INTERNATIONAL RESEARCH JOURNAL OF ENGINEERING & APPLIED SCIENCES
ISSN: 2322-0821(O) VOLUME 5 ISSUE 4
ISSN: 2394-9910(P) Oct 2017 - Dec 2017
www.irjeas.org

STRUCTURAL DESIGN & FEM ANALYSIS OF LARGE BUTTERFLY VALVE

Atul Shrivastava[1], Arun Patel[2]

[1]*PG Scholar, Mechanical Engineering Department, NIIST, Bhopal.*
[2]*Asst. Professor, Mechanical Engineering Department, NIIST, Bhopal*

Abstract: ***Valves for hydro power projects are fitted for safety, servicing and repair, and stop flow of water, as well as for flow and variation in pressure.*** **A Valve used in hydel power plant is known as Butterfly valve and is a type of flow control device; it is widely used to regulate a fluid flowing through a section of pipe. This type of valve is mainly used as safety valve, turbine inlet valve, and pump valve for low to medium pressures. They are hydraulic systems and operated by oil for opening and closing or with the help of weight and hydraulic pressure for opening., oil pressure can also be taken from the governor hydraulic oil system For turbine inlet valves. The capping system or stopping system is of flexible, adjustable rubber/metal type to reduce leakage. Water flow through the valve is possible in both directions.**

The scope of this thesis is to analyses the option of fabricated variant for door & body in place of casted, reduction in the material of valve body & door by FEM analysis & optimization in the material of valve component.

The 3D modeling is to be done for butterfly valve by using CAD software. And stress & displacement FEM analysis of the butterfly valve is done by using ANSYS tool to evaluate the optimized result.

Introduction

Hydro power is considered as one of the most economical and non- polluting sources of energy. Power generation from the water is termed as Hydroelectricity. Hydroelectricity means electricity generated by hydro power or from the use of the gravitational force of falling water or flowing water.One of the common form of generating power is hydral energy which do not produce direct waste material and also not produce exhaust emission.

Now a day's more and more hydro electrical power plants being setup and renovated. But still the design and development of hydro electrical power plant is based on the traditional methods. Therefore there is a huge scope of utilization of modern day's technique like finite element method (FEM) for achieving maximum possible optimization.

In any power plant valves for different purposes are usually needed. Normally it is a shut-off valve just in front of the turbine. In this way the turbine may be emptied without emptying the shaft or penstock. In addition the guide vane cascade is depressurised so that leakage flow is avoided.

The butterfly valve is one of the types of shut-off devices most commonly employed in hydropower station and systems. Its use is favored because of their relatively low cost, compactness, light weight, reasonable water tightness and simplicity of operation.

Basically: Butterfly valve consists of a circular, lens shaped or open frame moving disc and body. The disc is pivoted in the body by two trunnions. When open the plane of symmetry of the disc lies parallel to the penstock axis.

It serves the following purposes:

1. Unit isolation in multi-unit plants where one penstock feeds more than one unit.
2. Stops the water flow to the turbine when no water is to be allowed to flow through the guide vanes.
3. Stops the water entry in case of emergency that is non-closure of guide apparatus or in the event of low oil pressure in the system.
4. To facilitate inspection of water path passage.
5. To prevent large damage at an eventual rupture of the penstock, a pipe break valve is normally installed in the pipe just downstream of the shut off valve.

This dissertation describes that with the help of ANSYS and CAD software, design optimization of butterfly valves. To optimize the weight of butterfly valve analysis of voinmises stress and maximum deformation are done by ANSYS and compare stresses value for existing casted verses optimized fabricated design for door and of butterfly valve to structural design the butterfly valve.

