Ultrasonic flow sensor with swirl pins for flow conditioning

V. Petkus, P. Borodičas, A. Ragauskas, V. Pamakštis

AB "Axis Industries"

This study was supported by AB "Axis Industries" and EU Structural Funds
Project "Development of new generation system for automated energy account and control" BPD2004-ERPF-3.1.7-06-06/0022

Contact person:
Virgilijus Pamakštis
AB "Axis Industries"
Kulautuvos g. 45a, Kaunas LT-47190
Tel: 8 37 360234
Fax: 8 37 360358
E-mail: info@axis.lt

Abstract

The paper presents the ultrasonic flow sensor SDU-1L size DN50 developed by AB Axis Industries and prepared for manufacturing by using cost effectives technologies. The structure of the flow sensor and peculiarities of the sensor assembly are presented. The sensor includes the swirl pins for flow conditioning mounted at inlet of the sensor. The performed investigations showed that measurement stability is improved by about 1.6 times due to the swirl pins for flow conditioning. The assembly of the flow sensor ensures exact positioning of the reflectors and can be performed by means of simple mechanical operations. This flow sensor meets class 2 accuracy requirements according to EN1434 and can be used in the battery-powered heat energy measuring system.

Keywords: ultrasonic flow sensor, flow conditioning, flow measurement.

Introduction

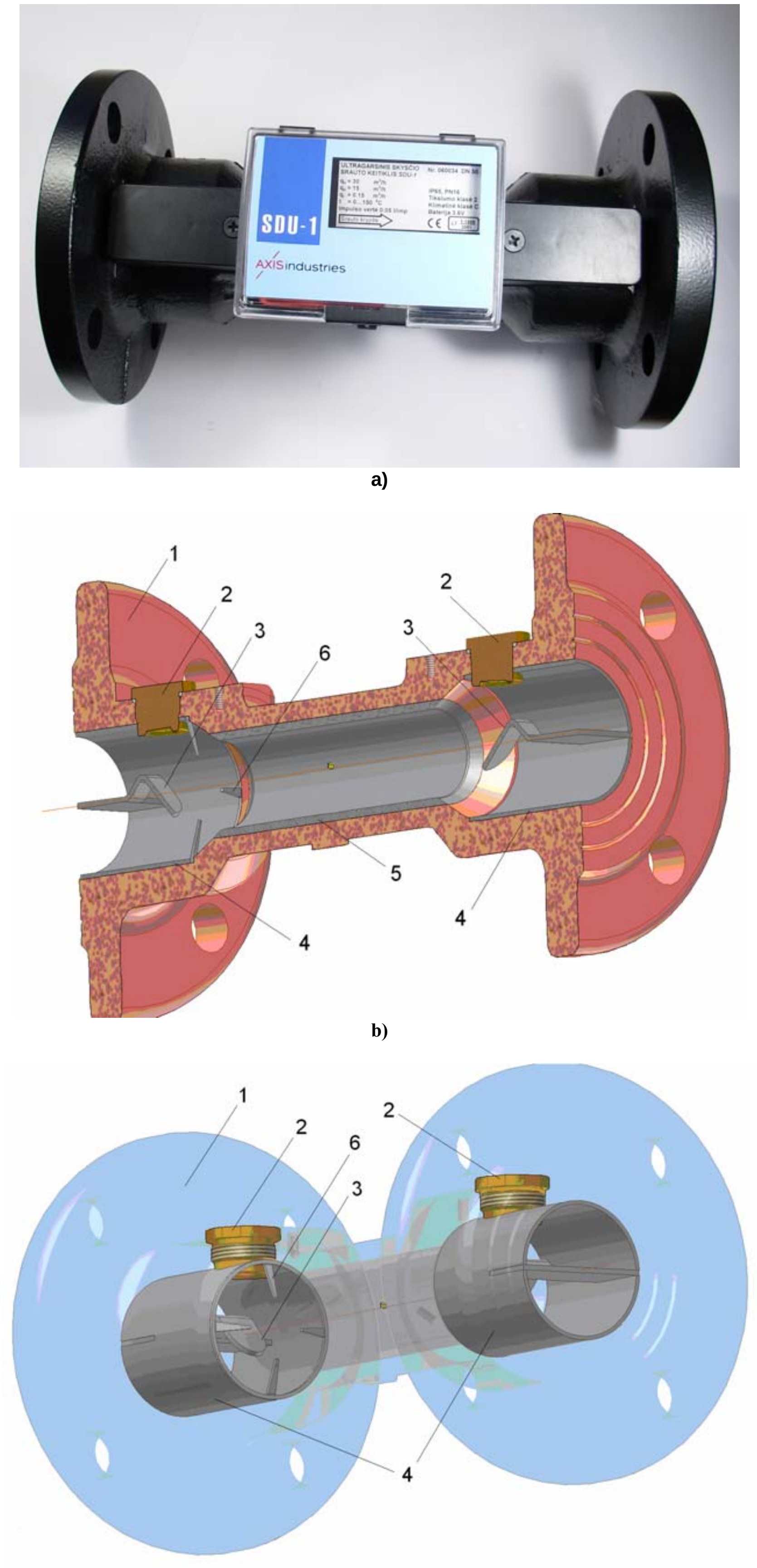
A typical design of the transit time ultrasonic flowmeter sensor includes a measurement tube and at least one pair of ultrasonic transducers, one of which transmits the ultrasonic wave into flowing fluid within the measuring tube, while the other receives this wave [1]. The difference between times of ultrasound wave propagation in upstream and downstream directions is proportional to the velocity and flow rate of the flowing fluid [1]. One of the common problems in designing a flow sensor of such type of flowmeters is the approach of placing ultrasonic transducers in the measuring tube and transmission of the ultrasonic wave into the flowing fluid. The most popular approaches of placing the ultrasonic transducers are the following:

