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Experimental characterization of globe and gate valves in vertical gas–liquid flows

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ABSTRACT

Valves are mechanical devices commonly used in pipelines and pipe networks for industrial applications, including petroleum, power and process industries. In two-phase flows more complex flowing conditions occur and special attention must be paid to predict pressure losses. To date, studies on two-phase flows through valves have been mainly devoted to safety relief valve (SRV). This paper presents the results of an experimental characterization study of a globe and a gate valves 2″ DN. The aim of the study is to investigate the flow through this type of valve, to understand the phenomena that occur inside and to improve models to calculate pressure drops in two-phase flow conditions.

The valve has been preliminary characterized in single phase flow obtaining quite good results. The flow coefficient of the valve has been determined in order to proceed in two phase tests. Comparison between two phase flow measured data and predictive models has been considered. The Chisholm model seems to give the best agreement with the data in the observed interval for the globe valve. The best model for the gate valve seems to be the Lockart–Martinelli modified model. Predicting pressure drops in both cases, the average error is close to zero and less than ±10%.

1. Introduction

Valves are mechanical devices commonly used in pipelines and pipe networks for industrial applications, including petroleum, power and process industries. in single-phase flow the sizing of a valve or a fitting (such as elbows, restrictions or expansions, tee junctions or splittings) is an easy operation to do. Instead, in two-phase flow more complex conditions occur and special attention must be paid to predict pressure losses.

In the case of control valves is important to have a reliable model for predicting the flow through the valve itself, in order to operate properly on the actuator of the valve. For this purpose different types of valve are used: gate valves, globe valves, orifice valves, etc.

To date, studies on two-phase flows through valves have been mainly devoted to safety relief valves (SRV). The attention has been focused on discharge coefficients [1], valves sizing [2], maximum flow rate prediction [3–5] and fluid dynamic effects of valve geometry [6,7].

Other studies on different type of valve have been done trying to define possible predictive models for pressure drop. Hewitt reported studies done before 1984 [8]. The larger part of studies are devoted to gate valve and few to globe valve. Between them the work of Fairhurst [9] on different types of valves is quite extensive. He did a lot of tests in air–water system comparing it to the Chisholm, the homogeneous and maximum slip models. The work of Chisholm [10] states that his model is applicable to globe valve assuming the value 2.3 for the coefficient *B*. For gate valves the value to be assumed is 1.5. After 1984 only the work of Morris [11] appeared. He developed a new model trying to improve the Chisholm model. Better results were obtained for gate valves.

This paper presents the experimental characterization study of a globe and a gate valve of 2″ nominal diameter in vertical upward flow and a comparison with the previous studies on MOV [12]. The aim of the study was to investigate the flow through this type of valve, to understand the phenomena that occur inside it and to improve a prediction model for pressure drops in two-phase flow conditions. A comparison with available models in literature is also presented.

2. Experiments

The experimental tests were carried out in the ARIEL rig, located at the laboratory of the Dept. ICMA, University of Rome "La Sapienza". The loop consists of a liquid supply system, a liquid reservoir, a gas supply system, a 4-meter long vertical test section in Plexiglas (with an internal diameter of 2″) and an upper degassing tank. The transparent pipe allows to verify the occurring flow pattern. The tested valve was installed in the upper part of the column.

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Nomenclature

K_v	valve coefficient (l min^{-1} bar^{-1})
Q	flow rate (m^3 s^{-1})
Δp	pressure difference (bar)
A	total flow area (m^2)
C_d	discharge coefficient (–)
C_a	flow area coefficient (–)
v	velocity (m s^{-1})
d	diameter (m)
D	diameter (m)
K_o	loss coefficient (–)
S	slip ratio (–)
x	quality (–)

Greek symbol

γ	specific gravity (–)
α	gas fraction (–)
ρ	density (kg m^{-3})
σ	flow area ratio (–)
Φ^2	two-phase multiplier pressure drop (–)

Subscript

w	water
l	liquid
lo	liquid only
g	gas
h	homogeneous
tp	two-phase
sp	single phase

The layout of the test rig is reported in Fig. 1. The used valves are commercial ones and are presented in Fig. 2a and b.

