Technical Article

Piezoelectric Measurement Technology: a Key Factor in Business Success for Industrial Manufacturers

Global competition in the industrial manufacturing sector is ratcheting up the requirements for quality and precision as time goes on. So what is the most efficient and cost-effective way of optimizing and controlling the entire production chain? For many production enterprises, the solution has proven to be integrated monitoring of dynamic processes – especially with the help of piezoelectric sensors.

The vision of Industry 4.0 is already becoming a successful reality in numerous industrial applications nowadays – in sectors such as automobile manufacturing, medical technology and electrical engineering. Unprecedented optimization of all production processes is now possible thanks to increased digitization and the growth of machine and system networking. Consistent control of the production chain – with zero-defect production as the goal – is essential for any modern production business to hold its own in the market of the future.

Just a few years ago, virtually all products were still being inspected offline – i.e. after the manufacturing process as such. Nowadays, by contrast, more and more products are actually monitored during the production process – or 'inline' – as a way of avoiding unnecessary costs. For joining, assembly and testing, sensor technology based on the piezoelectric principle is a fundamental factor in optimizing production processes with zero-defect production as the goal. This technology is outstandingly suitable for measuring physical variables such as force, pressure, acceleration and torque.

Piezoelectric Sensors: the Fundamentals

The physical basis for the use of sensors such as these is the 'piezoelectric effect', discovered by Pierre and Jacques Curie in 1880. When placed under a mechanical load (Greek "pie-zein": to press or squeeze), piezoelectric materials generate electrical charges. A major step towards the application of the piezoelectric effect was taken in 1950 when Walter P. Kistler patented the charge amplifier for piezoelectric signals.

Particularly good use can be made of the piezoelectric effect with a quartz crystal: when a mechanical load is applied to quartz that has been suitably processed, a charge signal can be generated from it that is directly proportional to the acting force. So – in contrast to other technologies – capture of the measurand using the piezoelectric effect is not dependent on strain and displacement. In this case, the dimension of the quartz element merely determines the maximum permitted amplitude for the measurand. It follows that the signal generated by a large sensor is comparable to one from a smaller sensor with the same structure. The downstream amplifier is then used to set the required measuring range, making precise measurements possible across several decades with just one sensor, and with no need to change the mechanical structure.

Kistler also offers piezoelectric force sensors with an ICP® output: in this case, the raw signal is already converted into an output voltage of 5 or 10 volts in the sensor.

Due to the extremely high rigidity of the crystal, the measuring deflection is low – usually in the range of several kilonewtons per micrometer, giving the measurement system a high natural frequency. This is a key criterion for highly dynamic processes in particular. Another important factor: quartz and crystals exhibit no fatigue or long-term effects such as zero point offsets or linearity changes. In some cases, the use of piezoelectric sensors may be limited by charge drift that occurs for physical reasons. Depending on the measurand's amplitude and the design of the measurement technology, quasi-static measurements are nevertheless possible for periods of several minutes or even hours.

Thanks to the quartz sensor technology developed by Kistler since the 1950s, dynamic forces can be measured both directly and indirectly. For direct measurements, the sensor is positioned fully in the force flux (1), and it measures the entire force. This approach yields high measurement accuracy that is virtually independent of the force application point. If the sensor cannot be positioned directly in the force flux, it will only measure part of the force (3); the remainder passes through the structure in which it is mounted (known as the force shunt). With indirect force measurement, strain sensors are used to measure the process force indirectly via the structural strain (2).

Applications in Research and Industry

In addition to overall economic considerations, installation conditions are becoming increasingly important nowadays. Dimensions are often a critical factor in the choice of a force sensor. Quartz sensors are outstandingly stable, rugged and compact; they can often be installed at measuring points where other technologies cannot be used at all. These attributes account for their widespread use not only in research and development but also – and to an increasing extent – on production lines and in industrial testing technology.

To take one example: dynamic force measurements that exhibit long-term stability are required for aging and load investigations on automotive components – such as pressure, tension, crash and endurance tests on locks, doors, engine hoods, trunk decks, seats and springs, etc. In this context, quartz force sensors are superior to other sensors because quartz exhibits no signs of aging, so calibrations can mostly be limited to cycles specified in quality assurance systems such as DIN EN ISO 9001:2015. These advantages save time and money across the board. For certain applications, quartz force sensors offer various technical benefits as well as the advantage of major cost reductions thanks to their lower life-cycle costs.

Piezoelectric force sensors are used for dynamic force measurements (e.g. in punching processes for sheet metal parts); in addition, they are deployed for quasi-static processes such as press-fitting of bearings in engine blocks. In such cases, the process forces can be activated safely: the measurement technology remains undamaged even when force peaks occur that could permanently destroy conventional measurement systems.

Systems from Kistler offer optimal quality assurance solutions for the analysis and documentation of injection molding processes. Cavity pressure is the most informative process variable, because it describes conditions immediately – while the molded part is actually being created. On the basis of cavity pressure, therefore, sensors and systems can detect at the earliest possible stage whether good parts or rejects are being produced.

System Solutions for Process-Integrated Quality Assurance

So that the data captured by highly sensitive piezo sensors can actually be used, it is visualized, evaluated and documented in suitable monitoring systems. When these measuring systems are integrated into the manufacturing sequence, early detection of production defects becomes possible – thereby reducing the potential risk of financial losses due to faulty parts.

In assembly technology, Kistler's maXYmos system reliably monitors the production processes. The result: production can be optimized towards the goal of zero defect production with maximum cost efficiency. Outstanding features of the system are its exceptional flexibility and user-friendly operating interface. It can be used not only for automated joining and press-fit processes but also for manual operations such as pressing processes carried out by hand. In addition to production and assembly, applications for Kistler's sensors and XY monitors include verifying the functionality of the end product. Thanks to the exceptional versatility of Kistler's XY monitors, they can meet the requirements in all industrial sectors where quality assurance is becoming a prime consideration.

