Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2015,27(4):624-632
DOI: 10.1016/S1001-6058(15)60524-8
www.sciencedirect.com/
science/journal/l0016058

The analysis of flow characteristics in multi-channel heat meter based on fluid structure model*

LIU Zheng-gang (刘正刚), DU Guang-sheng (杜广生), LIU Li-ping (刘丽萍)
School of Power and Energy Engineering, Shandong University, Jinan 250061, China,
E-mail: lzhenggang@sdu.edu.cn

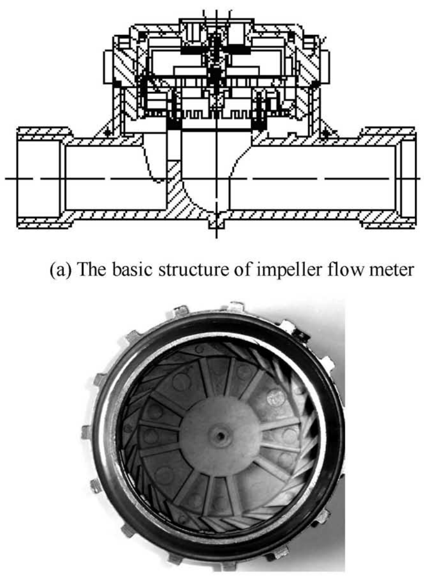
(Received June 12, 2015, Revised July 9, 2015)

Abstract: In this paper, a fluid structure interaction (FSI) model is used to study the internal flow field and the measurement performance of a multi-channel flow meter. The RNG k - ε turbulent model and the finite element model are used separately in the fluid domain and the structure domain to obtain the meter factor K and the deformation of the structure. The meter factor K of the flow meter is obtained through the FSI model at temperatures of 20°C, 50°C and 80°C. The calculated results show the thermo expansion of the structure can significantly influence the measurement performance of the flow meter. The meter factor of the flow meter is also measured experimentally, and the comparison between the experimental results and the calculated results shows the validity of the fluid-structure interaction model. In order to reduce the measurement error, the meter factor K should be modified as the water temperature changes.

Key words: fluid structure model, heat meter, numerical calculation

Introduction

With the continuous improvement of the heating fee system, more and more Chinese households use heat meters to measure the heat energy of the central heating system. The heat meter can measure the water flow flux and the temperature difference between the inlet and the outlet of the heating system, by which the heat energy consumed by the family can be calculated. The water temperature can be measured accurately by an integrated circuit module, so the accuracy of the heat meter is determined by the accuracy of the flow rate mainly. Many heat meters use the impeller flow meter to measure the water flow rate, Fig.1 shows the structure of a multi-channel impeller flow meter. In Fig.1, the circumference of the impeller chamber is divided into multiple channels, the water enters the impeller chamber through channels and drives the impeller to rotate. The impeller flow meter measures the volume flux based on Eq.(1)



(a) The basic structure of impeller flow meter

(b) The impeller chamber

Fig.1 The multi-channel impeller flow meter

* Project supported by the Natural Science Foundation of Shandong Province (Grant No. ZR2014EEM015).
Biography: LIU Zheng-gang (1973-), Male, Ph. D., Lecturer
Corresponding author: DU Guang-sheng,
E-mail: du@sdu.edu.cn

$$Q_v = \frac{f}{K} \tag{1}$$

where Q_v is the water volume that flows through the flow meter, f is the cycles of the impeller rotation, K is the meter factor of the heat meter.

According to the national standards for the household heat meter, the heat meter should measure the flow flux accurately while the water temperature changes from 5^{o}C to 95^{o}C. As shown in Fig.1(b), the impeller chamber housing is made of engineering plastics. Plastic has a large thermal expansion rate and can expand as the temperature rises, and the measurement error can be magnified after a long time use of the heat meter, which is induced by the structural deformation during the variation of the water temperature. In order to improve the measurement accuracy, the effect of the thermal expansion on the measurement performance of the flow meter must be considered.