a) Ultrasonic transducers are placed into the recesses made in the wall of the measuring channel and they radiate ultrasound wave at inclined angle to the fluid [2,3]. Such arrangement of the flow sensor is mostly encountered for flow sensors with diameter DN>100 mm. By designing small-size flow sensors (DN<50), however there are some problems due to the limited sizes of ultrasonic transducers. The relatively large-size recesses are obtained by placing transducers to radiate waves at the inclined angle into measuring channel with a small-size diameter. Typically, the presence of such recesses inside the flowing fluid acts to generate unwanted swirls and causes the increase of pressure loss [4], and, therefore they limit the application of such approach of ultrasonic transducers placement.

b) Ultrasonic transducers are placed into perpendicular holes on the wall of the measuring channel to radiate ultrasound wave perpendicularly to the fluid and directly to the reflectors [5,6]. The reflector placed at the inlet of the flow sensor redirects the ultrasound wave along the measuring channel into the other reflector at the outlet. The placement of reflectors inside the measuring channel is encountered with additional generation of local swirls, distortion of flow profile and increase of pressure loss. Minimization of these problems is possible by designing streamline and round-shape reflectors [6], or by forming the reflector in front of the ultrasonic transducer on the opposite side of the inner wall [7,8].

c) Ultrasonic transducers are placed into the inlet and outlet of the measuring channel and positioned face-to-face to insonate ultrasound wave along the flowing fluid into the measuring channel [9]. Such performance of the flowmeter causes higher pressure loss and requires more complex construction of ultrasonic transducers.

In order to overcome the mentioned problems of positioning ultrasonic sensors and reflectors, we proposed the idea to design reflectors capable of performing flow profile conditioning.



a)

b)

c)

Fig. 1. **The ultrasonic flow sensor SDU-1L , size DN50, permanent flow q_p =15 m3/h, manufacturer AB Axis Industries, Lithuania. The structure of the flow sensor is shown in b) - longitudinal cross-sectional view and c) - transparent view. The main components of the flow sensor are moulded cast iron body part (1), ultrasonic transducers (2), reflector (3), reflectors holding tubes (4), measuring channel (5) and flow conditioning swirl pins (6).**

The methods of conditioning flow disturbances and cancellation of the swirls include the placement of auxiliary obstacles into the flow capable of generation local swirls symmetrically around the measuring tube [10]. To obtain perfect flow conditioning, the rotation of these swirls should have the featured of opposite direction with regard to the swirl caused by constructional elements of the flow sensor that distorts the flow profile (i.e. reflector) or swirls at the flow sensor inlet caused by sensor installation condition. Such auxiliary obstacles might have symmetrically arranged pins or vortex tabs [10].

