Commissioning of sensors

This document contains some instructions for commissioning a force or torque sensor or multi - axis / multi - component sensor.

General

Before implementation of a series of measurements, preliminary tests should be carried out and documented since the characteristics of the sensor in the actual installation situation can differ from the properties under ideal measuring conditions.

Scaling factor

The prerequisite for the recording of measured data is the correct setting and documentation of the scaling factor.

The scaling factor represents the relationship between the physical input variable to be measured and the output value of the measuring chain.

Required data to set the correct scaling factor are:

- Characteristic value of the sensor in mV/V,
- Nominal force or nominal torque of the sensor, e.g. in N, kN or Nm or kNm,
- Input sensitivity of the measuring amplifier in mV/V,
- Output signal stroke of the (analog) measuring amplifier e.g. 5V, 10V, 16mA.

Technical data of the sensor		*Technical data of the measuring amplifier*	
Input	Output	Input	Output
Mechanical measuring range of the force sensor (**Nominal force FN**)	Electrical output of the strain gauge at nominal force FN (**characteristic value C**)	electrical measuring range of the measuring amplifier (Input sensitivity U_E)	Electrical output signal of the measuring amplifier at U_E (**Output signal amplitude U_A**)
500,00 N	1,005 mV/V	2,000 mV/V	5,000 V

In the example given, a sensor with a nominal force of 500 N is used which supplies an output signal of 1.005 mV/V.
The input sensitivity of the measuring amplifier used is 2 mV/V. The output signal of the measuring amplifier used at 100% control is 5,000 volts.

Measuring amplifier with analog output

$$U = \frac{1{,}005\, mV/V}{500{,}00\, N} \cdot \frac{5{,}000\, V}{2{,}000\, mV/V} = 0{,}005\, \frac{V}{N} \cdot F$$

The scaling factor for the whole measuring chain is 0.005 V/N.
At 500 N, the output signal is 2.500 volts.

At nominal load 500.00 N, the measuring amplifier is controlled by 50% because the sensor emits an output signal of 1.005 mV/V while the measuring amplifier has an input sensitivity of 2 mV/V.
In words: the scaling factor is
rated value / nominal force x output signal stroke / input sensitivity

Measuring amplifier with interface

For measuring amplifiers with interface, the following data are required to set the scaling factor:

- Characteristic value of the sensor in mV/V,
- Nominal force or nominal torque of the sensor, e.g. in N, kN or Nm or kNm,
- Input sensitivity of the measuring amplifier in mV/V,

Please use the corresponding function of the application software to set the scaling factor.
The maximum display range of a digital measuring system is in general:
Input sensitivity / characteristic value x Nominal force
This factor is often referred to as "measuring range" (U_A) or (MB) or "normalization factor" in the software.

$$MB = \frac{2{,}000\, mV/V}{1{,}005\, mV/V} \cdot 500{,}00\, N = 995{,}02\, N$$

For further information on the measuring chain, please refer to the document

http://www.me-systeme.de/de/basics/kb-display-en.pdf

Measures:

a) recording the unscaled measuring signal, or

b) documentation of the time of each deviation / modification / adjustment of scaling factors.

Sensor-characteristic value

The characteristic value of the sensor describes the relationship between the mechanical input signal of the sensor and the electrical output signal of the sensor.

The sensor characteristic value is determined during the calibration and is contained in the data sheet of the sensor's test protocol or in the calibration matrix of the 3- or 6-component sensor.

The data sheet contains the so-called nominal value. This is a target value (theoretical value) for the sensor. The "nominal value" can deviate from the real "characteristic value" in the test report.

The sensor characteristic value can also deviate in the installed state from the characteristic value in the test report, in particular in the case of diaphragm load cells or ultraminiature load cells. Causes for the deviations may be e. g. bending moments which are introduced in addition to the force or when the support of the force sensor is uneven or deformable.

The smaller the sensors, the more difficult it is to produce a reproducible voltage distribution within the sensor in the area of the strain gauges. Bending moments, transverse forces or deformation of the sensor on uneven contact surface, a voltage distribution is produced that deviates from the ideal case in the calibration machine.