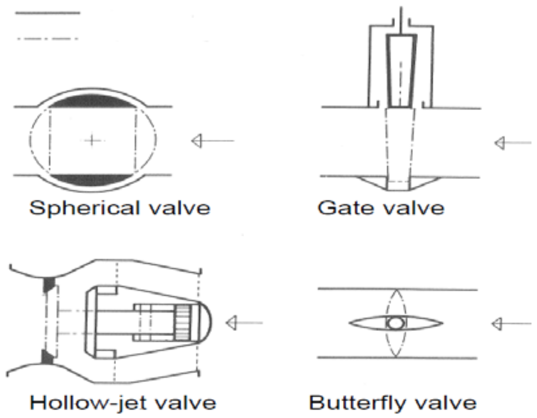

Fig. 1.1: Principle drawings for valves

Literature Review

The study of butterfly valves has evolved over the years; most of the earlier studies were based on analytical and experimental approaches. Because of the notable influence of the butterfly valve on the fluid flowing through it, many researchers have done lots of work to study the fluid characteristics of the butterfly valve.
One the earliest and most comprehensive pieces of research on the flow characteristics and performance of butterfly valves was performed by
Cohn [1]. Using data provided by previous authors, Cohn attempted to parameterize torque and flow coefficients based on thickness to diameter ratio for numerous butterfly valve geometries, most of which were symmetrical.
McPherson [2] studied various blade variations of single eccentric butterfly valves in incompressible turbulent flow subject to free, submerged, and continuous piping discharge arrangements. McPherson found that for a given type of installation, the flow characteristics were not significantly influenced by either the shape of the blade or by the closing angle except for the near-open and closed positions, respectively. Using a two dimensional setup of different symmetric butterfly valve blades, cavitation was also predicted.

Sarpkaya [3] also studied the torque and cavitation characteristics of idealized two-dimensional and axially symmetrical butterfly valves by considering an idealized case of laminar uniform flow through a symmetrical lamina (representing the butterfly valve) be-tween two infinite walls. Using these assumptions, Sarpkaya was able to extend approximate solutions to hydrodynamic torque, cavitation, and flow coefficients for three dimensional butterfly valves using semi-empirical equations.
Addy et al. [4] conducted several small-scale compressible flow experiments with sud-den enlargement configurations for butterfly valve models to predict mass flowrate and overall pressure characteristics. In addition, a full size butterfly valve was built and tested.
The sudden enlargement configurations were classified as three different types of nozzles: contoured converging, conical converging and sharp-edge orifice. It was concluded that the performance characteristics of the valve can be predicted if the valve flow coefficient is known for a specified operating pressure ratio.
Eom [5] building off the work of Cohn [1] and McPherson [2], studied the performance of butterfly valves as a flow controller. Eom compared the flow characteristics of perforated and non-perforated butterfly valve discs and found their performance to be in good agreement with one another, except at low blade (opening) angle values of about 10 degrees. He also studied the effect that blockage ratios (area of disc to area of pipe or duct) had on butterfly valves as throttling devices. Furthermore, Eom was able to predict loss coefficients sufficiently well from blockage ratios at Reynolds numbers in the range of 104.
Morris and Dutton [6] experimentally investigated the aerodynamic torque characteristics of butterfly valves using two dimensional planar models and three dimensional prototype valves at chocked and un-chocked operating points, and the results revealed the significance of the flow separation and reattachment phenomena on the aerodynamic torque characteristics of butterfly valves.
Morris and Dutton [7] also investigated the operating characteristics of two similar butterfly valves mounted in series, and an experimental investigation concerning the operating characteristics of a butterfly valve downstream of a 90 degree mitered elbow.
Kimura et al. [8] and Ogawa and Kimura [9] used free-streamline and wing theory to model symmetric butterfly valves between infinite parallel walls in two dimensions and used correction equations to compensate for pipe wall conditions. The correction equations also required a corrected opening angle and thickness of the discs, and uniform velocity. Using the given two-dimensional models, torque characteristics, pressure loss, and cavitation of three-dimensional experiments were predicted and analyzed. While the general pattern of torque coefficients followed the experimental data, the differences between the predicted and actual values were large. In more recent years since Kimura and Ogawa, scientific and engineering communities in the field of fluid dynamics and valve research have placed more emphasis in Computational Fluid Dynamics (CFD), especially with the advent of commercial CFD software in the 1990s.
Huang and Kim [10] were some of the first to use commercial CFD software to investigate three dimensional flow visualization of a symmetric butterfly valve (modeled as a thin flap valve disc). Huang used CFD code FLUENT to simulate a steady incompressible flow with k-ε turbulence modeling. Valve positions were simulated at openings of 30, 45, 60, 70, and 90 degrees. Huang also investigated the length downstream of the valve in which flow would return to fully developed conditions. Due to computational restrictions, a relatively coarse mesh of a maximum of 25,000 cells was

used in the CFD calculations. Huang also compared his numerical results with the experiments carried out by Blevins [11]. The 45 degree case was found to be the most agreeable with the experimental data, while the rest lacked agreement.

