Important characteristics of force transducers

Thomas Kleckers
HBM GmbH, Im Tiefen See 45, 64293 Darmstadt
Email: thomas.kleckers@hbm.com

4. Electrical specifications

Input resistance (R_E)
The input resistance is the resistance that can be measured at the transducer connections where the excitation is connected. Due to the fact that additional resistors for balancing of the force transducer are connected to the Wheatstone bridge, the input and output resistance values can vary.
When connecting force transducers in parallel, please remember that the resistance of the circuit as a whole is reduced. This total resistance must not exceed the limit specified in the amplifier's operating manual.

Output resistance (R_A)
This is the resistance present on the wires connected to the amplifier input. When connected in parallel, the output resistance's tolerance should not exceed 10 ohm; otherwise cross currents could affect the measurement result.

Operating range of the excitation voltage ($B_{U,GT}$)
The excitation voltage is the force transducer's supply voltage; in general a range is specified. It is essential not to exceed the maximum excitation voltage, since otherwise the permissible voltage at the strain gages will be exceeded. As a consequence, the electrical power will be too high and the strain gage will become too hot. This will result in a change in zero point (temperature effect on zero point) and a change in sensitivity (temperature effect on sensitivity).

Reference excitation voltage (U_{ref})
All measurements for determining the characteristics are taken at reference excitation voltage.

Insulation resistance (R_{ISO})
The resistance between any connecting cable and the spring element is called 'insulation resistance'. It is essential that the insulation resistance corresponds to the value at ambient temperature specified in the data sheet; otherwise the transducer needs to be replaced, since the characteristics no longer are correct.

5. Temperature specifications

Nominal (rated) temperature range ($B_{t,nom}$)
In the nominal (rated) temperature range the force transducer meets the values given in the specifications.

Operating temperature range ($B_{t,G}$)
In the operating temperature range the force transducer enables measurements to be taken, however, the measurement accuracy is limited.

Storage temperature range ($B_{t,S}$)
The force transducer may be subjected to this temperature, however, it must not be used for measurement.

Reference temperature (t_{ref})
All measured values that are not temperature dependent, e.g., reversibility error, oscillation width, etc. are determined at the specified reference temperature.

6. Accuracy specifications

Linearity (d_{lin})
Linearity describes the real characteristic curve's maximum deviation from the ideal straight line. The value is given in percent relative to the nominal (rated) force.

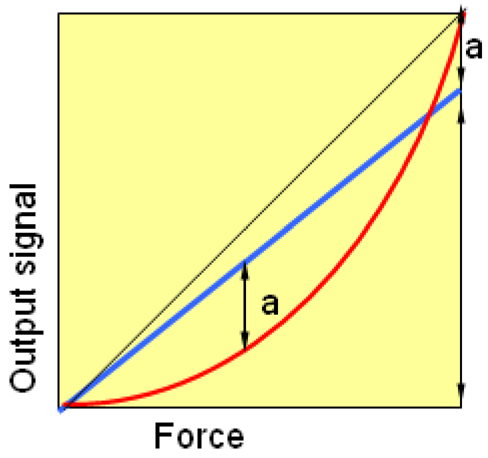
Often, no linearity error is specified with reference force transducers (U15, Top Class transducers, etc.) that offer maximum accuracy, because in these cases no sensitivity is used but, instead, a polynomial or interpolation points. In this case, the so-called relative interpolation error is specified, i.e. the maximum deviation from the fitting curve.

Furthermore, specifications for reference force transducers indicate the accuracy the force transducer will at least achieve during a calibration. In general, requirements as specified in the international ISO 376 standard are used, therefore, HBM provides corresponding values in its technical data sheets. Hence, the specified linearity refers to the actual value, i.e. it is relative to the measured value.

Force transducers for use in industrial applications or in experimental mechanics comply with VDI/VDE 2638. Here, linearity refers to the nominal (rated) force.

Example:

At 20% of its nominal (rated) force (1000 N), a force transducer has a linearity error of 0.2 N. The linearity error relative to full scale is 0.02%. The deviation relative to the actual value needs to be calculated based on 200 N and is 0.1%. This is five times the original value.