The flow conditioner consisting of four swirl pins has been applied by designing the new flow sensor SDU-1L (manufacturer AB “Axis Industries”, Kaunas, Lithuania) in order to minimize the influence of flow distortion at the inlet (Fig. 1). Such flow conditioner together with reflectors are low-price components which can be mounted into the flow sensor by using simplified operations of mechanical assembly. Moreover, the principle of the flow sensor assembly not only ensures proper and precise positioning of reflectors and ultrasonic transducers, but also allows us to reduce technological requirements of manufacturing all components of the flow sensor.

Method

The new ultrasonic flow sensor SDU-1L DN50 of battery-powered heat energy meter consists of:

- moulded cast iron body of flow sensor (1),
- a pair of ultrasonic piezoceramic transducers (2);
- two stainless steel reflectors (3),
- stainless steel tubes for holding reflector (4)
- stainless steel tube (measuring channel) fixed within the cast sensor body (5),
- four flow conditioning swirls pins (6), inserted at inlet in front of the measuring channel.

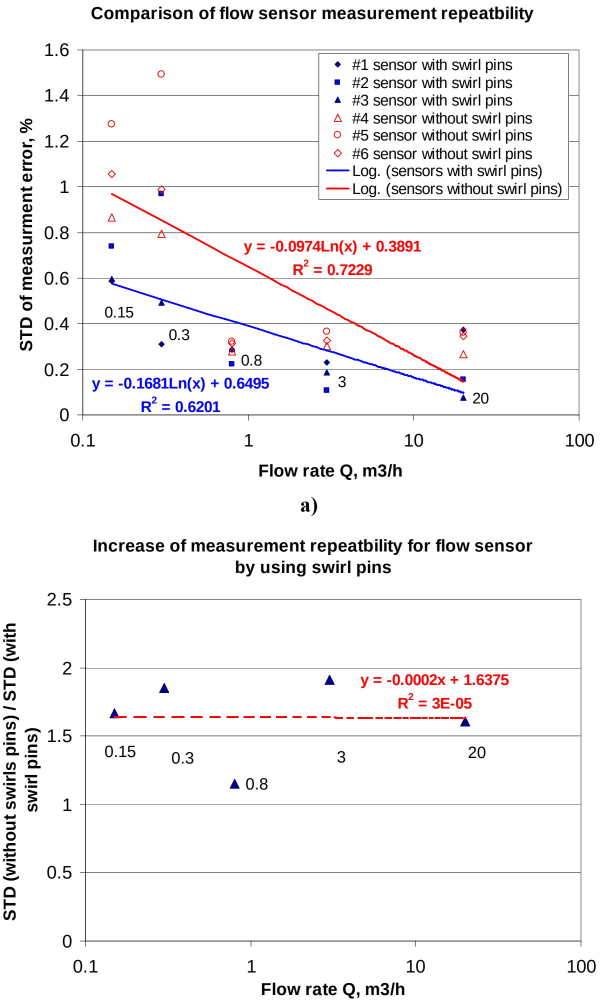
Both reflectors are mounted into the flow sensor by pushing them from the inlet and outlet sides. The reflector at the inlet is pushed together with the swirls pins for flow conditioning. Precise positioning of reflectors is ensured due to the presence of holes in the upper side of the tubes for holding the reflector. By screwing the ultrasonic transducer into the flow sensor, the housings of the transducer go through the holes of the tubes and fix the position of the reflectors.

Proper positioning and manufacturing quality of the reflector are controlled by specialized laser test equipment. The acoustic path between both ultrasonic transducers is controlled by screwing laser beam pointers into the holes for placement of the ultrasonic transducer and by inspecting the laser beam reflecting points on the reflectors.

The assembly and testing of the flow sensor can be carried out by using simple mechanical operations which do not require special knowledge for assembly personnel.