Lin and Schohl [12] used commercial CFD software FLUENT to predict drag coefficients for a symmetric coin shaped butterfly valve at opening angles in an infinite flow field with results obtained experimentally by Hoerner [13]. Sensitivity of the results to turbulence model selection, accuracy of discretization schemes, grid quality, and grid dependence were studied as part of the validation. Lin compared k- ε, k-ω, and k- ω SST turbulence models and opined that the later model was preferred for resolving the Reynolds-averaged Navier-Stokes equations and that use of a 1st order discretization for the flow domain led to predictions significantly higher than those from the 2nd order schemes. Flow coefficients aligned well with experimental data overall, however it should be noted that exact modeling comparisons between the experimental setup and the numerical model were difficult to match. Lin also modeled a 3.66 meter diameter butterfly valve within a pipe at valve openings of 20, 40, 50,60, 70, 80, and 90 degrees with cavitation free conditions and incompressible flow using CFD.

A computational mesh size included about 1.5 million tetra and hexa-elements. Pressure drop across the valve was calculated and predicted flow coefficients matched relatively well with experimental data provided by the United States Army Corps of Engineers (USACE) for a similarly shaped disc butterfly damper.

Song et al. [14] performed a structural analysis of large butterfly valves, in addition to validating three-dimensional experimental data of a butterfly valve's pressure drop, flow coefficient, and hydrodynamic torque coefficient using general purpose CFD code CFX [15].The k- ε turbulence model was selected by Song since it does not involve the complex non-linear damping functions required by other models. A mesh of nearly one million cells was used with a domain extending eight pipe diameters upstream from the valve and approximately ten pipe diameters downstream. Cases were run for disc opening angles of 5 to 90degrees in increments of 5 degrees. Generally, good results were obtained except when the valve opening angle was less than 20 degrees. In the 20 degree case, differences between experimental and simulation data were found to be nearly 50%.

Leutwyler and Dalton [16, 17] performed a CFD study in two and three dimensions for symmetric butterfly valves in compressible fluids at various angles and over a range of pressure ratios. The general purpose CFD code FLUENT was used with the following turbulence models: Spalart-Allmaras, k- ε, and k- ω. Leutwyler favored the k-ε turbulence model for its well-rounded capabilities and moderate computational costs. In addition to examining grid refinement, coefficients for lift, drag and torque were validated against experimental values.

Henderson et al. [18] measured torque and head loss of a symmetrical butterfly valve installed in a hydro-electric power generating scheme for steady flow at Reynolds numbers of order 106. This was done for valve opening angles of 10 to 80 degrees in 10 degree increments. The general purpose CFD software ANSYS CFX was validated using collected experimental data. In the experiment, Henderson used anti-vacuum valves downstream in a penstock tunnel to prevent severe cavitation. The CFD flow domain extended from about 58 diameters (D) upstream and 15D downstream to ensure fully developed flow conditions. Tetrahedral elements were used on the valve face to best model the butterfly valve features. Consequently, the number of cells in the domain ranged from 2.2 million to 220 million. Henderson favored the Shear Stress Transport (SST) turbulence modeled and found that for valve angles greater than 20 degrees, the flow downstream from the valve was dominated strongly by unsteady vertical disturbances. An estimated eddy shedding frequency of about 1.3 Hz was estimated. Cases were run in which the CFD models had a symmetrical boundary to improve solution time and one in which the whole model was used for a steady and transient solution, respectively. The main difference manifested between the full and symmetry models was that the whole model was able to show the eddy shedding alternate between sides, while the torque coefficients and flow patterns remained unchanged overall. While the overall patterns of the predicted torque characteristics are similar to the experimental data, they differ by over 25% in many mid-valve positions.

Henderson concluded that better field measurements, including the flow rate, could improve the modeling of the CFD boundary conditions.

Cheiworapuek et al. [19] investigated incompressible turbulent flow past a butterfly valve at 15, 30, 45, 60 and 90 degree opening angles. The CFD code FLUENT was used to validate experimental data for butterfly valves having diameters of 150 and 300 mm. The number of elements used in the simulation ranged from 1.1 million to 1.4 million. The k-ε turbulent model was used. For the experiment, pressure taps were located 1D upstream and 14D downstream. Cheiworapuek observed that vortices were found near the tips of the butterfly valve and became larger as the valve disc was oriented at more closed positions.

