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Investigations to Determine the Clamping Force of Screw Connections

Th. Frank, A. Grün, H. Jayaprakash, M. Kermann, S. Jagomast, A. Cyriax, C. Maier, Th. Ortlepp
Forschungsinstitut für Mikrosensorik GmbH, Konrad-Zuse-Straße 14, 99099 Erfurt, Deutschland,
tfrank@cismst.de

Summary:

A screw is a machine element for frictional connection of two or more components. Particularly security-relevant connections require regular checks. Subsequent checking of the assembly preload is not possible without various additional measures. It is advantageous to monitor the assembly preload. The article describes two methods for determining the clamping force using silicon strain gauges. The clamping force stretches the screw shaft, compresses the elements to be joined and deforms both the screw head and the nut or washer. The deformation of the screw head or the washer contains all information about the clamping force. The described use of the silicon strain gauges enables the deformation to be precisely recorded. The clamping force can be determined via the deformation.

Keywords: silicon, piezoresistive, stress, force tensions, screw shaft, assembly preload, strain gauges, washer, clamping force

Investigations to determine the clamping force of screw connections

A screw is a machine element for the frictional connection of two or more components. The tightening torque creates the clamping force between the screw head and the nut thread. The maximum permissible preload is defined by the screw diameter and the strength class of the screw. For a permanently secure and functional connection, it must be ensured that the preload is within a defined tolerance range over the entire service life. Particularly security-relevant connections require regular checks. A subsequent check of the assembly preload is not possible without various additional measures. By default, the tightening torque is checked manually. It is advantageous to monitor the assembly preload. The article describes two methods for determining the clamping force with strain gauges made of silicon. The clamping force tensions the screw shaft, compresses the elements to be connected and deforms both the screw head and the nut or washer. The deformation of the screw head or the washer contains all information about the clamping force. The deformation can be recorded precisely by using the silicon strain gauges described. The clamping force can be determined via the deformation.

Force measurement in microsystem technology is usually based on strain-sensitive resistors, strain gauges. A mechanical load in the doped areas leads to a change in the conduction mechanism, which changes the resistance. Here, the piezoresistive resistors are monolithically integrated into the silicon component by diffusion or implantation. Compared to standard metal strain gauges, the integrated semiconductor resistors have a higher coupling factor and significantly higher long-term stability.

Due to the piezoresistive properties of the silicon orientation <100> used, the measuring resistances are differentiated transversally and longitudinally. The change in resistance is similar in amount but with the opposite sign. A measuring bridge is built from two pairs of these measuring resistors, see Fig. 1.

To analyze the mechanical stress, the silicon strain gauge (according to Fig. 1.) is attached to the spring body. At the optimal position there is a large difference between mechanical tension in the X and Y direction. If there is no such optimal position, another construction is necessary. This is necessary because the silicon strain gauge has a symmetrical structure and does not have its own anisotropy. No other structure is possible in the silicon material used.

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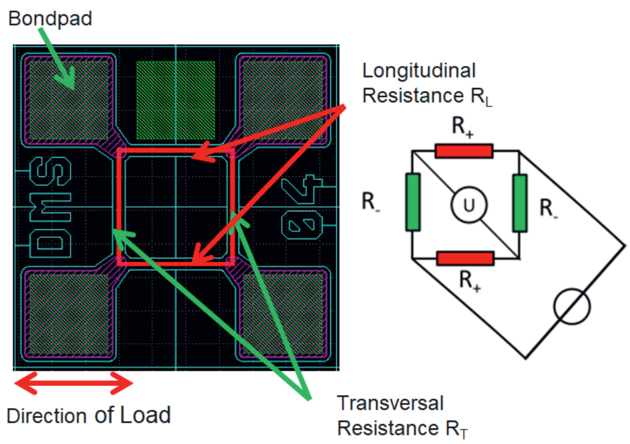

Fig. 1. Silicon strain gage with complete measuring bridge with two resistors for the longitudinal and the transverse effect.

Joining the strain gauge

The silicon strain gauges are joined using glass frit. Fig. 2 shows the joined silicon strain gages. The electrical contact for signal processing is ensured by wire bonding.

