effect. A second pin pushes down the belt to maximise the enlacement of the first pin. For starting the forming procedure the conveyor belt is moved and the plain coil is pushed into the gap between the belt and the central pin, Fig. 2 right. The principle was previously published in [1, 2] and patented. The quality of the formed parts is greatly affected by the parallelism of the rotational axis of the central pin and the leading edge of the planar coil. A deviation from parallelism leads to an inclined wrapping around the pin and scrap of the part.

To ensure the quality of the automated forming a feeding slider has been developed, Fig 2. It consists of a piece of thin sheet metal that has the same thickness of the plain coils of 100 µm. A downholder prevents the plain coil from slipping over the feeding

slider. At the beginning of the forming process, the slider is moved faster than the metal belt and so the slider angularly aligns the plain coil just before the forming starts. Figure 2 shows a sketch of the described arrangement.

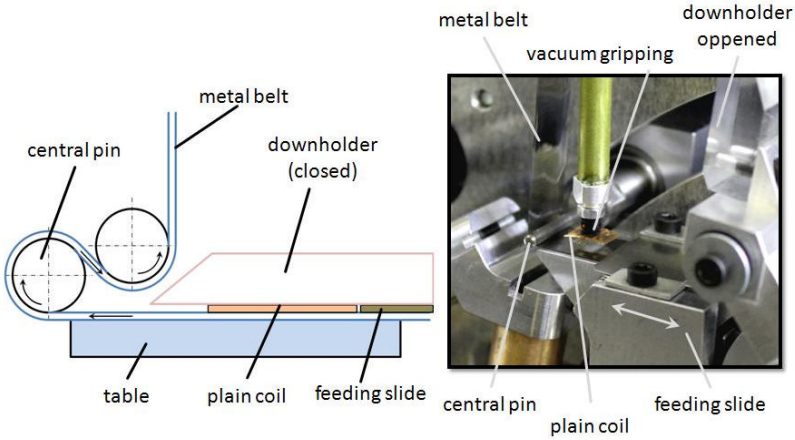

Figure 2: Forming principle and feeding arrangement

3 Assembly into the motor housing

After the forming process the coil arrangement sits between metal belt and central pin. For the assembly process the metal belt is automatically removed and the pin is moved sidewards to the assembly station. Figure 3 shows the central pin with a formed coil sitting on it. To complete the stator of the micro motor, the coil arrangement is inserted into the motor housing that is made from a high precision steel tube. This assembly process is done by moving the housing over the formed coil and the central pin that stabilises the fragile coil. The forming is regulated that way, that the formed coil has a certain amount of springback. This is necessary to fix the formed coil into the motor housing, but it makes the insertion process more complicated. To enable an automated assembly, a split device with internal funnel shape is positioned in front of the pin and the housing is pushed against it. Split device and housing are then pushed over the coil while the funnel compresses the springback. Just before the final position the split device is retracted and the coil further pushed in until both sides match, s. Fig. 3 (lower right).

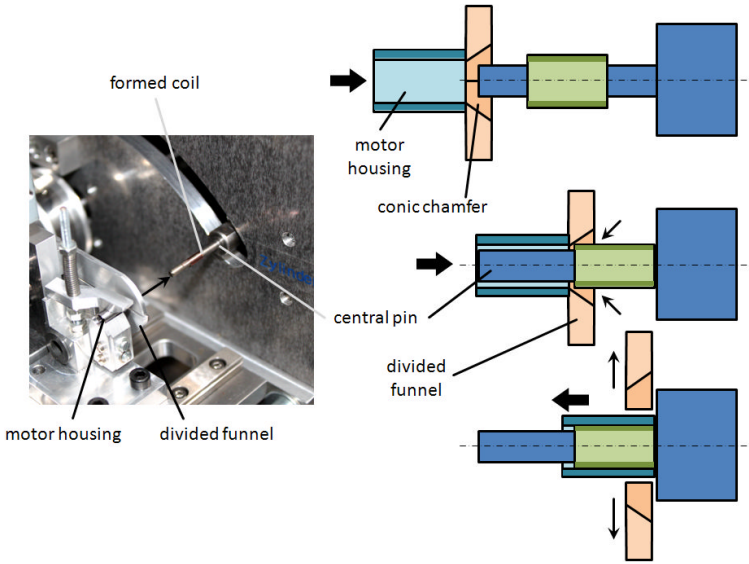

Figure 3: Assembly process of the formed coil into the motor housing

4 Quality control

The ohmic resistance has to be measured after the insertion of the formed coils into the motor housing as a measure of quality and to avoid further assembling of motors with non functional electric elements. Therefore the connector clip that is at the bottom of the formed coils is connected to 3 pins by which the resistance is measured and logged for each coil separately.

5 Prototype of forming machines for inner diameters of 1mm

Currently investigations are made of a further miniaturisation of the cylinder and therefore motor diameter. A prototype forming machine with a pin diameter of just 1 mm and manual coil feeding has been build up and first tests were successfully performed. It works with the same principle like the described set up for 3 mm coils. But the smaller bending radius of the metallic belt in case of the 1 mm motor leads to an increased bending stress on the metallic belt. This is solved by using a metal belt with a thickness of just 5 µm. Due to the small diameter of the pin, it needs to be mechanically supported on its second end. The small diameter also inhibits pin rotation when the belt is moved. So it was equipped with a separate drive and its speed is synchronised to the speed of the metal belt.

This automated forming device is an example of how MST-processes for the manufacturing of micro-products can be successfully expanded with process steps from the field of micro-forming. Also the possibilities for high quality and stable processes in the micro range by integration of well adapted features are demonstrated.

References:

[1] Kuhfuß, B.; Allers, S.: Forming planar micro-structures into 3D objects 10th International euspen Conference, May 31st-June 4th, 2010, Delft/Niederlande

[2] Schutzrecht (Offenlegungsschrift); DE 10 210 016 599 A1, Embedded Microsystems Bremen GmbH, DE 10 210 016 599 A1 2011.10.27. – Verfahren und Vorrichtung zum Biegen eines ebenen Werkstücks