The loss coefficient was generally unaffected by a change in inlet velocity for a given disc orientation. Large differences between the experimental data and simulation results were on the order of 50% for loss coefficients and torque.

Feng et al. [20] used a general purpose CFD code with a k-ε turbulence model to study cavitation and flow characteristics of a 1.2 meter diameter double eccentric butterfly valve. A hybrid mesh of quadrilateral and triangular elements were used. The flow domain extended from five diameters upstream to about ten diameters downstream. Feng found that a double eccentric structure had improved dynamic response and

International Research Journal of Engineering & Applied Sciences, IRJEAS
www.irjeas.org, ISSN(O): 2322-0821, ISSN(P): 2394-9910, Volume 5 Issue 4, Oct 2017-Dec 2017, Page 25-30

self-sealing in comparison with a single or no offset butterfly valve.

Xue Guan Song, et al [21] studied the multidisciplinary optimization of a butterfly valve. The initial model of valve is made and then the initial analysis including fluid and structural analysis is carried out to predict the fluid and structure performance of the valve. Optimization is carried out in the form of mathematical functions and using with the trade-off method. Validation simulation shows that the orthogonal array experiments drastically reduced the numbers of the computer experiments, and trade-off method combined with response surface model can predict the optimum conditions accurately and effectively.

While many have researched butterfly valves over the years, the following comparison study will seek to contribute insight into the use of CFD to predict butterfly valve performance factors, especially in specifying the level of agreement that can be expected at various valve opening angles, and discuss meshing methods to improve results.

However, only studying the fluid characteristics is not enough for the large diameter butterfly valve because the pressure produced by the fluid is too high, which has great effect on the stress distribution in valve.

Now a day's more and more hydro electrical power plants being setup and renovated. But still the design and development of hydro electrical power plant is based on the traditional methods. Therefore there is a huge scope of utilization of modern day's technique like finite element method (FEM) for achieving maximum possible optimization.

Valves are very widely used for hydro mechanical part which is used to control the flow of water under high heads.

This dissertation describes the design optimization of butterfly valves using CAD software and ANSYS. To structural design the butterfly valve for weight optimization the Principal stress first, second, voin mises stress & maximum deformation value are find out by using ANSYS and compare stresses value for existing casted verses

Finite Element Analysis Results: The finite element analysis was used to obtain the stress and displacements.

Disc: As a result of finite element analysis, were obtained the von Mises equivalent stress shown in figure 5.1 for disc casted & shown figure 5.3 for disc fabricated.

The total deformation shown in figure 5.5 for disc casted & shown in figure 5.6 for the disc fabricated variant of the butterfly valve.

It can be observed that the maximum von Mises equivalent stress not exceeds the allowable stress 150 Mpa.

The maximum values (Figure 5.2 and Figure 5.4) for the equivalent stress appear in the transition area between support rib and discseat area.

The major parts of equivalent stresses do not exceed σ=225 N/mm2, which are smaller than admissible stress value σ_a=1.5x150=225 N/mm2.

The maximum total deformation value for disc in closed position is 0.3426 mm (casted) & 0.8499 mm (fabricated) at center of the disc.

