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PROBLEMS OF DYNAMIC PRESSURE MEASUREMENT

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Abstract: Pressure sensor elements are in general able to swing. Some data sheets tell the damping constant and the natural frequency. These dynamic characteristics influence the measuring values in case the pressure alters very fast. If the pressure changes with frequencies which are in the near of the resonance frequency of the sensor large measuring deviations will occur. But we did not learned yet how much the damping constant and the natural frequency of the sensor will be, when it is mounted and has contact with the fluid.

Keywords: dynamic measurement, pressure measurement, damping constant, natural frequency, resonance frequency

EXTENDED SUMMARY

There are an increasing number of applications of dynamic pressure measurements. It is important to measure fast changing pressure signals correctly. In theory therefore it is necessary a pressure sensor with an infinitive high natural frequency. Of course this is not possible, because nobody can create a sensor with a spring element (membrane or tube with strain gages) without mass or with infinity stiffness. It is the similar thing with piezoelectric sensors. Pressure deforms the sensible part of the sensor independent from the measuring principle. Without deformation you cannot get an output signal which is proportional to pressure. Deformation means that a mass is displaced a little bit. The displacement needs time. In case the time is too big a dynamic measuring deviation will occur. The dynamic measuring deviation depends on the velocity of pressure change and the dynamic characteristics of the pressure sensor: natural frequency and damping constant. But the dynamic measuring deviation is also influenced by the application conditions.

This is easy to understand for force transducers and load cells. These are also systems, which are able to swing, because they do have a mass and stiffness. Their damping constant is roughly 0.01 in general. That means we do not have to distinguish between natural frequency and resonance frequency. Now an example: It is given a measuring range of 1 kN, a nominal displacement of 0.4 mm and a fundamental natural frequency of 2.5 kHz in the data sheet for a force transducer. That means we can measure sinus wave changing forces up to 500 Hz with a deviation of the amplitude with less than plus 4 % of the true value. And we are able to measure a force step within a time of only 19 ms with a deviation of less than 5 %. But now we will consider the application condition too. Very often is mounted a machine part with the force transducer. A dynamic force in front of this part is not the same as it is behind between the machine part and the force transducer. Assume the mass of the machine part is 25 kg. Than the natural frequency will be only 50 Hz of the force transducer with the mounted part. Now we have to wait after a force step nearly one second to get a measuring value with a deviation less than 5 %. The frequency range in which we can measure sinus wave changing forces with a deviation less than 4 % is now reduced to 10 Hz. At higher frequencies we will get the following deviations: +33 % at 25 Hz, +5000 % at 50 Hz, -67 % at 100 Hz. It is similar for torque transducers. They also do have a stiffness (against torsion) and mass (moment of inertia) [1, 2, 3].

Pressure sensors are also able to swing. Their spring element has stiffness and mass, therefore a natural frequency and a damping constant. Both are given in the data sheet often, for example 10 kHz and 0.01. We know from theory and experiments with force transducers, that we get a lower natural frequency and a bigger settling time mostly in praxis. The equations are not difficult for the calculation of the above shown values. But unfortunately it is much more difficult for pressure sensors. The reason is the unknown oscillating mass of the fluid, which is loosely connected to the membrane or the inner surface of the measuring tube. Oscillating pressures generate an oscillation of the measuring membrane. That means there will be an oscillating fluid column too. The fluid moves forth to and back from the sensor element. Because there are current resistances pressure loss will occur. Friction between the fluid current and the inner surface (of fittings, connecting pipe, stopcock, connecting element) will increase the damping constant. The pressure we like to measure will be another one than we are able to measure direct in front of the sensor membrane. And worse: There will be an influence of the mounted pressure sensor to very fast changing pressures too.

There are some possibilities for test machineries to investigate these topics in laboratories. But the effort is big. There are some publications about dynamic pressure calibration [4, 5, 6, 7, 8].

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