INTELLIGENT FLOWMETERS FOR METALLURGICAL INDUSTRY

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Abstract

In the global metallurgical industry, the volume of products produced is currently growing, and there is also pressure to reduce input costs while evenly increasing output quality and occupational safety. One of the ways, in which this can be achieved is to focus on the correct measurement of individual process variables already during the technological process. In most metallurgical plants in Central Europe, standard measuring devices without advanced functions have been used for many years, however, in connection with the Industry 4.0 trend, it is important to allow remote operators to monitor, configure and also analyze traffic at individual measuring nodes, or service the device on-site. without telephone contact with the operator and the need to shut down the entire technological unit. This article is devoted to the analysis of the current possibilities of measuring the flow of liquid media and then there is a part that deals with the development of a new type of sensor, which has these functions and will directly contribute to the gradual reduction of production costs. Undoubtedly, the undeniable advantage of this research is that the device can be configured during its production so that it can be used in manufacturing companies outside the heavy industry.

Keywords: Flow meter, heavy industry, liquid, velocity, measuring

1. INTRODUCTION

With the roll-out of Industry 4.0 and the associated cost reductions in the near future, manufacturing companies will start to install measuring devices that are more accurate, less disruptive, and offer more functions than traditional and dedicated solutions. Flow sensors are one of the most widely used measuring devices in the metallurgical industry. The main problem today is that metallurgical production often takes place in specific, sometimes even extreme conditions, and therefore when servicing the measuring equipment, it is necessary to manually remove the equipment from the circuit, install a by-pass, take the equipment away, perform service operations and then reassemble. All this takes a lot of time and employs several people, while some, especially software service operations can be performed with remote access to the equipment and in this operation, it is not necessary to shut down a specific technological circuit but this can be done from the command room, which is a huge advantage for night shifts when there are not so many maintenance technicians present in the company. It also has the opposite advantage in that the service can be performed by a technician directly on the built-in industry display and sees in real-time how the device behaves and whether the service operation was performed correctly. There is a large number of principles that are used to measure the flow of media and therefore there are several basic types of flow meters. However, the difference between mass and volume flow measuring must be explained.

2. PRINCIPLES OF FLOW MEASURING

2.1. Volumetric flow rate

The volume flow rate of the medium Q_v is the volume of the medium that passes through the conduit in a certain time unit. A unit is a cubic unit of volume divided by a unit of time (1). To determine the volume that has flowed over a time derivative, it is often used to calculate the flow velocity of a medium in a pipe of a known cross-section. In this calculation, however, it is assumed that the medium fills the entire volume of the tube, which is not always true. However, the flow rate can also be measured using a pressure differential. Sometimes, however, it is also necessary to correct the flow due to changes in temperature and pressure. However, when measuring the volumetric flow of vapors and gases, corrections must always be made - due to the easy compressibility of the flowing medium and thus possible rapid changes in the input constants over time [1].

$$Q_v = \frac{\mathrm{dV}}{dt} \tag{1}$$

where:

Q_v – volume flow ($m^3 \cdot s^{-1}$)
V - fluid volume passed through sensor (m^3)
t – time (s)

2.2. Mass flow rate

The mass flow rate Qm is the mass of the substance which has flowed through a certain point in the pipeline per unit of time (2). This method can be measured in two ways - thermal mass flow meters and also flow meters whose measurement is based on the Coriolis principle [1].

$$Q_m = \frac{\mathrm{dm}}{dt} \tag{2}$$

where:

Q_m – mass flow rate ($kg \cdot s^{-1}$)
m – weight of fluid flowed through (kg)
t – time (s)

2.3. Velocity flow rate

The velocity flow rate is defined as the mean velocity of the particles flowing through a tube of strictly defined cross section (3).

$$v_s = \frac{\mathrm{ds}}{dt} \tag{3}$$

where:

v_s – velocity flow ($m \cdot s^{-1}$)
s – orbit of one single particle (m)
t – time (s)

3. TYPES OF FLOW METERS

Cross-sectional flow sensors

These sensors gradually throttle the channel, causing a differential pressure in front of and behind the throttle element within the measuring line. The pressure difference between the two points is measured by a differential pressure gauge. It means that it is dependent on the speed of the flowing liquid.The final flow can be easily calculated by the Bernoulli equation. Throttling elements within cross-sectional flow meters are mostly orifices or nozzles. A special case is a knee – in this case, the pressure is measured on its inner and outer sides [1].

Float flow sensors (rotameters)

A conventional rotameter consists of a truncated cone tube, that extends upwards. In the middle of the tube is a float, which is hit by a liquid stream and lifts it towards a wider cross-section. The float is raised to a position proportional to the flow velocity. This implies that the flow of the medium is sensed from the current position of the float. All rotameters are very simple sensors with minimal pressure loss.

Vane and turbine flow sensors

Sensors of this type to measure the flow rate. The liquid medium flowing through the device transmits kinetic energy to suitably arranged vanes of the body, which cause it to rotate. The difference between the turbo meter and the turbine flowmeter is in the axis of rotation of the housing. If the axis of rotation is in the flow direction, it is a turbine flow meter. If the axis of rotation is perpendicular to the direction of the fluid flow, it is a vane sensor [2].

Vortex flow sensors

A shell of a suitable shape (triangle, arrow, etc.) is inserted into the flow channel, which, upon the impact of the flowing liquid, causes vortices to be sensed. The frequency of vortices is directly proportional to the velocity of the liquid before the obstacle [2].

Ultrasonic flow sensors

The ultrasonic waves are transmitted by a channel through which the liquid flows obliquely to the opposite side, and thus is partially carried by the flowing medium. At the same time, the time it takes for this signal to pass from the transmitter to the receiver is recorded. Often, the waves are sent in both directions - in the direction and against the direction of the liquid flow. Then the difference between the two is calculated, which is proportional to the flow velocity.

Coriolis flow sensors

It is a pipe that is usually anchored at two extreme points. The flowing fluid causes vibration of these points and then senses its position at two points equidistant from the anchorage points. Due to the liquid being under the influence of the Coriolis force, the tube vibrates asymmetrically, and the mass flow, which is independent of temperature, pressure or viscosity, can be accurately measured on the basis of variations at the individual points.

4. PROPERTIES OF CURRENT SENSORS

Flow sensors are currently available in many designs, depending on the parameters of the medium to be measured, the ambient conditions, and other individual requirements. In general, however, a conventional device of this type consists of a tube through which the measured liquid passes and an evaluation unit with a display that shows the actual value. This unit is supplied with power and there is also an output, which subsequently transmits a signal to the control system. This is often a 4-20 mA current loop. Often there is also the possibility of communication with other protocols, e.g. RS485 or MODBUS. It is usually a small, black and white display, showing analog values and enabling device settings. The unit is often grounded by routing to the metal body of the flow tube. Some types of flow meters also have a thermometer measuring the current temperature of the medium.

The fact is, that the vast majority of sensors currently on the market are not in direct competition with this newly developed device, since they usually deal with the measurement of only one or two different physical quantities. In this case, however, four quantities will be measured, which are extremely important for the proper functioning of chemical processes. Commonly offered sensors are not directly oriented to specific requirements and the production environment metallurgical industry. It is also important to mention that there are currently no devices on the market that have the ability to self-control and auto-configure if an error occurs in the device.

These advanced features will already be implemented in the device firmware and will directly contribute to reducing maintenance costs.

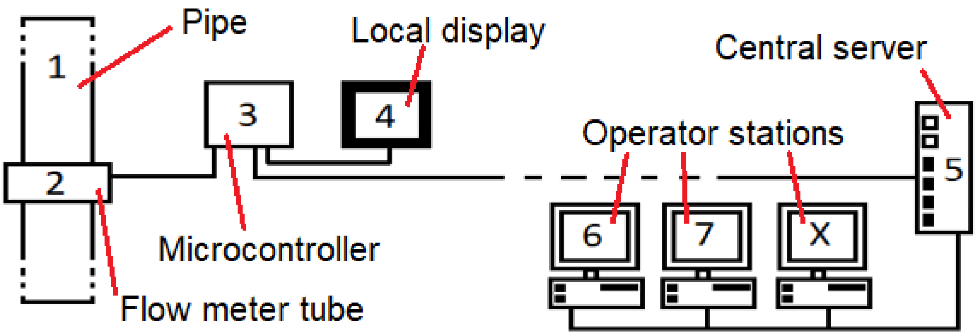

Figure 1 Drawing of the flow meter measuring system and its visualization. Source: (own)

5. INTELLIGENT FLOW SENSOR DEVELOPMENT

The professional focus of the author is control systems, sensors, and the Industrial Internet of Things (IIoT). According to his own experience in the metallurgical industry, when servicing flow sensors during their operation, it is demanding to find the cause of the current failure. This is usually done through phone communication with the operator and administrator of the control system. However, this is not always possible because of the noisy, hot, or explosive environment [3]. Due to the lack of adequate technical solutions on the market to facilitate these situations, the author of the article decided to develop a new type of intelligent flow sensor in cooperation with technological and metallurgical companies (**Figure 1**). Turbine measurement was chosen as a suitable principle due to its easy construction, high accuracy, and low-pressure drop [4].

Most flow sensors that operate with a mechanical principle use the principle of the magnetic bonds for hermetic separation of the speed counter from the chamber in which the medium flows. These devices are called dry dial meters [5-7]. Their opposite is wet dial meter, in which the reading mechanism is usually completely immersed in water. Although these wet meters are popular, however, they are more sensitive to signal interference or blocking the reading of data by strong magnetic fields that occur in metallurgical production very often [8-10]. It is possible to use the Hall effect sensor to detect the speed of individual magnets inside the dry dial, thanks to the magnetic coupling mechanism. The disturbing effects of the environment can be reduced through the implementation of more Hall sensors [4].

5.1. Microcontroller and electronic devices

A new generation of Nvidia Jetson seems to be a suitable microcomputer for this application. This unit will include a color display, about 7 "- 8" diagonal (**Figure 2**).

The display will be waterproof and resistant to adverse effects due to the frequent placement of flow sensors in outdoor or aggressive environments. A great advantage will also be the ability to control the display with a hand wearing a glove. In the chemical and heavy industry, the need to wear OSH aids and take them off at each patrol is not ideal.

On this screen, it will be possible to monitor various actual values for the pipe and the medium flowing in it. An essential part will be the possibility to adjust the upper and lower limits of the measured temperature and flow. When exceeded or below the threshold, signalization will be triggered on the local display and at the operator station in the control room. The problem will be also signalized by a local light banner with a sound signal and by light alarm describing the current cause. This device will be able to not only measure the flow, but also viscosity, acidity, and temperature (**Figure 2**). One of the main advantages over other devices on the market will be that the device will "self-check" at cyclic intervals and immediately inform the operator and maintenance personnel if it detects a fault [5,11]. At the same time, if the fault matches any of the predefined failures from the database, an attempt will be made to auto-configure and solve the problem without the need for human intervention. Of course, there will be the possibility of communication using several communication protocols, a conventional 4-20 mA current loop and also wireless communication, and also the possibility to communicate by industry RJ45.

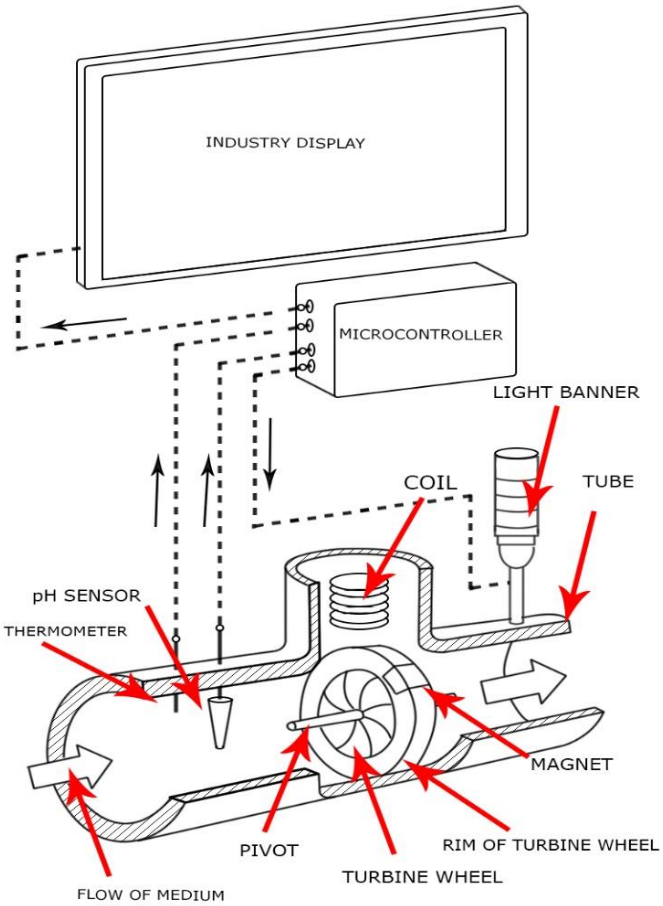

Figure 2 Newly developed flowmeter with microcontroller and other electronic devices.
Source: (own)

6. CONCLUSION

In conclusion, this type of device has a high chance of commercial success due to the fact, that there are currently no similar sensors on the market, that allow such expanded control options, such as a local color display with the ability to show trends of individual values in real time and also track trends from the past, set alarms, reset or set the device's internal configuration. The vast majority of companies specializing in metallurgical production in Central Europe address these needs using independent hardware assemblies, which are common sensors along with external computing units, often of the PLC type, which are located at a greater distance in the control room or server room. As already mentioned, devices that are multifunctional and directly reduce input costs due to more accurate measurements and faster analysis of production process data are very popular items on the market. The safety of maintenance staff and quality controllers, who will no longer have to physically inspect equipment located in hazardous locations, cannot be neglected. Research has also led to cooperation with an international metal company, which has promised partial co-financing for research into the device, so that there is a high probability that the device will be the new standard, launching a new era of measurement and analysis in heavy industry, particularly in areas described in [12-15].

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