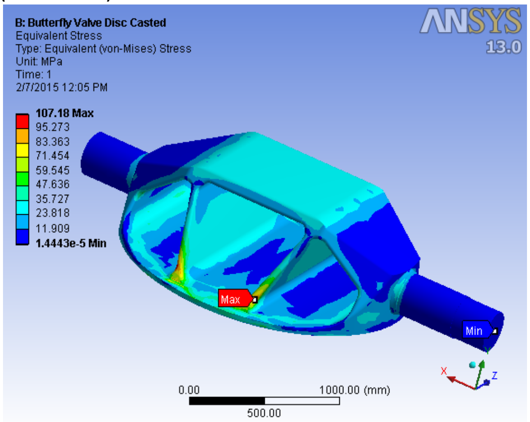

Fig. 5.1: von Mises equivalent stress for valve disc casted

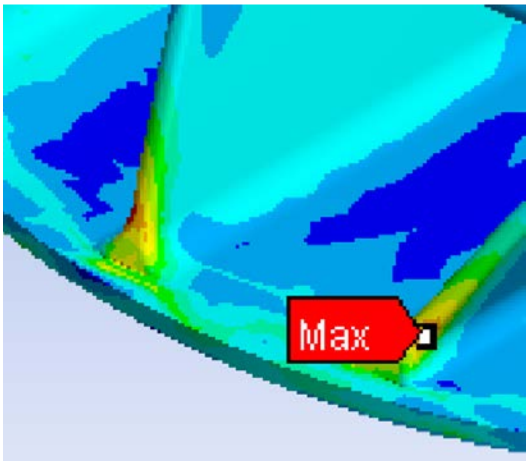

Fig. 5.2: Detail showing the area of maxi von Mises equivalent stress for
Butterfly valve disc casted

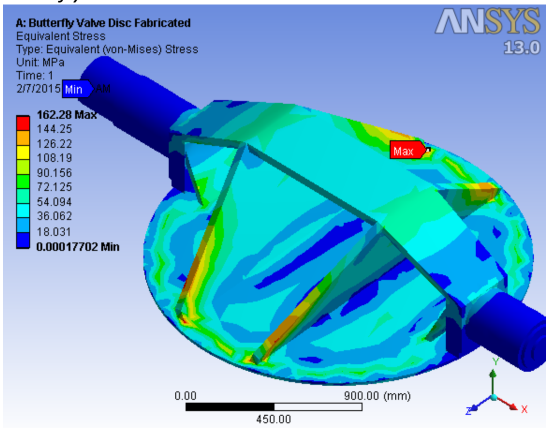

Fig. 5.3: von Mises equivalent stress for valve disc fabricated

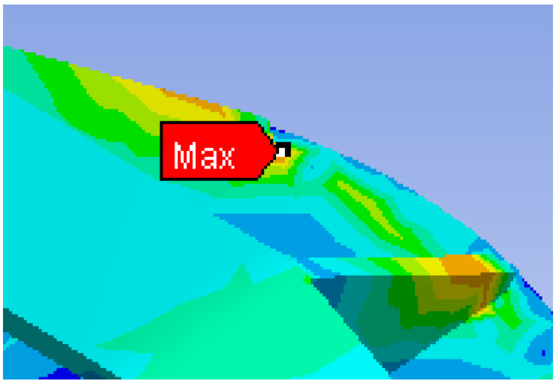

Fig. 5.4: Detail showing the area of maxi von Mises equivalent stress for Butterfly valve disc fabricated

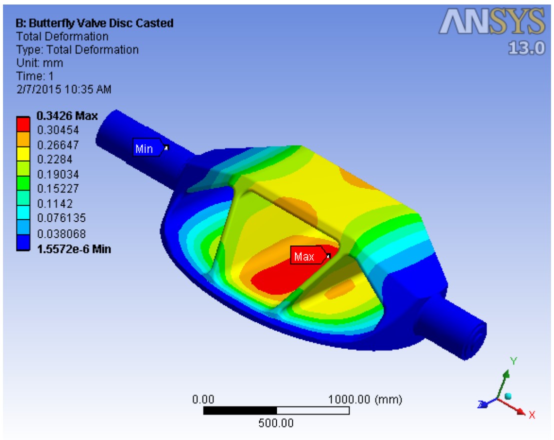

Fig. 5.5: Total deformation for valve disc casted

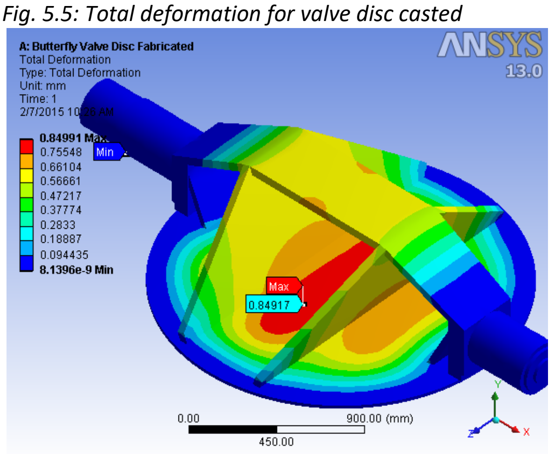

Fig. 5.6: Total deformation for valve disc fabricated

References

[1] Cohn, S.D., 1951, \Performance Analysis of Buttery Valves," J. Instruments and Control Systems, 24, pp. 880{884.

