

Elastically stable tensile force sensors for belt tension monitoring

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Summary:

In drive technology, timing belts and transmission belts are used to transmit large forces at large distances. Optimal power transmission depends on the belt tension. Consistently perfect belt tension increases service life and reduces wear. This ensures consistent quality and technical safety in the respective application. This article describes a silicon strain sensor and the necessary connection technology to enable continuous determination of the belt tension.

Keywords: silicon, piezoresistive, strain gauges, transmission belts, belt tension, force tensions

In drive technology, timing belts and transmission belts are used to transmit large forces at large distances. In order to withstand the operating conditions and force loads, the belts are combined with tension members made of steel cord or Kevlar. These run helically in the belt. In order to be able to detect the various changes in force acting on the belt, the sensor must be integrated on or in these tension members.

Miniaturized silicon-based strain sensors are used for the sensor, Fig. 1 left. Due to its small geometric dimensions of $500\ \mu\text{m} \times 500\ \mu\text{m}$, the strain sensor can be integrated into flexible arrangements. Based on the measuring principle and the small chip thickness, the smallest changes in force such as strain and tension can be detected. This makes them ideal for this application.

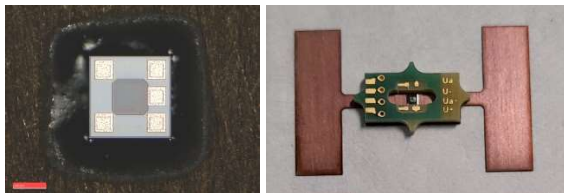


Fig. 1. Strain sensor (left) joined to mounting bracket (right)

To permanently determine the belt tension, the sensors must be directly coupled to the tension member. The coupling must completely enclose the tension member at the respective points. Fig. 2 shows the result of the simulation for coupling to the tension member.

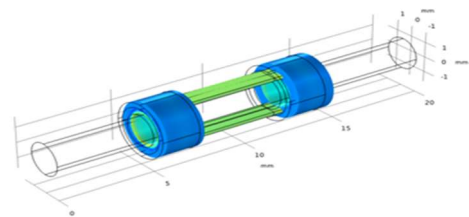


Fig. 2. Simulation of the coupling of the sensor system via mounting bracket to a tension member

H-shaped mounting brackets made of, for example, 1.4310, 1.4542, 1.4301 V2A are used for this, Fig. 1 right. The free ends are used for fastening to the tension member. Reinforcement with an adapted press sleeve is provided. For tension members made of steel cord, the two ends of the mounting bracket and the compression sleeve are optimally joined to the tension member using the laser welding process. In the case of tension members made of Kevlar, they are closed using a crimping process. Fig. 3 shows both variants.

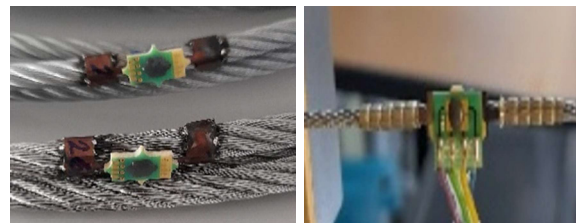


Fig. 3. Coupling to tension members with laser welding (left) and crimping (right)

This ensures that both joints are in contact with the same wires or threads. This significantly minimizes possible measurement errors.

Depending on the diameter of the existing tension members, different mounting brackets and correspondingly designed circuit boards are used for electrical contacting. The strain sensors are joined to the sensitive area of the mounting carriers using the glass frit method. Depending on the variant, the sensor and the contacting areas are encapsulated or covered to protect them from external influences.

The respective variants of the tensile force sensors were characterized according to the planned areas of application and showed positive results.

Fig. 4 shows the maximum change in the electrical sensor signal from the zero signal in relation to the measuring span of the sensors as a function of the temperature profile -10°C , $+30^{\circ}\text{C}$, $+85^{\circ}\text{C}$, $+30^{\circ}\text{C}$ and -10°C . With the exception of one setup variant, all show the same expected drift behavior.