Focusing on Enhanced Cost-Effectiveness

Piezoelectric sensors and the related monitoring systems from Kistler are now being deployed in Europe, the USA and Asia – in fact, across the entire globe. Sensor technology based on the piezoelectric principle delivers a remarkable increase in process reliability within a company's production chain, coupled with a sustained improvement in productivity – opening up the way to zero-defect production and maximized process efficiency. From a business point of view, this high-precision technology serves one purpose above all others: it creates a sound basis for economic success in a market where competition is fierce in every part of the world.

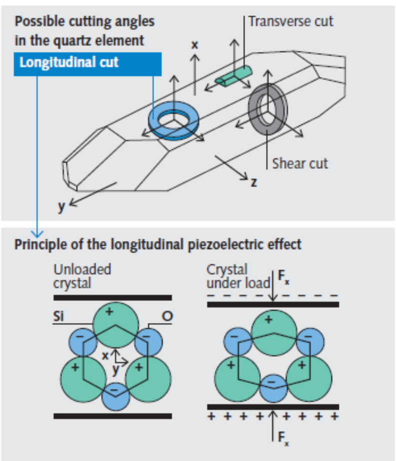

Figure 1

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measure. analyze. innovate.

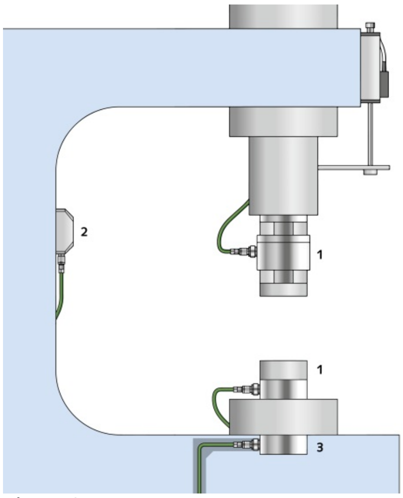

Figure 2


Figure 3

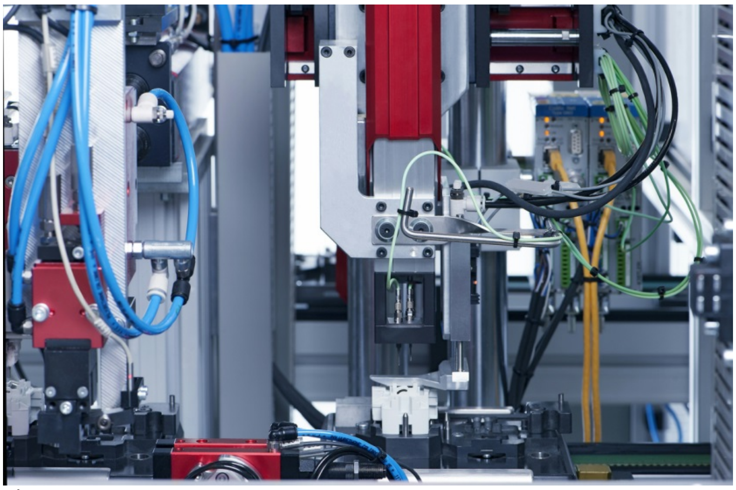
Figure 4

Figure 5

Captions:

Figure 1: Particularly good use can be made of the piezoelectric effect with a quartz crystal: when subject to a mechanical load, it generates a charge signal that is directly proportional to the acting force.

Figure 2: Depending on the installation conditions, various sensors are available to provide optimal production monitoring: 1. Direct measurement (the entire process force passes through the sensor). 2. Indirect measurement (a small part of the force passes through the sensor). 3. Shunt measurement (force is measured indirectly via the bending of the C-frame press).

Figure 3: maXYmos XY monitors can monitor and evaluate the quality of a product or manufacturing step on the basis of a profile. With the help of evaluation objects (EOs), the user adapts the curve evaluation to the specific monitoring task.

Figure 4: Small force sensors are compact and space-saving to optimize integration into the machine design.

Figure 5: With its exceptionally narrow diameter of only 8 mm, this measuring pin is the perfect addition to Kistler's extensive range of strain sensors.

About the Kistler Group

Kistler, the originator of piezoelectric measuring technology, is the global leader in dynamic pressure, force, torque and acceleration measurement. Cutting-edge technologies provide the basis for Kistler's modular systems and services.

Customers in industry, research and development benefit from Kistler's experience as a development partner, enabling them to optimize their products and processes so as to secure sustainable competitive edge. This owner-managed Swiss corporation plays a key part in the evolution of automobile production and industrial automation, and its innovative sensor technology also helps foster the development of many newly emerging sectors. Drawing on our extensive application expertise, and always with an absolute commitment to quality, Kistler drives innovations ahead in lightweight construction, vehicle safety, emission reduction and Industry 4.0.

Some 1,500 employees at 56 facilities across the globe are dedicated to the development of new measurement solutions, and they offer individual application-specific support at local level. Ever since it was founded in 1959, the Kistler Group has grown hand-in-hand with its customers and in 2015, it posted sales of CHF 329 million. About 10% of this figure is reinvested in innovation and research – with the aim of delivering better results for every customer.

About the Author

Matthias Giese heads the Production Monitoring Business Field at Kistler Instrumente AG in Winterthur, Switzerland. He has many years' experience of piezoelectric force measurement and its application in connection with XY monitoring systems. Monitoring systems play a crucial part in 100% quality assurance for the Business Field's customer base, which largely consists of direct or indirect suppliers to the automotive industry.

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