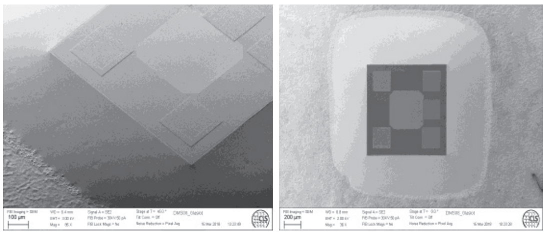

Fig. 2. Silicon strain gauge, fitted with glass frit on a steel spring body.

Placement on the screw head

The screw head is deformed by the clamping force. To determine this, strain gauges are placed on the head. The sensors can be attached directly to the screw head or via a mounting bracket. The mounting bracket enables easy mounting on larger screws. To enlarge the measuring span, the mounting bracket is provided with a bar, see Fig. 3. The measured values for an M33 are shown in Fig. 4.

Placement on the washer

Like the screw head, a washer also deforms. The use of the washer is more complex. The position of the bolt and washer depends on the tolerance. To compensate for this, at least three sensors are required. The measured values for a washer are shown in Fig. 5.

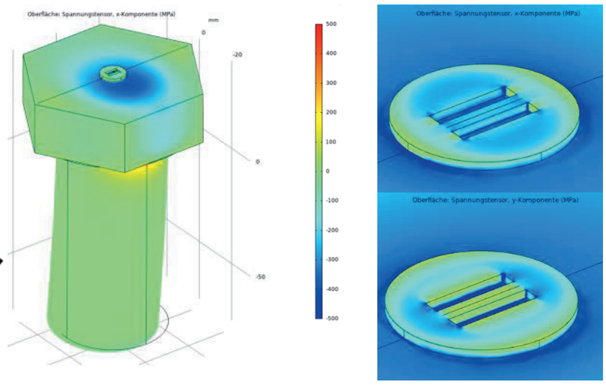

Fig. 3. Silicon strain gauge, mounting bracket.

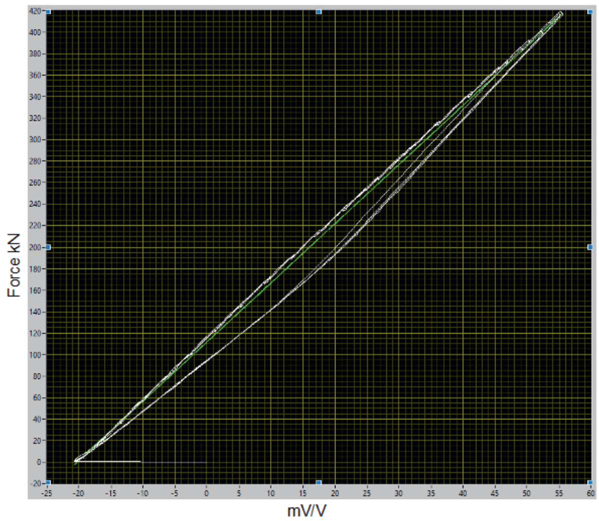

Fig. 4. Measured values for an M33, measurement signal vs. clamping force.

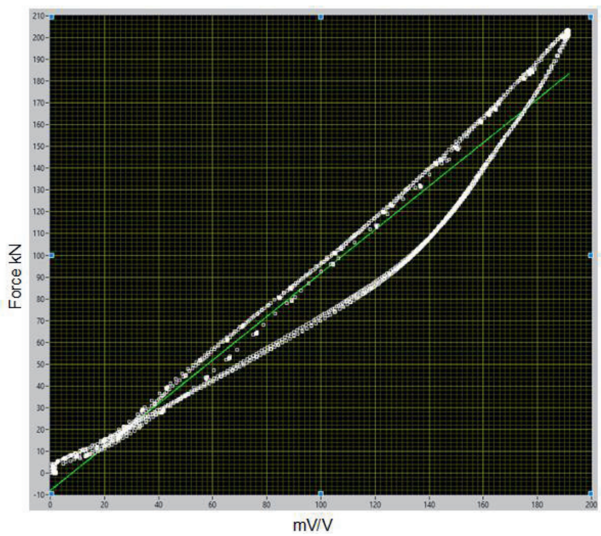

Fig. 5. Measured values for an M27 washer, measurement signal vs. clamping force.