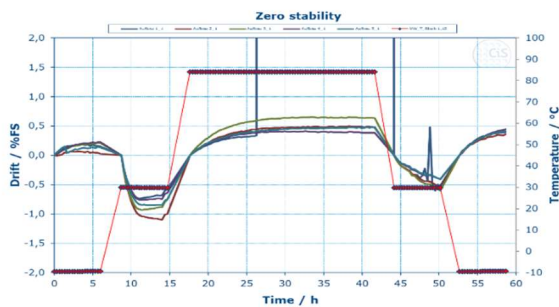


Fig. 3. electrical stability test at $T = -10^{\circ}\text{C}$ to $+85^{\circ}\text{C}$

Long-term measurements were carried out at $T = 25^{\circ}\text{C}$, $T = 85^{\circ}\text{C}$, relative humidity $\leq 40\%$, time = 168 h in order to rule out possible influencing factors due to the structure. Fig. 4 and Fig. 5 show that there is only a certain dependence on the relative humidity (red characteristic curve) at low temperatures ($T=25^{\circ}\text{C}$, blue characteristic curve) due to the PCB material and the protective encapsulation used. Due to the planned application, integration of the sensor system into the transmission belt, this influence is no longer decisive later on. The integration is hermetically sealed. As a result, good long-term stability could also be demonstrated.

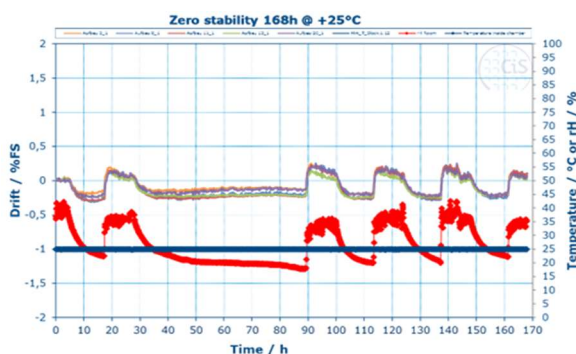


Fig. 4. Long-term stability measurement at $T=+25^{\circ}\text{C}$

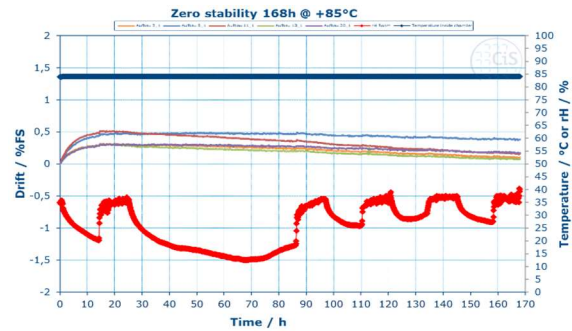


Fig. 5. Long-term stability measurement at $T=+85^{\circ}\text{C}$

With the positive characterizations, the planned measurement deviation of 1 - 2 %FS at $T = 25^{\circ}\text{C}$ and of 2 - 5 %FS in the range -10°C to $+80^{\circ}\text{C}$ for the mounted tensile force sensors could be successfully demonstrated.

The tension members (steel cord, Kevlar) were tested with the integrated tensile force sensors using various cable tensioning devices. For example, a force effect of up to 500N on a 2mm thick stainless-steel cord was detected for the tensile force sensor in Fig. 3 on the right, as shown in Fig. 6. The still low hysteresis is due to the crimp connection.

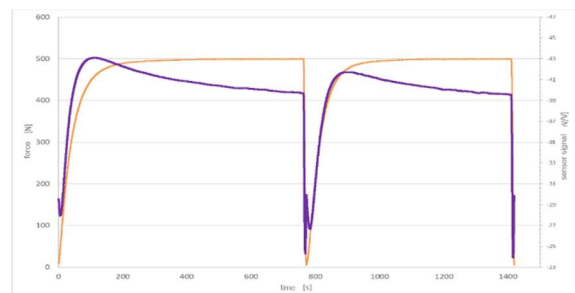


Fig. 6. Characteristic curves of tensile test up to 500N, force N on stainless steel cord (orange), sensor signal mV/V (purple)

This results in a signal change of 1mV/V per 50N of force applied for this cord variant. This corresponds to a sensitivity of 0.02 mV/V/N. And is therefore within the desired parameter range.

The tensile force sensor is used to monitor belt tension in drive technology systems, for example in sawing, cutting, milling and pointing machines, in packaging systems for conveyor belts or at test stations for table positioning. This allows maintenance intervals to be planned precisely, material fatigue to be detected at an early stage and unplanned downtime to be avoided.

Sources:

- [1] Verwendung von Siliziumdehnungssensoren für makroskopische Prüfkörper, Th. Frank, St. Hermann, A. Grün, D. Hanig, M. Kermann, M. Hintz, A. Cyriax, R. Röder, U. Krieger, MST Kongress 2023, Dresden, 23.-25.10.2023