[2] McPherson, M.B., Strausser, H.S., and Williams, J.C., 1957, \Buttery Valve Flow Characteristics," J. Hydraulics Division, 83(1), pp. 1{28.

[3] Sarpkaya, T., 1961, \Torque and Cavitation Characteristics of Buttery Valves," J. Applied Mechanics, 28(4), pp. 511{518.

[4] Addy, A.L., Morris, M.J., and Dutton, J.C., 1985, \An Investigation of Compressible Flow Characteristics of Buttery Valves," J. Fluids Engineering, 107(4), pp. 512{517

[5] Eom, K., 1988, \Performance of Buttery Valves as a Flow Controller," J. Fluids Engineering, 110(1), pp. 16{19.

[6] Morris M. J. and Dutton J. C., 1989, "Compressible Flowfield Characteristics of Butterfly Valves", ASME J. Fluids Eng., 111, pp.400-407

[7] Morris M. J. and Dutton J. C., 1991, "An Experimental Investigation of Butterfly Valve Performance Downstream of an Elbow", ASME J. Fluids Eng., 113, pp.81-85

[8] Kimura, T., Tanaka, T., Fujimoto, K., and Ogawa, K., 1995, \Hydrodynamic Characteristics of a Buttery Valve - Prediction of Pressure Loss Characteristics," ISA Trans.,34(4), pp. 319{326.

[9] Ogawa, K., and Kimura, T., 1995, \Hydrodynamic Characteristics of a Buttery Valve- Prediction of Torque Characteristics," ISA Trans., 34(4), pp. 327{333.

[10] Huang, C., and Kim, R.H., 1996, \Three-dimensional *Analysis of Partially Open But*tery Valve Flows," J. Fluids Engineering, 118(3), pp. 562{568.

[11] Blevins, R.D., 1984, Applied Fluid Dynamics Handbook, Van Nostrand Reinhold, New York, NY, Chap. 6.

[12] Lin, F., and Schohl, G.A., 2004, \CFD Prediction and Validation of Buttery Valve Hydrodynamic Forces," Proceedings of the World Water and Enviornmental Resources Congress, pp. 1{8.

[13] Hoerner, S., 1958, Fluid-Dynamic Drag: Practical Information on Aerodynamic Drag and Hydrodynamic Resistance, Hoerner Fluid Dynamics, CA.

[14] Song, X., Wang, L., and Park, Y., 2008, \Fluid and Structural Analysis of Large Buttery Valve," AIP Conference Proceedings, 1052, pp. 311{314.

[15] Song, X., and Park, Y.C., 2007, \Numerical Analysis of Buttery Valve - Prediction of Flow Coe_cient and Hydrodynamic Torque Coe_cient," In Proceedings of the World Congress on Engineering and Computer Science, pp. 759{763.

[16] Leutwyler, Z., and Dalton, C., 2006, \A Computational Study of Torque and Forces due to Compressible Flow on a Buttery Valve Disk in Mid-Stroke Position," J. Fluids Engineering, 128(5), pp. 1074{1082.

[17] Leutwyler, Z., and Dalton, C., 2008, \A CFD Study of the Flow Field, Resultant Force, and Aerodynamic Torque on a Symmetric Disk Buttery Valve in a Compressible Fluid," J. Pressure Vessel Technology, 130(2), p. 021302.

[18] Henderson, A.D., Sargison, J.E., Walker, G.J., and Haynes, J.H., 2008, \A Numerical Prediction of the Hydrodynamic Torque Acting on a Safety Buttery

Valve in a Hydro-Electric Power Scheme," WSEAS Trans. on Fluid Mechanics, 1(3), pp. 218{223.

[19] Chaiworapuek, W., Champagne, J., El Haj em, M., and Kittichaikan, C., 2010, \An Investigation of theWater Flow Past the Buttery Valve," *AIP Conference Proceedings,* 1225, pp. 249{262.

[20] Feng, W., Xiao, G., and Song, L., 2009, \Numerical Simulation of the Flow Field to the Double Eccentric Buttery Valve and Performance Prediction," In Power and Energy Engineering Conference, pp. 1{4.

[21] Xue Guan Song, