Ain-Shams University
Faculty of Engineering
Cairo, Egypt

A STUDY OF THE INTERACTION BETWEEN THE VALVE CONFIGURATION AND THE FLUID DYNAMICS IN OSCILLATING SYSTEMS

Ashraf Ibrahim Mostafa Sharara

A thesis submitted in partial fulfillment
of the requirements of Ain-Shams University
for the degree of

Doctor of Philosophy

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Mechanical Engineering Department
Faculty of Engineering
Ain-Shams University
2010

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EXAMINATION COMMITTEE

The undersigned certify that they have read and recommend to the Faculty of Engineering at Ain Shams University the acceptance of a thesis entitled "**A Study of The Interaction between The valve Configuration and the Fluid Dynamics in The Oscillating Systems**", submitted by Eng**. Ashraf Ibrahim Mostafa Sharara**, in partial fulfillment of the requirements of Ain-Shams University for the degree of **Doctor of Philosophy in Mechanical Engineering**.

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TO

MY GREAT PARENTS,

AND BELOVED WIFE

MAY GOD BLESS THEM ALL

Statement

This dissertation is submitted for the partial fulfillment of the requirements of mechanical engineering department in Ain-Shams University for the degree of doctor of philosophy.

The work, included in this research, is carried out by the author and no part of it has been submitted for a degree or qualification at any other university.

Signature

Ashraf I. Sharara

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ABSTRACT

One of the main sources of the flow – induced vibration in the piping systems is the presence of control valves. When the valve operates at relatively small openings and under certain operating conditions, vibration problems arise from the interaction between the valve configuration and the fluid flow. Therefore, the valve, as well as the piping system will experience severe vibration levels. The impact of the vibration may result in fracture damage in the valve and/ or the piping system. The present research work is dedicated towards the study of the interaction between the configuration of a flat -face globe valve, operating at different openings, and the fluid dynamics in the oscillating systems. A hybrid study of numerical and experimental work is to be conducted. A mathematical model for the flow, passing through the control valve, has been developed. The flow model was numerically solved by using FLUENT 6.3 commercial code. The numerical results were obtained for different valve openings and operating conditions. The incompressible turbulent flow, through the valve, was found to be transient for a small period. Then, the flow reaches a steady-state condition. Moreover, the observed flow phenomenon was found to be a circumferential jet flow that comes out from the annular gap between the plug and the seat. The phenomenon is associated with a steady system of vortices, resulting from the interaction between the jet flow and the internal configuration of the valve. On the other hand, a test rig had been designed and manufactured by the author, in order to conduct necessary tests on the control valve, under different operating conditions. The test rig is equipped with all transducers for both flow and vibration measurements. The flow measurement includes the pressure drop across the orifice to calculate the volume flow rate, the upstream and downstream pressures of the valve and the flow force acting on the stem of the valve. The flow measurement was performed by using an S-Shape Load cell, which was designed and developed by the researcher. Moreover, a good correlation between the

numerical and experimental values of the flow force was noticed. On the other hand, the vibration measurement is limited to the valve vibration level. The experimental results indicate that the control valve, under study, is of Quick-Opening Inherent Characteristic. Moreover, the measurement of the volume flow rate and the downstream pressure, for different conditions, were used as actual boundary conditions for the CFD simulations. The flow measurements results were reduced by performing a dimensional analysis for the flow force, acting on the valve stem. Therefore, an empirical formula was obtained between the dimensionless force and the volume flow rate. The dimensionless exciting force decreases as the valve opening increases. For small valve opening values, a little change in the plug position yields to a significant variation in the value of the exciting force which means that the effectiveness of valve position becomes very much pronounced for small values of valve opening. Regarding the vibration measurements, the frequency spectrums for all performed test conditions (Re= $1*10^5$ – $3*10^5$) and different stiffness of the stem, were found in the low frequency range (up to 55 HZ). Moreover, the reduction of the stiffness of the stem supports yields to an increase in the vibration level. Moreover, for a certain value of valve opening, the increase in the flow rate tends to an increase in the vibration level of the stem. On the other hand, the recirculation zone, occurring at the downstream of the valve plug, as indicated by CFD simulation, causes periodic variations in the pressure differences across the plug with three dominant frequencies of 10.94, 12.5 & 14 HZ. An experimental correlation between Reynolds and Strouhal numbers was obtained. The later was found to be in qualitative agreement with previous research work. Finally , a better understanding of the flow phenomenon and its consequences for the turbulent flow, passing through the globe control valve with flat -face plug, had been achieved.

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