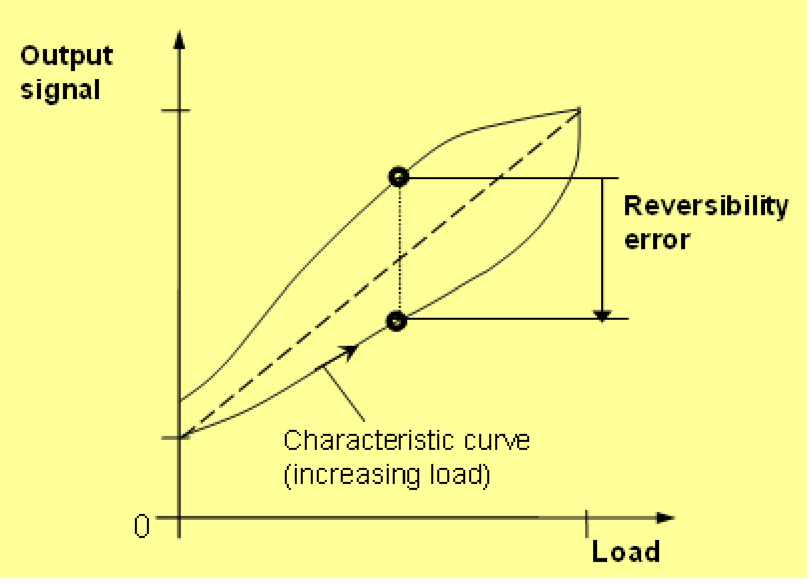


About linearity: The blue line is the ideal straight line, the red line is the actual characteristic curve. "a " is the deviation. "a" is specified relative to the nominal (rated) force in the data sheet.

In practical applications, the linearity error can be substantially reduced by competently selecting the transducer's calibration range. If a force transducer with a nominal (rated) force of 100 kN, e.g., is used at 50 kN, it can be calibrated in this range. This halves the error, since computation of the linearity error now can be based on the calibration range.

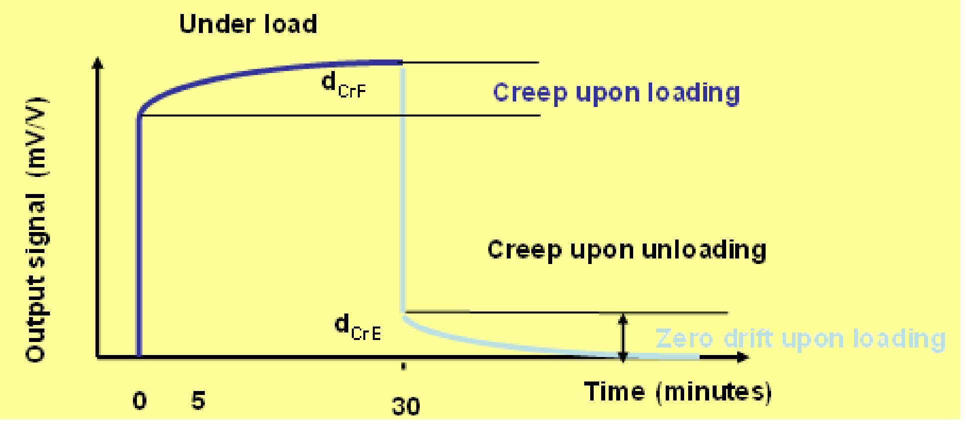
Relative reversibility error (v)
The relative reversibility error is the difference between the force transducer's characteristic curve with increasing and decreasing force. HBM specifies the maximum deviation. In addition, the data sheet specifies the force range in which the relative reversibility error has been determined. The value is specified in fractions of the nominal (rated) force (e.g., 0.4 F_{nom} = at 40% of the nominal (rated) force).

The relationship used for linearity applies analogously; with reference force transducers, the relative reversibility error is specified relative to the actual value.



About the relative reversibility error: The difference in measured values with identical force applied between increasing and decreasing force.

Relative creep (d_{crf+E})
All strain gage-based transducers show a small signal variation under constant loading which approximately has the form of an exponential function. This process is also called "creep upon loading". With the transducer being relieved of the force, the signal changes in the reverse direction in more or less the same way. This process is also called "creep upon unloading".