Results

In order to investigate the peculiarities and advantages of flow conditioning swirl pins, 3 flow sensors with flow conditioning swirl pins and 3 flow sensors without flow conditioning swirl pins have been taken for testing with the flow calibration facility. These flow sensors have been calibrated and flow measurement repeatability has been determined by performing series of flow measurement within flow rate ranges 0.15 - 20 m^3/h at cold and hot water temperatures (20^{0}C and 55^{0}C). The standard deviation has been calculated as a parameter representing the repeatability of flow measurement (Fig. 2, a). The ratio between the averaged standard deviations of flow measurements obtained by using flow sensors without swirl pins and with swirl pins is shown in Fig. 2, b. This ratio clearly demonstrates that flow measurement repeatability is improved approximately 1.6 times due to using flow conditioning swirl pins over a full flow measurement range (Fig. 2, b). The measured hydrodynamic pressure loss for such flow sensor with flow conditioning pins illustrates that such solution of designing flow conditioning swirl pins and reflectors allows us to obtain comparatively low pressure loss at a permanent flow rate qp=1.5 m^3/h (Fig. 3), i. e., the obtained pressure loss is 100 mbar, when the maximum permissible pressure loss is 250 mbar according to the requirements in LST EN 1434 [11].



a)

b)

Fig. 2. **The comparison of measurement repeatability of ultrasonic flow sensor with and without flow conditioning swirl pins (a). The increase of flow measurement repeatability has been calculated as a ratio between the averaged standard deviations**

(STD) of measurements for flow sensors with swirl pins and without swirl pins (b).

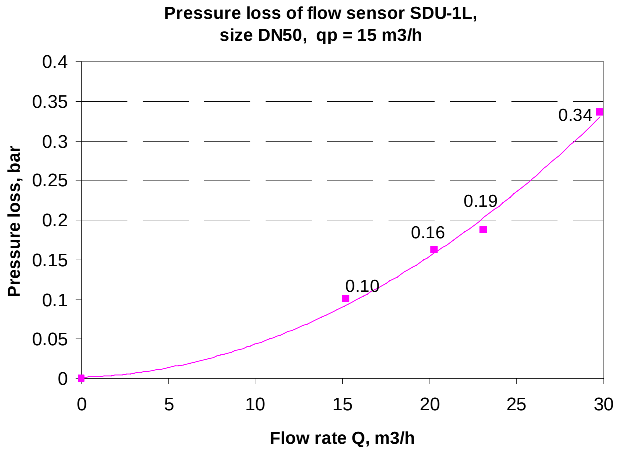


Fig. 3. **The pressure loss of the flow sensors SDU-1L, size DN50 with flow conditioning swirl pins. Pressure loss at permanent flow rate q_p=1.5 m3/h is 100 mbar (maximum permissible pressure loss at permanent flow rate is 250 mbar). Pressure loss has been measured with differential pressure transmitter Fuji Electric FCX-CII.**

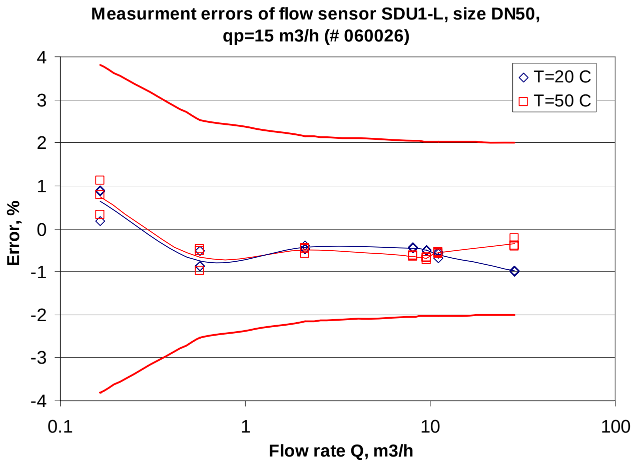


Fig. 4. **Flow measurement errors of the flow sensors SDU-1L, size DN50 measured during device certification test at the Laboratory of Heat Equipment Research and Testing (Lithuanian Energy Institute).**

Additionally, the flow sensors SDU1L, size DN50 that contain flow conditioning swirl pins were tested at the Laboratory of Heat Equipment Research and Testing (Lithuanian Energy Institute) by performing a pattern approval test according to the requirements of EN 1434. The results of flow sensor measurement errors at water temperature 20^0C and 50^0C obtained by performing performance test are shown in Fig. 4.