The numerical calculation based on computational fluid dynamics (CFD) is one of the main methods of studying the flow characteristics. For studying the influence of the thermal expansion of the impeller on the flow characteristics, the fluid structure interaction (FSI) model should be used. The fluid structure interaction model plays a very important role in many engineering applications, especially for the coupling effect between the fluid and the structure. Zhang et al.[1] used the FSI model to study the influence of the wind shear on the wind turbine blade and obtained the displacement and the stress along the span of the turbine blade. Pita Claudio and Felicelli Sergio[2] presented an immersed element-free Galerkin method (IEFG) to solve the fluid-structure interaction problems involving large deformation of a slender solid body. Patek et al.[3] et al researched the dynamic characteristics of a transformer-bushing system by using the fluid structure interaction approach. Benra and Dohmen[4] simulated the deflection deformation of the pump impeller with a fluid structure interaction method and it is shown that the impeller orbit curves obtained by the FSI is consistent with the measurement. Sun and Gu[5] analyzed the wind-induced responses of a saddle membrane structure under wind actions by the FSI model. Zhang et al.[6] investigated the fluid-structure interaction for a super-long flexible beam with the FSI model. Liu et al.[7] investigated the propulsive performance of a flexible articulated caudal fin by the FSI model. Gim et al.[8] simulated the interaction between a fluid and a 2-D/axisymmetric hyperelastic body based on FSI model. Wen et al.[9] researched the relastic parameters of artery bypass graft with FSI method. These researches mainly focus on the structural deformation and the stress caused by the fluid, the change of the fluid field caused by the structural deformation is largely ignored. Some references only study the structural deformation and the stress with an unidirectional coupling, the fluid field change is not considered.

In the study of the flow meter, Liu et al.[10] and Shi et al.[11] analyzed inter flow characteristic of impeller flow meter. But the researches that consider the fluid structure coupling effect were rarely carried out for impeller flow meter. But there are not so many studies that consider the fluid structure coupling effect for the impeller flow meter. In this paper, the flow characteristics of the multi-channel impeller flow meter are studied based on the fluid structure interaction model and the effect of the structure deformation on the fluid field is analyzed. The model and the methods used in this study can also be used for similar problems.

1. The calculation model and calculation domain

In this paper, the FSI model is used to study how the structure deformation affects the measurement performance of the heat meter. The turbulence model is adopted to calculate the velocity and pressure distributions of the flow field in the fluid domain and the finite element model (FEM) is used to calculate the stress and deformation of the structure caused by the thermal expansion and the water impact in the structure domain.

1.1 *The turbulence model of fluid domain*

Because the flow in the heat meter is turbulent in most cases, so the RNG k - ε turbulent model is used to obtain the velocity and pressure distributions. The RNG k - ε turbulent model consists of the continuity equation, the momentum equations, and the k and ε equations[12-15].

(1) Continuity equation

$$\frac{\partial U_i}{\partial x_i} = 0 \tag{2}$$

where U is the mean velocity.

(2) Momentum equations

$$\frac{\partial U_i}{\partial t} + U_j \frac{\partial U_i}{\partial x_j} = -\frac{1}{\rho}\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\nu \frac{\partial U_i}{\partial x_j} - \overline{u_i u_j}\right) \tag{3}$$

where P is the mean pressure, ρ is the density, ν is the kinematic viscosity and $\overline{u_i u_j}$ is the Reynolds stress tensor.

(3) k equation

$$\frac{\partial k}{\partial t} + U_j \frac{\partial k}{\partial x_j} = -\overline{u_i u_j}\frac{\partial U_i}{\partial x_j} + \frac{\partial}{\partial x_j}\left(\frac{\nu_t}{\sigma_k} + \nu \frac{\partial k}{\partial x_j}\right) - \varepsilon \tag{4}$$

Download English Version:

https://daneshyari.com/en/article/1722015

Download Persian Version:

https://daneshyari.com/article/1722015

Daneshyari.com