FORCE, STRAIN AND PRESSURE TRANSDUCERS BASED ON FOIL TYPE STRAIN GAUGES AS WELL AS THE PIEZOELECTRIC PRINZIPLE FOR THE USE IN INDUSTRIAL APPLICATIONS

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Abstract: Sensorics in industrial processes increasingly require both fast date processing and very accurate measurement. This is because manufacturers expect consistently reliable quality control in their production. HBM force, strain and pressure transducers measure static and dynamic loads, according to the need of the specific measuring task, using the latest technology.

Keywords: force, strain and pressure transducers, strain gauges, piezoelectric principle

INTRODUCTION

There are two trends in industrial processes that seem to in opposition. One trend has been present for some time and that is the demand for increasingly faster processes. By contrast, quality, and thus measurement precision during manufacturing, is more important than ever before.

There are clear reasons for these trends. Both the cost of labor and the value of the goods, mostly the raw materials they are made from, are increasing in value. This trend is going to continue for the next few years, however, there are limits on the price increases of finished goods. Market sensitivity means that manufacturers are unable increase the price of their products by the full cost burden. This leaves them with only one option, to further increase the yield in the industrial processes. This means that product tests can only be done on completion, but selection of the materials must be done at an early stage of production to keep material and labor costs limited as low as possible. That results in the need for both fast data processing and, simultaneously, very accurate measurement.

BASICS OF SIGNAL PICK-UP

It is worth considering the basic measurement techniques with a view to comparing them to each other.

HBM has more than 55 years of experience in measurement and most of our success is becaue of the strain gauge principle. The application of any measurand - force, strain or pressure – causes a deformation in the steel measuring body that can be determined with strain gages.

In a material's elastic deformation range the methods of calculating material stresses from the measured strains are based on Hooke's Law. In its simplest form Hooke's law is [1]:
s = e · *?* (1)

where s = material stress; e = strain; and *?* = modulus of elasticity of the material

This version of Hooke's Law only applies to the uniaxial stress state**.** Other stress states require extended versions.

This strain can be picked up by the well-known strain gauges shown in figures [2], [3].

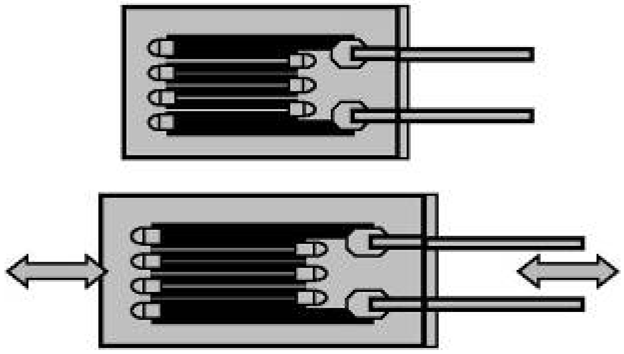
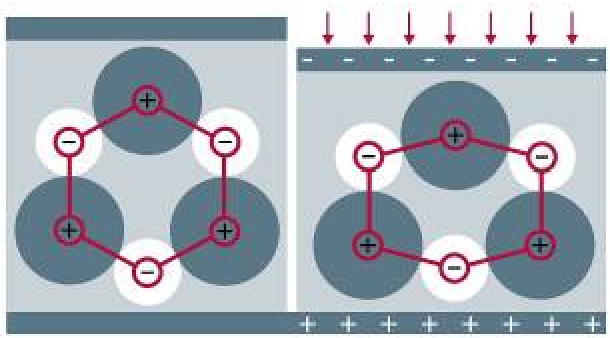


Figure 2. Schematic sketch of a strain gauge a) Original situation b) Changed resistance under force

The variation of its resistance is

$\Delta R/R_0 = k \cdot \varepsilon$. (2)

Where e = strain; k = gage factor; ΔR = change of resistance; and R_0 = basic resistance. The other possibility is to use the piezoelectric principle. The following picture shows what happens to the crystal if a compression force is applied.



a) b)

Figure 3. Schematic sketch of piezoelectric principle a) Original situation b) Charge displacement under force

Charge is generated by

$Q = q_{11} \cdot F$. (3)

Q = charge q_{11} = piezoelectric constant F = force

Basically both measuring principles transduce the force into an electrical signal. The dependence is similar, while sensitivity and linearity are often not really selection criteria anymore (Fig. 4).

