ScienceDirect

Flow Measurement and Instrumentation
Volume 77, March 2021, 101837

Performance evaluation of Coriolis mass flow meter in laminar flow regime

Vikram A. Kolhe [a], Ravindra L. Edlabadkar [b]

Show more

Share Cite

https://doi.org/10.1016/j.flowmeasinst.2020.101837
Get rights and content

Abstract

In many fluid flow applications, mass flow rate is preferred over volume flow rate, as it is more beneficial in terms of cost and material balance calculations. Coriolis mass flow meter (CMFM) is accepted widely for mass flow measurement owing to its accuracy and reliability. However, it has been found to under-read the mass flow rate in laminar flow region [1], thus limiting its application in this region. The secondary flow in the curved tube section influences the generated Coriolis force and leads to a deviation in meter readings. Commercial CMFMs are available with various curved tube configurations and need to be analyzed for their application in laminar region. This paper presents comprehensive experimental and numerical investigations performed to evaluate the influence of tube configuration and other meter parameters, such as drive frequency, amplitude of vibration, and sensor position, on the performance of the CMFM in laminar region. The findings of this study have put forth a suitable combination of tube configuration, drive frequency, and sensor position while using the CMFM in laminar flow regime.

Introduction

The process industries mainly demand the accurate and reliable flow measurement which is utmost satisfied by CMFM offering various advantages such as accuracy, sensitivity, repeatability, independency on fluid properties, etc. CMFM works on the principle of Coriolis force which is the combined effect of the linear velocity of the fluid and angular velocity of tube. The studies carried out on the CMFM so far were mainly performed using the available commercial meters and were predominantly concerned with the effect of external vibrations, meter installation, velocity profile, etc. on the performance of the meter. However, very few researchers have attempted a study of the influence of different parameters, such as drive frequency, amplitude, and sensor position, with respect to various indigenously-developed tube configurations in the laminar flow region. A scan of literature has highlighted that in a laminar regime a secondary oscillatory shear force is generated and a part of Coriolis force is wasted in overcoming this secondary force and contributes less in producing the phase shift (i.e. time lag) between two arms of the tube. Hence, the tube section experiences a reduced effect of Coriolis force leading to under-read the flow in the laminar regime. Kumar et al. [1] presented the numerical results of a commercial flow meter comprising a twin U shape sensor tube, and commented on the deviation in the meter readings at low Re. An oscillatory shear force caused by the secondary flow in the curved tubes has been pointed out to be affecting the meter performance. A need for further research with respect to tube shape and size for CMFM application in the laminar regime has been reported. Bobovnik et al. [2] studied the effect of velocity profile on a shell-type straight tube meter for different aspect ratios and noticed a remarkable loss in meter sensitivity at low Re. The results were compared using the weight vector theory for two turbulence models. Kutin et al. [3] performed a numerical comparison between two modes of straight meter tube; beam-type and shell-type to study the effect of velocity profile. A significant deviation was found in the performance of the beam-type meter at low Re.

Limited data is available on indigenously developed tube configurations of the meter as well as the influence of different parameters, such as drive frequency, amplitude of vibration, flow regime, and sensor position, on its performance. Prabhu et al. [4] carried out tests on various tube configurations made of aluminum and PVC to predict meter sensitivity and sensor position for maximum sensitivity. Patil P. et al. [5] experimentally evaluated the performance of U tube configuration with different L/D ratios for different drive frequencies and for minimum percentage error. Clark et al. [6] performed experiments on different meters and reported error in readings owing to an additional component in the sensor signal at Coriolis frequency. They have suggested implementing a phase difference algorithm in order to minimize the error. Further, in their investigation on straight and curved tube meters' response to step changes in the flow rate, Clark et al. [7] reported that external vibrations affect the meter response. Luo et al. [8,9] performed numerical analysis of a straight tube, followed by a U shape tube meter and put forth the percentage of deviation in the measurements of flow rate in laminar and turbulent regions. Sultan et al. [10] investigated the time difference for a U shape CMFM with respect to water and Kerosene and observed more deviation between experimental and numerical readings for Kerosene. Hemp et al. [11] noted a boundary source of secondary vibration in CMFM while calculating meter sensitivity using the weight vector theory. They have reported the importance of viscosity in vibrating fluid flow. Hemp [12] presented the effect of velocity profile on the sensitivity of straight tube meter with free ends. Under-reading of the meter owing to the viscosity effect was observed. Hemp et al. [13] presented the theoretical approach of error calculation in the measurement of density and the mass flow rate of compressible fluid using a lumped-parameter model for a straight tube meter. A close agreement of results has been noted between the obtained and established results.

The present work is aimed to study the best suitable combination of different meter parameters which influences the performance of meter for various tube configurations of CMFM to obtain maximum Coriolis effect in laminar flow regime.

