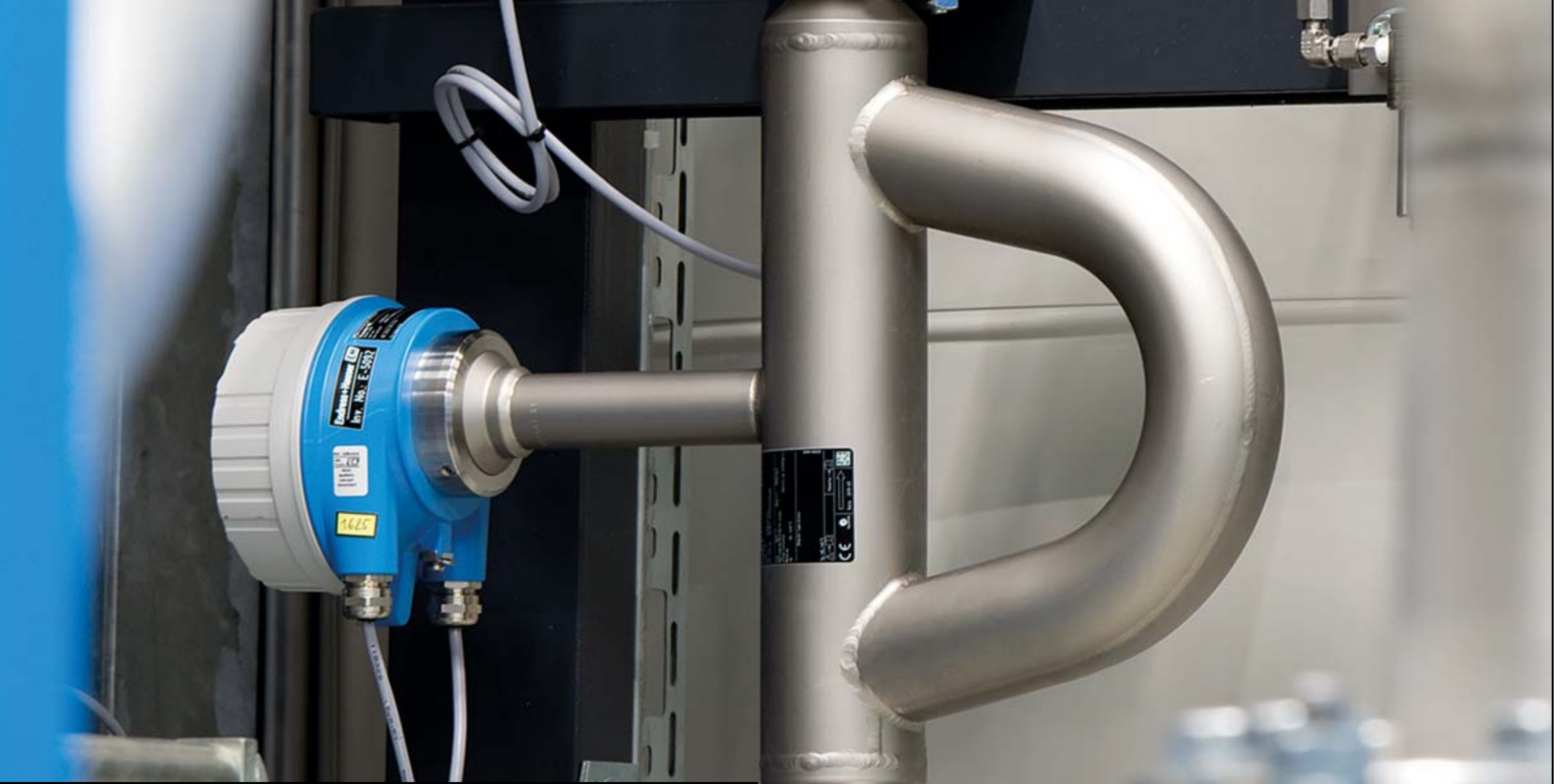

HIGH-QUALITY CORIOLIS MASS FLOW-METERS

The Promass Q is an awarded product from Endress+Hauser. The innovation was achieved by using an experimental set-up complemented by simulation methods of ANSYS Workbench and optiSLang.

Endress+Hauser Group

The Endress+Hauser Group is a leading supplier of measuring instruments, services and solutions for industrial process engineering. Endress+Hauser provides sensors, devices, systems and services for level, flow, pressure and temperature measurement as well as analysis and measurement logging. The company supports its customers with automation, logistics and information technology services and solutions. The products are setting standards in terms of quality and technology.

Coriolis Effect allows accurate measurement

Multivariable sensor technology and maximum measuring accuracy are only two reasons why gases and liquids are increasingly captured with the Coriolis measuring principle.

The Coriolis mass flow-meter is an outstanding product from Endress+Hauser's wide range of products. This measuring instrument is inserted into a process line and continuously detects the parameters of the fluid flowing through it (see title image and Fig. 1). In addition to the mass flow rate (±0.05%), this instrument also tracks the density (±0.2 kg/m³) and the temperature (±0.1°C) with extraordinarily high accuracy. The Coriolis Effect is used to directly determine the mass flow rate. For this purpose, the measuring tubes located between the process connections are resonated by an activator (Fig. 2). If a fluid now flows through the measuring tubes oscillating in the opposite direction, the tubes begin to tumble due to the Coriolis force. This movement is picked up by two sensors at the inlet and outlet of the measuring tubes. A signal processor calculates the phase difference between these two signals, which is directly proportional to the mass flow. In addition, the fluid density can be derived from the resonance frequency, and finally the fluid temperature is measured precisely by a temperature sensor on the measuring tube.

Sensitivity Analysis, Optimization and FEM Simulation with optiSLang and ANSYS

The decisive factor for the reliability and measuring accuracy in practice is the non-dispersion of the measuring tube vibrations into the connected process line. The process connection must stand still at all fluid densities. High-quality Coriolis mass flow-meters are therefore always "in balance", which results in outstanding measuring accuracy. Usually, the principle of the tuning fork is used, whereby the flow is divided between two pipes oscillating in opposite phases (Fig. 2). Both, this balance and the insensitivity of the measuring tube vibration towards changes in process values (temperature and pressure) and material properties (density, viscosity and sound velocity) were optimized with ANSYS Workbench and optiSLang. This optimization is based on parameters, implemented in the ANSYS programming language APDL, which reflect the properties of the measuring instrument relevant to practice. The search for a robust and optimal compromise between often conflicting design goals was realized with optiSLang.

Fig. 1: Coriolis mass flow-meter Promass Q

Fig. 2: Fundamental oscillation of the measuring tubes at about 100 Hz and a few micrometers of deflection (shown in heightened form).

An engineering preselection resulted in a sum of approximately 100 relevant geometric parameters as well as numerous objective values for the optimization problem. Then, sensitivity analyses were performed with ANSYS optiSLang. On this basis, the relevant geometric optimization parameters were identified and preliminary decisions were made regarding the most important objectives and criteria (Fig. 3). In this case, a ranking of several targets in the objective function was sufficient, since no serious conflicts arose. This reduced the number to 10 key criteria. Taking geometric constraints into account, such as the avoidance of component collisions, the assurance of production-ready geometries or the consistency of component shapes, optimal and robust design layouts could be found quickly and purposefully.