Conclusions

The ultrasonic flow sensor containing flow conditioning swirl pins inserted at the inlet of sensor in front of the measuring channel is presented. The performed investigations showed that such flow conditioner allows us to increase measurement repeatability by about 1.6 times over a full measurement range. All components of the flow sensors are manufactured by using cost-effective technologies:

- body part of the flow sensor is manufactured by using cast iron moulding technologies,
- reflectors and flow conditioning pins are made from stainless steel by using water cutting technologies.

The structure of the flow sensor and assembly ensures precise positioning of reflectors. The flow sensor assembly and manufacturing control are performed by using simple mechanical operations which do not require a special knowledge for assembly personnel.

The described peculiarities of the flow sensor have been applied in designing and preparing a serial manufacture of the battery-powered flow sensor SDU-1L size DN50 (manufacturer AB Axis Industries, Kaunas, Lithuania). This flow sensor meets the class 2 accuracy requirements according to EN1434 and is certified in Lithuania, Ukraine, Russia and Belarus. The described flow sensor together with the heat energy calculator can be used in battery-powered heat energy measuring systems.

Acknowledgements

This study was supported by AB “Axis Industries” and EU Structural Funds (Project BPD2004-ERPF-3.1.7-06-06/0022).

References

1. **Spicer D.W. and Boyes W.** Consumer guide to ultrasonic and correlation flowmeter. Copperhill and Pointer Inc. USA P.9. 2004.
2. **Molenaar M.M.** Ultrasonic flowmeter for flowing media. US Patent US6584862. 2003.
3. **Brun E.G.** Ultrasonic flowmeter with straight measuring tube and measuring section. Patent DE4439399. 1996.
4. **Raisutis R.** Investigation of the flow velocity profile in a metering section of an invasive ultrasonic flowmeter. Flow measurement and Instrumentation 2006. No.17. P.201-206.
5. **Polinski E.** Ultrasonic flowmeter. Patent EP1328778. 2003.
6. **Sonnenberg H.M and Mesthaler R**. Ultrasonic flowmeter has an ultrasonic transducer and ultrasound mirror that has an additional flow guide for optimizing the fluid flow over its surface Patent DE10327076. 2005.
7. **Greppmaier P.** Ultrasonic flowmeter. Patent EP0708313. 1996.
8. **Ragauskas A., Daubaris G. and Petkus V**. Ultrasonic flowmeter with triangular cross-section. Patent EP1742024 2007.
9. **Hauenstein G.** Ultrasonic flowmeter. Patent EP0897102. 1999.
10. **Smith C.R., Greco J.J. and Hopper P.B**. Low-loss flow conditioner for flow distortion/swirl using passive vortex generation devices. In Proc. of Int. 5th Conf. Flow Meas. Flomeko, P.57-67, 1989.
11. **European Standard** EN 1434-4:2007. Heat meters - Part 4: Pattern approval tests. European Committee for Standardization CEN, 2007.

V. Petkus, P. Borodičas, A. Ragauskas, V. Pamakštis

Ultragarsinis srauto jutiklis su srauto lyginimo adatomis

Reziumė

Aprašytas baterinio ultragarsinio srauto jutiklio SDU-1L DN50 dydžio matavimo ruožas (gamintojas AB „Axis Industries“), kurio gamyboje bus taikomos veiksmingos liejimo ir surinkimo technologijos. Matavimo ruožo konstrukcija ir jos surinkimo operacijos užtikrina tikslų ultragarso bangą nukreipiančių veidrodėlių pozicionavimą. Šio srauto jutiklio matavimo ruožo įtekėjime yra įrengtos srauto lyginimo adatos, kurios leidžia padidinti srauto matavimo stabilumą apie 1,6 karto. Aprašytasis srauto jutiklis atitinka 2 tikslumo klasės reikalavimus pagal standartą EN1434 ir gali būti naudojamas šiluminės energijos apskaitos sistemose.

Pateikta spaudai 2008 05 28

DOI: 10.5755/j01.u.63.2.17065