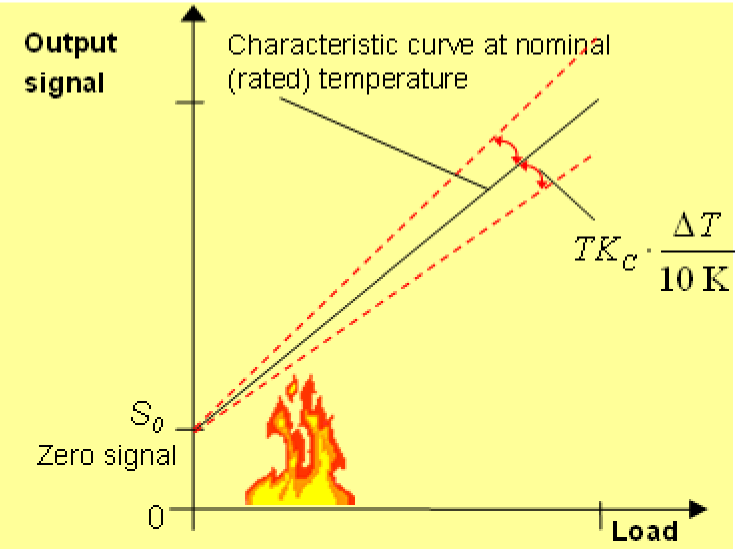


About force transducer creep: the principle.

The time period during which the value has been determined is specified in addition to the maximum value of the signal variation in percent.
It is essential to keep in mind that the creep influence must not be calculated relative to the nominal (rated) force but, instead, always needs to be calculated relative to the force applied. HBM specifies the creep value after 30 minutes; due to the typical form of an exponential function, this value can be assumed in good approximation as the creep maximum. This value must in no case be linearly extrapolated.

Temperature coefficient of sensitivity (TK_C)
Strain gage-based sensors show only a minute change in sensitivity resulting from temperature variation. This is due to the fact that the spring element materials' module of elasticity decreases with increasing temperature - equal force results in higher strain and thus a bigger output signal.
The strain gages' gage factor (the sensitivity), too, is dependent on temperature.

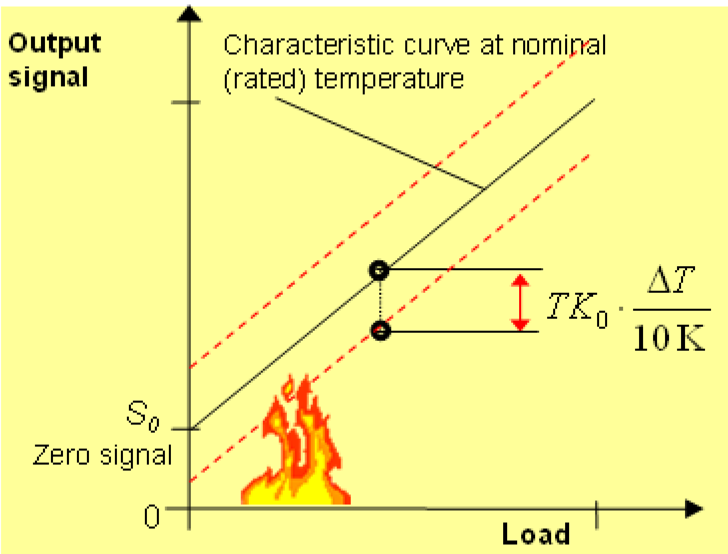
With many force transducers the sensitivity's resulting dependence on temperature is compensated for and is thus very small. With both creep and error computation, it is essential that the specified value is always related to the current measured value.



About TK_C: The gradient of the characteristic curve varies if the temperature changes.

Temperature coefficient of the zero point (TK_0)
In addition to the sensitivity, the zero point slightly varies according to the temperature. The Wheatstone bridge largely compensates for the effect of the individual strain gages. The remaining error is explained by tolerances that cannot be avoided. This small error can be further reduced by appropriate wiring so that modern force transducers have a remaining error of less than 0.05%/10K.

The temperature coefficient of the zero point always needs to be related to the nominal (rated) force, irrespective of what force is measured. For this reason, we recommend using a force transducer with a particularly small TK_0 when working under major temperature variations and/or in the partial load range.



About TK_0: Parallel shift of a force transducer's characteristic curve in the event of temperature variations.