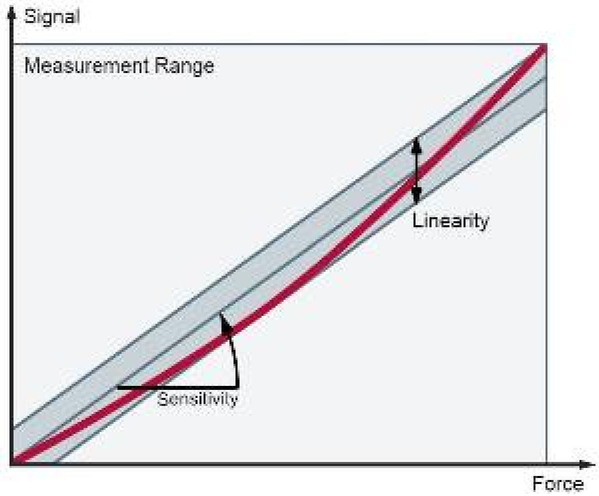


Figure 4. Relation of force and signal out

ULTRA HIGH PRESSURE MEASUREMENT

The capability of the strain gage principle can be demonstrated by pressure transducers. Applications in the ultra-high pressure range are growing with the manufacturing of diesel injection components, such as nozzles and rails or even just pipes, of particular interest. Functional testing can be carried out at working pressure or under increased test pressure.

Applications include increasing the lifetime of diesel engines along with abrasive water-jet cutting and high-pressure cleaning. High-pressure sterilization, as a method of conservation in the food industry, is growing in importance and the improvement of the equipment constantly requires transducers with higher nominal pressure ranges.

Figure 5 shows the schematic electric circuit of a pressure sensor with a Wheatstone Bridge (WB) based on the strain gauge principle.

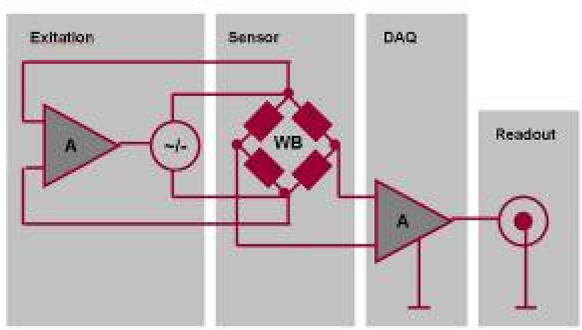


Figure 5. Principle of strain gauge amplifier

The strain gages are applied after the measuring body is finalized, which has the advantage of not limiting design possibilities or hindering machine tool technology steps. This means the measuring body can be realized as a monolithic design, making its lifetime much higher than systems available so far [4].

The patented design of the transducer, without any welding seams gives excellent properties, even in the maximum pressure ranges [5]. The newest development is HBM‘s P3 “TOP Class Blue Line” Transducers.

The Top Class series provides a better temperature response by individually documented values, improved accuracy class and a closer sensitivity tolerance [6].

For emerging high-pressure applications, traceability with the highest possible accuracy is also a standard requirement for these ultra high pressures. Many National Standard Institutes throughout the world rely on its outstanding accuracy [7].

Table 1 is giving the key technical data, figure 6 shows a picture.

Nominal range	5 000 bar	10 000 bar	15 000 bar
Nominal sensitivity	1 mV/V	1 mV/V	1 mV/V
Initial accuracy	0.25%	0.4%	0.6%
Long-term stability of zero signal and span (data per year)	0.2%	0.2%	0.2%

Table 1. Key technical data of P3 “TOP Class Blue Line” Transducers

Figure 6. P3 Top Class Blue Line, Pressure Transducers for Ultra High Pressure up to 15 000 bar

FAST FORCE MEASUREMENT BY PIEZOELECTRIC MEANS

The key advantages of the piezoelectric solution are the very compact shape of the transducer, virtually without any displacement, and the very dynamic pick-up of any signal changes.

Figure 7 shows the schematic electric circuit of the piezoelectric sensor.

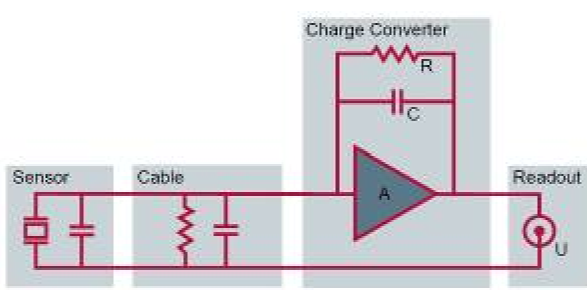


Figure 7. Principle of Charge amplifier

The PACEline CMC -Piezoelectric force measurement chain, consisting of the piezoelectric transducer core and a galvanically isolated charge amplifier, enable loss-free determination of the breaking force directly in the force flow. The robustness and rapidity of the piezo technology used here, together with the high rigidity of the piezo sensors, is perfectly designed for tough industrial applications.

The force transducer and analog amplifier are supplied as a unit that has already been adjusted and calibrated. This also enables the unique zoom function to be implemented which can be used, in particular, for monitoring overload critical processes at increased resolution (20% of the nominal measurement range). So where formerly two transducers needed - now only one transducer may be sufficient.

PACEline offers more than you could expect from piezoelectric sensors so far. It provides smart features to make process control more reliable and convenient. It provides the technology that ensures maximum quality assurance in production – even for measurements with virtually no displacement and where space is a constraint.

Figure 8 shows the range of PACEline transducers.

Figure 8. PACEline CMC - Piezoelectric Force Measurement Transducers

Typical application areas in industrial applications include bench testing, such as force measurement to check material quality and automation technology, e.g. for monitoring quality during reshaping or bonding operations.

SIDE BY SIDE AND TWO IN ONE

Still the majority of HBM´s force measurement line is based on the strain gauge. There is a simple reason for this. Often zero point stability as well as long term stability is more important than speed. Most strain gage-based force transducers are suitable for measuring tensile forces and pressures. They measure static and dynamic forces with highest accuracy [8].

This is why HBM provides both transducers based on foil-type strain gauges as well as the piezo-electric principle for use in a very wide range of industrial applications [9]. All transducers are manufactured from stainless steel and are suitable for use under harsh environmental conditions and severe operating constraints. They are maintenance free and can even be installed in places that are hard to reach. An important additional feature on the piezo-electric side is that the higher accuracy additionally allows providing the same performance of two or more sensors with different measuring ranges in one sensor.

STRAIN MEASUREMENT

Strain measurement is moving forward and giving quite tight tolerances in the manufacturing process. They are easily installed on existing structures. The strain gauge based SLB 700A strain transducer attaches directly to a plane surface with a friction joint and four bolts. This arrangement enables the strain of the test object to be transferred directly to the strain meter, making it ideal for installations where lack of space, or installation conditions, makes it difficult to use standard force transducers**.** Up to date applications cover weighing as well as in, for example, wind wheels.

TEDS IDENTIFICATION

A very innovative feature is TEDS (Transducer Electronic Data sheet). HBM offers transducer identification for both pressure transducers by means of strain gauges and also piezo-electric force transducers. The principle is about the same. The characteristics of a transducer are stored in a chip inside it in the form of an electronic data sheet. The amplifier can import this data and then converts it automatically into the right settings. This means it gets on with measuring straight away, in the correct units, with no further effort on the user's part. The user can benefit from this "Plug and Measure" – the technology that lets you just plug in and get started.

CONCLUSION

The strain gauge, in the classic shape as a foil-type strain gauge, is perfectly dedicated for the measurement of pressure, force, load or torque. If a suitable measuring body shape is chosen and a good compromise between solidity and sensitivity of the construction is found, there is no better solution around. Nowadays sensors are exposed to ambient conditions that used to be avoided, which increases the demands made on our products. New technologies in encapsulation or progress with the strain gauge's carrier and measuring grid make it easy for the strain gage to cope with such conditions.

Often an amplifier should be on-board. It started with pressure transducers, their easy installation and stand-alone features first forced the development of pressure transmitters, so pressure transducers were developed with built-in amplifiers. Nowadays the customer's request this solution for nearly all types of quantities. Both strain gauge and piezoelectric principle benefit from this solution, as it provides a well-defined output signal.

Taking this into consideration a charge amplifier, necessary to run the piezoelectric crystal, is not really an additional effort. Today's charge amplifiers are superb and allow a quite stable signal over a long time. The user has certain advantages in terms of a very compact shape of the transducer with nearly no displacement and, of course, very excellent dynamic behavior.

Finally ultimate accuracy is required for force, load, torque and pressure measurement in national institutes and accredited calibration laboratories. This is to remain the domain of the strain gauge. Thanks to years of varied experience HBM precision transducers for calibration meet this high standard. HBM is – since 1977 – the first accredited German Calibration Service (DKD) Laboratory. Today it covers all the mentioned quantities: force, pressure, torque and voltage ratio mV/V, and is one of the best known and most capable calibration laboratories of its kind holding accreditation according to DIN EN ISO/IEC 17025.

HBM ´s industrial transducer line benefit from this heritage and possibly the future lies in a combination of the two very different principles in one universal transducer with both unlimited accuracy and dynamics at the same time. Also, from a different perspective, there are applicable principles of working side-by-side, due to the very different approaches, that make safety orientated solutions very interesting.

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