The tests were carried out at low pressure (max 2 bar gauge), with total flow rates up to 3 m^3/h and gas fractions up to 50%.

All measurements were acquired by a DAQ system based on a personal computer with a 16 channel DAQ card and a signal conditioning box. The data acquisition system was managed by a program developed in LabView®. The air flow rate is controlled by the software and the liquid one is regulated by hand.

Each measurement is obtained through processing data acquired with a sampling rate of 200 Hz and for 2.5 s. After processing, average values were stored in worksheet files.

2.1. Measurements and experimental matrix

Two pressure taps were used to measure the pressure at the inlet, P_u, and at the outlet, P_d, of the valve. Both are located one diameter far from the connection flanges. The pressure in the test section and the supply pressures of water, P_w, and air, P_g, were measured. A differential pressure gauge was installed along the vertical test section to measure the pressure drop over 1 m pipe length. From this measurement the gas fraction of the two-phase mixture was calculated. Water and air supply temperatures were measured by RTD Pt100 sensors.

The water flow rate Q_w was measured by an electromagnetic flow meter with a range of 0–167 l/min (0–10 m^3/h). The air flow Q_g was controlled by a flow controller with the range 0–500 Nl/min (0–30 N m^3/h).

Single-phase as well as two-phase flow conditions were achieved in tests. Each set of tests was repeated three times, in order to assess the repeatability of measurements. The water flow rates ranged between 1 and 3 m^3/h with increasing steps of 0.5 m^3/h for the single-phase and two-phase experiments. The gas flow rates were set in order to obtain a given gas fraction in test section. It ranged between 5% and 50%, with increasing steps of 5%.

The tests have been done varying also the opening of the valves. For the globe valve analyzed openings ranged from full opening to near closing condition each 20% opening. For gate valve analyzed conditions are between 7% and 60% opening.

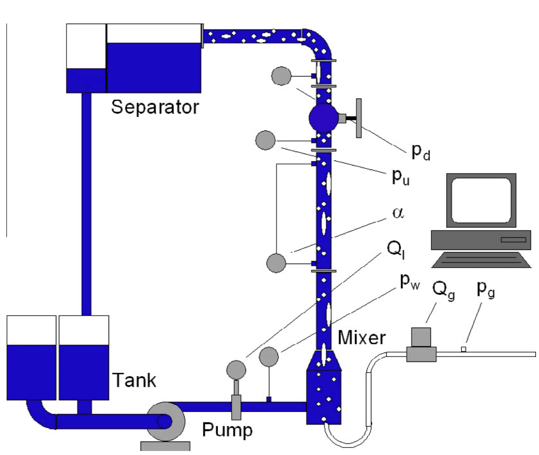

Fig. 1. Layout of the ARIEL test rig.

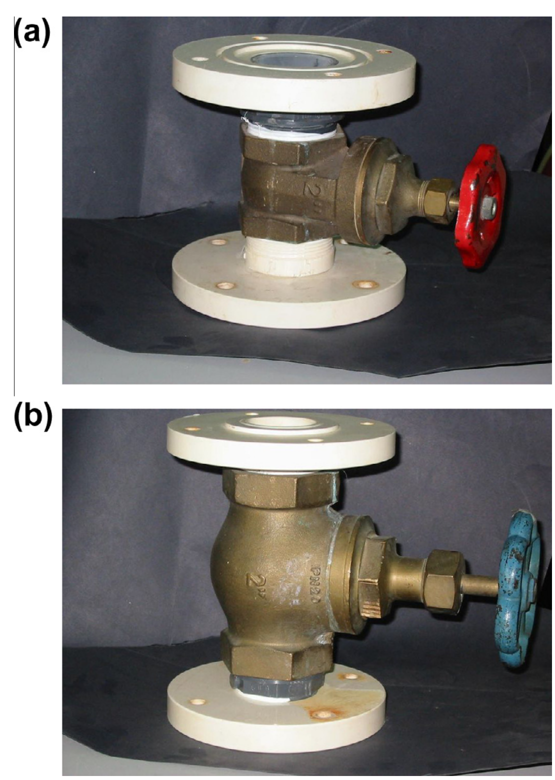

Fig. 2. (a) Globe valve and (b) gate valve.