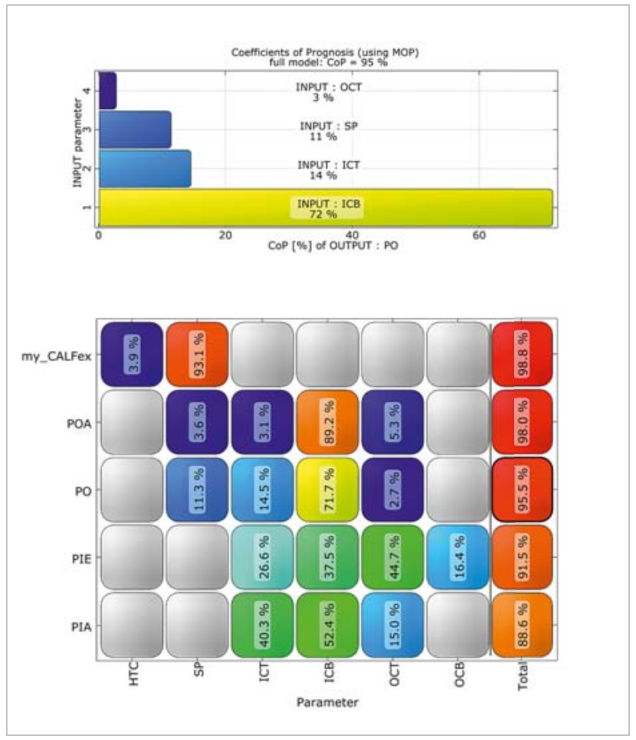

Fig. 3: Illustration of CoP Plott with objective function.

In order not to lose the correspondence to reality, it is helpful to build bridges as often as possible between the realized prototypes on the one hand and the FEM simulation on the other hand. The thereby related synchronization of the material parameters is the basis for an exact prediction of the real system behavior by simulation. As a result of this procedure, out of the FEM simulation a better understanding of the functional principle of the measuring device is gained. Using ANSYS Workbench, experimentally observed phenomena can be reproduced on the computer and can also often be understood, which contributes significantly to the development of solutions. With the aid of simulation, many costly and time-consuming experiments can be omitted in this phase.

Until now, high measurement accuracy was only possible under ideal conditions, in other words under stable process conditions as well as under single-phase and homogeneous media that follow the pipe vibration without any restrictions. In practice, however, such ideal conditions often do not exist. Food - for example ice cream or cream cheese - is deliberately foamed. However, gas often also emerges unwanted from media such as mineral oil, which cannot be removed due to its high viscosity. Promass Q (Title and Fig. 1 see previous page) is a Coriolis flowmeter that has been developed especially for applications in the oil, gas and food industries.

Active Real-Time Compensation of Measurement Errors

Gas bubbles enclosed in the medium reduce the fluids ability to follow the tube motion, resulting in considerable measurement errors. Thanks to revolutionary "multi-frequency technology" (MFT), active real-time compensation of these measurement errors is possible. For this purpose, the measuring tubes are stimulated simultaneously with a fundamental and a harmonic component (Fig. 4). This harmonic component now provides the missing information to determine a system of equations and a reliable correction algorithm. When the fluid density changes, the fundamental as well as the harmonic component cover wide frequency bands. With the help of ANSYS Workbench, first interfering resonances in these frequency bands can be detected and second measures can be defined to shift these resonances out of the frequency bands. In Promass Q, 15 patents were implemented, and during the six-year development and industrialization phase, approximately 1,000,000 virtual prototypes were generated. The innovative "multi-frequency technology" was honored with, among others, the "Swiss Technology Award" and the "German Innovation Award" (Fig. 1 see previous page). Complex vibration-capable systems such as Promass Q would be impossible without numerical simulation. Within the development of modern process sensors it is no longer feasible to imagine prototyping without a combined approach using experimental set-up supported by simulation methods. In this process, ANSYS Workbench in combination with optiSLang has proven to be a powerful instrument. Endress+Hauser has been using simulation tools from ANSYS for more than 25 years.

Fig. 4: Harmonic component at about 1000 Hz (deflection shown in heightened form)

Author //
Dr.-Ing. Alfred Rieder (Endress+Hauser Flowtec AG)

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