The industrial benefits of utilizing well-proven strain gauges

Sensors are extremely important in the modern world. They are used to measure many different quantities in diverse fields of operation such as testing, data acquisition, automation and for quality assurance. This means that the market is expanding rapidly [(1)] and various different pick-up principles are increasingly being utilized.

This transitional trend towards a wider choice of technologies can lead to increased enthusiasm for newly emerging methods and it is worth considering the possibility that established technologies may have considerable advantages by the great experience built over many years.

For example, the foil-type strain gauge is based on well-established scientific principles [(2)(3)] that have been enhanced by technological advances to improve their tuning. In addition foil-type strain gauges are simple to install and utilize as well as being very low cost even for individual and singe solutions. The advantages of foil-type strain gauge easily outweigh their disadvantages.

Measuring with foil-type strain gauges

Metal foil-type strain gauges are widely used as the pick-up principle in force, torque and pressure measurements. The vast majority of force transducers, and also load cells, torque transducers and ultra-high pressure transducers are based on this design and are available in a wide variety of measuring bodies.

All foil-type strain gauges are based on a common principle; they use positive or negative strain to convert mechanical changes into electrical signals. In dedicated spots on the spring body, there high strain occurs in case of load introduction a minimum of four strain gauges – two under positive and two under negative strain – are connected to a Wheatstone bridge circuit. This kind of a „double voltage divider“ with resistances changing opposed to each other, so the output voltage is nearly proportional to the deformation of the spring body.

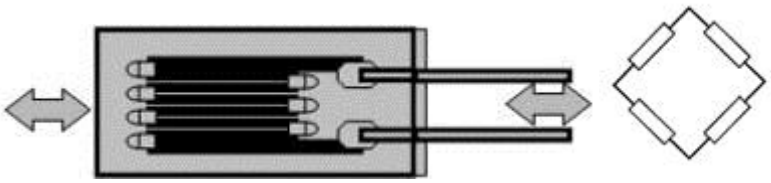

Fig. 1: Strain gauges are connected to a Wheatstone bridge circuit to give a voltage output that enables any deformation to be easily measured.

The output signal is given as a ratio between the voltage supply and the output voltage. It is calculated as follows:

$$\frac{V_o}{V_i} = \frac{1}{4} \cdot \left(\frac{\Delta R_1}{R_1} - \frac{R_2}{R_2} + \frac{\Delta R_3}{R_3} - \frac{\Delta R_4}{R_4} \right)$$

Foil-type strain gauge transducers are the most accurate for determining mechanical quantities. At the same time they are the best choice to provide lowest uncertainties.

If at the same time dynamics are important strain zones have to be designed as small as possible ensuring high stiffness [4][5][6].

The principles of strain gauge operation are well established meaning that full focus can be maintained on the measuring task.

Unlike many other pick-up principles foil-type strain gauges can be built for nearly unlimited high nominal loads simply by scaling up the measuring body. Examples are force transducers in MN range, torque trasducers in MNm range and ultra-high pressure transducers in GPa range [7].

In other applications, for example, pressure transducers measuring hydrostatic pressure there are more pick-up choices than for other mechanical quantities. Lower pressure applications, which account for the largest segment of this market, usually utilise capacitive or piezo-resistive MEMS solutions, especially for measurement of low pressures of a few bars. Overload resistance is particularly important for measuring high pressures that effectively excludes capacitive and piezo-resistive MEMS solutions – despite some progress with newer designs in recent years.

Figure 2 provides a comparison of the different types of strain gauge technologies and their suitability in pressure measurement from a number of different perspectives.

Pressure Transducer characteristics	Importance	Foil-type strain gauge	Thin film strain gauge	Piezoelectric crystal	MEMS
Accuracy	10				
Ultra High pressure	10				
Robustness	10				
Dynamic load cycles	10				
Long – Term stability	10				
Overload resistance	10				
Low pressure	5				
Temperature	5				
Dimension/size	1				

Legend	
Very good	
Fairly good	
Reasonable	
Poor	

Figure 2: Comparison of different pressure measurement technologies [8]

Examining this table reveals that strain gauge based ultra-high pressure transducers are the primary choice for measurements where very high accuracy and long term stability are needed. This is especially relevant when comparing the results of various national metrology institutes in different counties [9].

It is possible to undertake a similar analysis of the different principles for every other measurable quantity. This is best undertaken when trying to design a measuring chain optimized for a particular measuring task since the selected pick-up principle is an important interface to the process or phenomena being investigated.

Conclusion

Strain gauge transducers provide incredible accuracy, very high long-term stability and a good bandwidth suitable for rapid measurements. Passive resistive networks can easily adjust most remaining errors in transducer manufacturing. Strain gauge based transducers are the best choice for most large-scale but also individual and single industrial tasks and especially for high precision measurements. The high levels of accuracy facilitate the tracing of mechanical quantities up to national and international level [(10)(11)(12)].

In more mainstream applications the simplicity and low cost of foil-based strain gauges make their use significant in core markets such as load cells of all types ranging from retail up to truck scales.

Aiming at the importance of strain gauges, they deliver considerable contribution to industrial development of both developed and emerging markets.

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