NUMERICAL SIMULATION AND PIV MEASUREMENT ON THE FLOW FIELD WITHIN JET PUMPS

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The jet pump is a kind of fluid machinery and mixing device that uses fluid as its driving power. It has no rotating parts and possesses many advantages. Up to now, the performance of jet pump was calculated by one-dimensional or so-called semi-two-dimensional theory. Many details of the flow field were ignored and result in larger error between the prediction and experiment. The flow within a jet pump is confined coaxial jet developing in an irregular area. It refers to many basic phenomena that have not been understood quantitatively. The interested flowing zone in a typical jet pump is downstream part of the nozzle, which is a symmetrical zone with convergent and divergent part. So, TTM method was employed to transform half of the axial plane into a regular one. In doing so, the source item of transforming equations at boundary was corrected by method proposed by Hilgenstock, to improve the orthogonality of mesh near boundary.

HFAM is a newly developed discrete method, which is some better than FVM in the convergence speed when simulating confined jet flow. So, HFAM was chosen as the discrete method. Inducing $k-\varepsilon$ turbulence model, the dimensionless governing equations by taking nozzle exit radius and jet velocity as reference length and reference velocity, were transformed into equations used in calculation plane and in forms needed by HFAM. In solving above equations, staggered-mesh and the corresponding SIMPLE method were employed.

The influence of the wall of nozzle cannot be neglected by assuming upcoming flow to behave as turbulence boundary layer, which thickness was set as 1/10 of the hydraulic diameters of the appropriate flow cross-sections. The downstream and symmetrical conditions can be treated as Newman conditions in the physics plane. The wall function proposed by Launder and Spalding was adopted in the wall boundary. But some details were modified.

The convergent angle of throat entrance tube and divergent angle of diffuser of the jet pump are 19.65º and 3.5º respectively. The diameter of throat pipe is D_3=40.01mm. The nozzle is replaceable. Corresponding diameter of nozzle exit section are 14.02mm, 16.01mm, 18.39mm and 20.02mm respectively. That gives 4 kinds of area ratio of jet

pump as m=4.73, 6.28, 8.14 and 3.99.

The flow fields in throat pipe of the same jet pumps were measured in a closed test rig by TSI PIV system. Due to space limitation, only results of m=6.28 (corresponding nozzle diameter is 16.01mm) were discussed.

The velocity decay in centerline as well as wall pressure distribution were obtained both by calculation and simulation. Both simulation and measurement shows apparently that the centerline velocity gets some acceleration just a little downstream of the nozzle, and then decays as usual. This performs a little difference to that of free jet. The centerline velocity distributions at different q have the same tendency (q represents the volumetric flow rate ratio of the secondary flow to that of the primary flow). While, the flow core with bigger q disappears quickly than that of small q. This implies that the centerline velocity with bigger q decays quickly than that of small q. The wall pressure distribution shows that it declines a little in the entrance pipe and fore of throat pipe because of the convergent shape of the entrance and only a little energy exchange between the two flows in that part. After that, with great momentum exchange from primary flow to secondary flow, the wall pressure ascends quickly until the flow reaches the end of throat pipe. In some case as q =0.90, the two flows mix thoroughly before the end of the throat pipe, the wall pressure will declines slightly because of the friction lose. In diffuser, the pressure of mixed flow will climb continually because the velocity energy is converted into the pressure energy. The pressure recovery takes place mainly in the throat pipe and secondly in the diffuser. The position of the lowest wall pressure will move forward into the throat pipe when the q is bigger.

The velocity vector field as well as iso-u velocity distribution were also obtained numerically and experimentally. The results reveal that the development of confined coaxial jet is of some resemblance to that of the free coaxial jet. At starting part of the flow there is a flow core, which will disappear downstream with the jet spreading. The primary flow exchange momentum with secondary flow in the jet boundary layer. The jet boundary layer spreads approximately linearly with the flow developing downstream until it reaches the wall of throat pipe. After that, because the spreading of jet boundary layer is confined by the wall, it performs difference to the free jet.

The structure of fully developed confined coaxial jet flow is controlled mainly by dimensionless number Ct. As all geometric dimensions are determined, the flow structure is governed by the velocity ratio of the primary flow to the secondary flow, i.e., q of jet pump. In the case of larger q, the velocity ratio is also larger. The driving flow exchanges relatively less energy to the secondary flow for both flows getting drastically mixing. In that case, the decay of jet is slower than that of smaller q. With the drop of q, the secondary flow can't offer enough flux for the primary flow to entrain before it spreads to the wall. So, the primary flow will entrain downstream flow to satisfy its requirement. Then separation and eddy occur. So, the structure of the fully developed confined coaxial jet flow can be divided into four sections. The first one is flow core section. The second one is jet boundary layer section. The third one is separation flow section. It may be occur or not. The last one is pipe flow section.

Keywords: Jet pump; Confined coaxial jet; Numerical simulation; PIV