SENSORS FOR THE SHEET-BENDING PROCESS

Sensorized Future – Sensing of temperature and pressure in harsh environments (SensoFut). In the project SensoFut, on which the Fraunhofer IST worked together with the Fraunhofer Institute for Machine Tools and Forming Technology IWU and the Belgian research association Sirris, innovative sensor modules for the sheet-bending process were developed. SensoFut was funded in the 13th Cornet Call (Collective Research Networking) by the Federal Ministry for Economic Affairs and Energy (BMWi) and the German Federation of Industrial Research Associations (AiF).

The challenge

In the production of sheet metal components, manufacturing defects often arise in the reshaped parts, such as creases, cracks and necking, and these mean a higher level of rejects. Integrating thin-film sensor systems makes it possible to regulate process control and thus even out fluctuations and minimize rejects. The development of thin film sensor systems for local force and temperature measurements on 2D and 3D geometries, in combination with tribological resistance is a special challenge here.

The solution approach

At the Fraunhofer IST a new kind of thin film sensor system was developed which stands in direct contact with the workpiece to be formed. The remarkable aspect is that temperature and pressure distributions could be detected locally on a strip drawing tool with a curved surface for the first time. Thereby the sheet-bending behavior is precisely determined by measurement of pressure and temperature distributions in the process.

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Strip metal drawing tool with full thin film sensor system.
Manufacturing process

The coating system consists of a piezoresistive amorphous hydrocarbon layer (Dia-Force®, d ~ 6 µm), a lithographically structured metal layer (chromium, d ~ 250 nm) and an insulating and wear-protective layer (SiCON®, d ~ 3 µm). To increase the sensitivity of the pressure sensors and to enable integration of temperature sensors, the coating system is given an additional insulating coating (SiCON®, d ~ 1.5 µm) in the region of the conductors and contacts. As can be seen in figure 1 and 2, the force and temperature sensor structures are distributed in an offset order over the curved face of the tool. The temperature sensors are meander structures made of chromium which are located between the force-sensing structures. The contact areas of the individual sensor structures are located on the edge region of the tool.

Test of the sensor module

At the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz the sensor module was fitted into a strip drawing machine in which load cases during the bending of metal strip were investigated. The functional capability of the multifunctional thin-film system was tested with aluminum strip (AA6016) as an example. It was preheated to a temperature of 200 °C and shaped over the curved face of the bending tool. To keep frictional losses between the sheet metal and the sensorized coating system on the tool as low as possible a special lubricating oil was used. An example of measurement results is shown in the diagram below. As a result of the contact between the hot sheet metal and temperature sensors T1 to T4 there is initially a rise in temperature. During the bending process the aluminum sheet moves over the individual sensor structures and thereby causes a fall in the sensor resistance of the force-measuring sensors F1 to F8. The bending process finishes with an abrupt unloading of the sensor structures which causes local resistance minima at each individual force sensor structure, as is clear from the diagram.

In the further course of the project the multifunctional coating system was transferred to complex-shaped tools in deep-drawing machines.

Characteristic curves of the individual sensor structures (cf. Fig. 3) during the forming process (sheet metal drawing force F = 10 kN, metal temperature T = 200 °C).

2 Microscopic image of the force and temperature sensor structures.

3 Coloured representation of the claimed force-measuring sensors F1 to F8 and temperature sensors T1 to T4 during the bending process.