Section snippets

Tube configurations

The key principle of the CMFMs is to maximize the Coriolis action in order to comply with various tube configurations. Most tube configurations comprise curved tube sections with different diameters and lengths. At present, twin tube configurations are gaining attention due to the advantage of vibration balancing. Available literature about tube configurations does not clarify the selection of specific tube configurations for a particular application. Hence, the need to analyze the performance…

Mathematical modeling

In case of CMFM, when the fluid flows through a vibrating curved tube it exerts forces on the structure due to change in momentum of the flowing fluid leading to structural deformation. The amount of deformation depends upon pressure and velocity of the flowing fluid and the material properties of the structure. In case of small structural deformations and at slower rates, the deformation will not affect the behaviour of fluid much more. But if the time variations are fast (greater than few…

Influence of vibration frequency on time lag for various sensor positions

For fixed sensor positions, higher time lags were recorded at lower frequency (F1) for all three sensor positions as shown in Fig. 4. However, in case of sensor position SP2, natural frequency (F2) was observed to cross the lower frequency (F1) with an increase in the flow rate as highlighted in Fig. 4b. The effect of natural frequency on time lag could be realized only in case of sensor positions SP1 and SP2. With the sensor position moving towards the point of excitation, time lag remained…

Experimentation

Fig. 10 shows the experimental setup developed for the study of the laminar flow regime. The entire experimentation program was designed using water as the working fluid. The main components and instruments involved in the development of this setup have been earmarked based on the requirements and measurement criteria. The key components of the experimental setup include vibration exciter, time lag measurement unit, sensors, and tube configurations. The selected test tube configurations were…

Comparison between numerical and experimental results

The numerical time lag values were compared with the experimental results of time lag for all selected tube configurations. Furthermore, the experimental results for same values of frequencies, amplitude of vibration, and sensor location as adopted in the numerical simulation were also compared. The results of comparison for Basic U tube configuration have been shown in Fig. 11. It has been observed that the numerical simulations were qualitatively in agreement with the experimental results.…

Summary of the parametric study

The results of the numerical simulations for all tube configurations have been summarized in Table 3 for the maximum performance of the meter.…

Conclusions

The main objective of this study was to evaluate and analyze the performance of CMFM for different tube configurations and to examine the effect of parameters including sensor location, amplitude, and frequency of vibration on time lag in laminar flow regime. Implementation of FSI has helped to analyze the dynamics of mutual interaction between two systems viz. fluid and solid structure. The FSI exercise and experimentation has revealed the following salient observations for different tube…

Authorship contributions

Please indicate the specific contributions made by each author (list the authors' initials followed by their surnames, e.g., Y.L. Cheung). The name of each author must appear at least once in each of the three categories below. Category 1: Conception and design of study: Vikram A. Kolhe, Ravindra L. Edlabadkar. Acquisition of data: Vikram A. Kolhe, Ravindra L. Edlabadkar. Analysis and/or interpretation of data: Vikram A. Kolhe, Ravindra L. Edlabadkar. Category 2: Drafting the manuscript: Vikram …

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

Acknowledgement

The authors acknowledge the financial support received from Savitribai Phule Pune University, Pune, Maharashtra, India. The authors would also like to thank Dr. Satyajit V. Kasar, Indian Institute of Technology, Bombay for his assistance during the work.…

Recommended articles

References (14)

G. Bobovnik *et al.*
Estimation of velocity profile effects in the shell-type Coriolis flowmeter using CFD simulations
Flow Meas. Instrum. (2005)

J. Kutin *et al.*
Velocity profile effects in Coriolis mass flowmeters: recent findings and open questions
Flow Meas. Instrum. (2006)

P. Gupta *et al.*
Tests on various configurations of Coriolis mass flowmeters
Meas. J. Int. Meas. Confed. (2006)

S.C. Sharma *et al.*
Performance evaluation of an indigenously designed copper (U) tube Coriolis mass flow sensors
Measurement (2010)

C. Clark *et al.*
The influence upon Coriolis mass flow meters of external vibrations at selected frequencies
Flow Meas. Instrum. (2003)

C. Clark *et al.*
Experimental determination of the dynamic response of Coriolis mass flow meters
Flow Meas. Instrum. (2006)

J. Hemp *et al.*
The weight vector theory of Coriolis mass flowmeters-Part 2. Boundary source of secondary vibration

Flow Meas. Inrtrum (1995)

There are more references available in the full text version of this article.

Cited by (7)

Metering inaccuracy analysis and improvement measures of typical scenarios in hydrogen refueling station

2024, International Journal of Hydrogen Energy

Show abstract

Mass flow prediction in a refrigeration machine using artificial neural networks

2022, Applied Thermal Engineering

> *Citation Excerpt :*
> …Therefore, flowmeters based on the Coriolis principle have become one of the most important area of development in flow measurement over the past two decades [51]. This type of flowmeters can offer several advantages, such as accuracy, sensitivity, repeatability, and independency in fluid properties. [31]. Hu, Chen and Chang [26] also highlight the high accuracy of Coriolis mass flowmeter because it is less affected by factors such as density, pressure, and room temperature.…

Show abstract

Recent advancements in volumetric flow meter for industrial application ↗

2023, Heat and Mass Transfer/Waerme- und Stoffuebertragung

Parameter optimization of coriolis mass flow meter in laminar flow regime using Doe-Taguchi method ↗

2023, Journal of Thermal Engineering

Flow-induced vibration characteristics of the U-type Coriolis mass flowmeter with liquid hydrogen ↗

2022, Journal of Zhejiang University: Science A

Mass Flow Prediction in a Refrigeration Machine Using Artificial Neural Networks ↗

2022, SSRN

View all citing articles on Scopus ↗

View full text

© 2020 Elsevier Ltd. All rights reserved.

ELSEVIER

All content on this site: Copyright © 2023 Elsevier B.V., its licensors, and contributors. All rights are reserved, including those for text and data mining, AI training, and similar technologies. For all open access content, the Creative Commons licensing terms apply.

RELX™