Sensors for mechanical quantities must be switched "in series" to the measured value. There must be no force shunt. In the case of sensors for small forces, the supply lines and connecting cables can even effect a power shut-off. The force to be measured is then not transmitted 100% via the sensor. A part of the force is absorbed by the connection cable.

Measures:

a) calibration of the sensor on site in the device,

b) Provision of installation accessories for the calibration laboratory,

c) Multiple calibrations in different installation positions to measure the reproducibility.

Sensor-zero point

In the delivery state, the output signal of the unloaded sensor is e. g. ± 0.05 mV/V or ± -0.02 mV/V. The output signal of the sensor can be ± 1% in the unloaded state. ± 2%, in some cases also 10% or 20% of the sensor characteristic value. Causes for the deviations of the signal in the unloaded state are manufacturing tolerances and the dead weight and the mounting position of the sensor.

Wechselnde Belastung mit ±100% der Nennkraft kann zur Ermüdung des Federkörpers und zu einer Nullpunktverschiebung und schließlich zum Bruch des Sensors führen.

Measures:

a) adjustment of the sensor zero point before each measurement with the zeroing function of the measuring amplifier or with the zero-setting function of the data acquisition with short-term measurements,

b) check the zero point in the load-free state before or during the execution of long-term measurements.

Deviation of the zero point by drift

The zero point of the sensor depends on the temperature. Typical are, e. g. deviations from ± 0.01% of the characteristic value per °C temperature change. These deviations have always been determined on the assumption of a homogeneous temperature distribution at the sensor.

In the installed state, the deviation may be greater if the temperature does not have the same amount via the sensor.

Causes can be radiation sources, but also different heat capacities at the clamping (mounting surface, mounting flange) of the sensor and at the force introduction of the sensor.

An inhomogeneous temperature distribution in the sensor impedes the drift compensation by the Wheatstone bridge circuit.

Touching sensors results in a non-uniform temperature distribution and thus a drift of the zero point.

The drift of the zero point is usually also a function of the rate of change of the temperature due to different heat capacities between the force input and the force output.

Both the transmitter and the sensor require a period of a few minutes after switching on until a stable state is set.

As a rule, the power-on drift is not included in the technical data.

The insertion drift is dependent on the supply voltage of the measuring amplifier, the material thickness under the strain gauge, the covering mass, and the quality of the electronic components of the measuring amplifier.

Measures:

a) the use of thermally conductive sensor housings which provide "isotherms" for a homogeneous temperature distribution,

b) shielding radiation sources,

c) thermally insulated assembly to prevent unequal heat capacities between the injection and discharge of forces,

d) recording of the power-on drift of the measuring system,

e) carry out a zero adjustment in the unloaded state in the respective temperature stage.

Deviation of the zero point by zero point return error

The deviation of the zero point of sensors with strain gauges remains well below 0.1% as long as the corresponding spring steels or high-strength aluminum or titanium alloys are used and the sensor is not loaded above ± 2 mV/V.

When the force or torque is introduced via a linear guide or a lever system, considerable hysteresis errors can occur which are some percent of the measuring range.

Since the displacement of the force introduction is of the order of magnitude of approximately 0.1 mm, a hysteresis error of 1% corresponds to a permanent deformation of only 1 µm by means of adhesion.

<u>The sensor is only unloaded if an air gap between the sensor and the further construction is visible.</u>

In the parallel connection of force sensors, e.g. in weighing platforms, deformation energy can be stored in the weighing plate, e.g. by setting the screw connections.

Force sensors with two mechanical supports, e.g. Measuring bolts or double shear bars (sensors of the KS series), as well as 3D force sensors and 6D force / torque sensors can also store deformation energy in the mounting flange, which can lead to a zero point return error.

<u>Measures:</u>

a) use of "friction-free" spring-loaded guideways,
b) complete relief of the sensor during each load cycle,
c) use of force injections to prevent transverse forces,
d) support of the frictional connections by increasing the coefficient of friction, e. g. with Loctite 603 or similar products.

Deviation of the zero point by the assembly

Due to the deformation of the mounting surface, there is a detuning of the output signal, in particular with sensors with small dimensions or with sensors with large mounting surfaces.

The change in the prestressing force of a screw connection can therefore also lead to a displacement of the zero point.

Distortions on the machine frame e.g. through setting phenomena in the foundation can also lead to a bending or torsional loading of the mounting flange of a torque sensor and thus to the deviation of the zero point.

The hardness and flatness of the bearing surface have an effect on the characteristic curve of the sensor, since e. g. the zero point of the sensor is displaced with increasing load by pressing the sensor against an uneven contact surface.

<u>Measures:</u>

a) record the influence of the assembly.

Deviation of the zero point by environmental influences

Despite a degree of protection of IP65 ... IP67, a permanent use of a sensor under high humidity or with frequent wetting with condensation water and short drying times can lead to failure of the sensor. Moisture initially leads to a shift in the zero point and to a higher noise in the case of a reduction in the insulation resistance of the strain gauges to the sensor housing.

Sensors with a high degree of protection against humidity can sometimes have a higher temperature-induced drift due to the thermal expansion of potting compound. This applies in particular to sensors with small forces.

Measures:

a) avoid high humidity and wetting with water,

b) avoid permanent use of the sensor with moisture or water,

c) If necessary, provide cover against dripping water and regular drying of the sensor.

Sensor-linearity

The deviation of the sensor curve from a straight line is determined under ideal conditions. In particular, attention is paid to the flatness of the mounting surfaces and to point-shaped or bending-free force introduction.

These conditions can not always be realized in the actual testing device. Especially if the sensor is attached to two cutting edges for measuring tensile and compressive force or for measuring left and right torque.

This can lead to transverse forces and bending moments, which have an influence on the linearity of the sensor as a load-dependent disturbance variable.

The calotte of the force sensor represents a joint with 5 degrees of freedom and is thus a structural measure for reducing transverse forces and moments.

The loading of a force sensor between two planar plates places high demands on the flatness of the force sensor and the testing device. Under load, the tolerances are usually shifted.

Measures:

a) constructive measures in the test apparatus, e. g. joints, compensating couplings, symmetrical construction, etc.

b) select the appropriate sensor.

Error in data collection

Shielding

If the measurement data are recorded electronically, errors can occur. Mass loops in particular are one of the most frequent sources of error.

Some notes on proper shielding can be found in this document:

http://www.me-systeme.de/de/basics/kb-shield-en.pdf

USB interface

For electronic data acquisition via a USB interface, it must be noted that the data transmission may cause an interruption of the connection to the measuring device in the case of long-term measurements or in the case of electrical disturbances, thus leading to the recording of measured values.

The connection of additional USB devices can also cause the connection to the measuring device to be terminated, e. g. if the maximum permissible power requirement at the USB interface is exceeded.

If a Windows operating system should be used for long-term measurements, the automatic update must be deactivated.

The mass potentials of the USB interface are significantly above the potential of the protective conductor, especially for notebook computers.

This usually causes considerable interference with the power frequency. This results in a reduction in the ratio of measurement signal to noise amplitude. In this case, the low voltage terminal on the notebook must be connected to the protective conductor or the USB connection must be earthed.

USB hubs with their own power supply may help improve the stability of the USB interface.

Measuring frequency

For data acquisition according to the "sigma-delta" transformation principle, the ratio of measurement signal to noise amplitude is a function of the data frequency. In this case, it is advantageous to carry out the data acquisition with the maximum necessary data frequency. Setting a high data frequency followed by averaging may result in a poorer ratio of signal to noise.

In the detection of analog signals should be an oversampling with subsequent decimation of the data by filtering, such as. e. g. mean value formation.

From a measurement point of view, it must be ensured that no "aliasing effects" occur due to lack of filtering or low sampling frequency.

Measures:

a) correct shielding of the sensor leads,

b) separate laying of sensor and power cables,

c) use of separate power supplies for sensors and line electronics,

d) use of power supplies with grounding, especially when operating notebooks with USB data acquisition,

e) connecting the low-voltage connection of notebooks to protective conductors,

f) measuring the noise signal of the notebook during mains and battery operation,

g) defining a mass star point,

h) if necessary, connecting the USB cable with protective conductor or earth potential,

i) recording the measurement signal in the unloaded state, switching on additional consumers / sources of interference, e.g. Motors, thermostats, etc,

j) recording the measurement signal at different sampling frequencies in order to detect interference sources or aliasing effects,

k) insert additional load resistors at the inputs of the data acquisition (if permissible and necessary).

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