Abstract

An experimental and numerical study was carried out to investigate the characteristics of the turbulent flow through a conical poppet valve with sharp edge seat.

In the experimental work, a test rig was manufactured with support in the mechanical workshop in School of Engineering / Cardiff University/UK. A Particle Image Velocimetry (PIV) system was used to investigate the fluid flow passing the poppet valve. The dimensions of valve body are (inside diameter of the seat=43 mm which represents the inlet diameter, and the valve chamber diameter=85 mm). Water was used as a working fluid. This study gives a performance data for valve with a plenary or truncated conical poppet, and with a right angled or conical seat. In order to evaluate the performance, a series of experiments was carried out at different flowrates(15, 20, 25, 30, 35, 40, and 45) l/min, axial valve openings (1.5, 3.5, 5.5 and 7.5) mm, and different poppet angles (20°, 30°,and 45°)for the plenary conical poppet. The valve with a poppet of 30° was tested with two types; plenary and truncated conical poppet. The valve with poppet of 20° was tested with two types; right angled or conical seat.

In the numerical investigation, and in order to analyze the flow field in the conical poppet valve with different types of poppets and seats, a domain of 2D Navier-Stokes equations was solved. These equations are the conservation of mass and momentum equations as well as a standard (k-ε) turbulence model associated with laws of the wall along solid boundaries. The mathematical models of flow in poppet valve were solved numerically based on the finite volume method using (FORTRAN 90) with SIMPLE algorithm and Upwind scheme. The steady- state behavior of fluid flow under different parameters was analyzed and presented. The numerical investigation covers all the cases tested in the experimental work for different flowrates, different valve openings and different poppet angles.

The results showed that the discharge coefficient is approximately constant with increase of flowrate, while the force coefficient slightly decreases. Also, the discharge coefficient decreases with increase of poppet angle at constant axial valve opening, while the force coefficient has a contrary behavior, where it decreases with increase of poppet angle from 20° to 30° due to increase of orifice area and increases with increase angle from 30° to 45° due to the increase of momentum change. It is found that the increasing of axial valve opening leads to decrease the discharge coefficient and rapidly decreases the force coefficient. The use of truncated poppet depicted an evident decrease of discharge coefficient and high increase of force coefficient, while the use of a conical seat instead of right seat showed a slight increase of discharge coefficient. This study revealed that the built model of poppet valve is suitable for PIV investigations. The instrumentations and the used seeding particles are good for the study of the velocity distributions. The images of PIV showed one vortex is formed in the corner of valve chamber as plenary poppet is used, while another vortex is formed between the flow and poppet as truncated poppet is used. The radius and intensity of the first vortex are increased with the increasing of flow rate and the valve opening, while the second vortex is formed at large opening and low flowrate.

The comparison between the numerical and experimental results gave a good agreement. For the case of valve with a right angled seat, the results showed that at the low flowrates (15 l/min), the deviations between the numerical and experimental results reach to 3.1% and 6.3% for discharge and force coefficients, respectively, while these deviations are about to 9.2% and 14.1% at the highest flowrates. The comparison between velocity vectors of the CFD and PIV images manifested some different in valve chamber region at small opening due to three dimensional effect. This study gives many indicators which help the engineer during the design process of poppet valve for a certain application in hydraulic system.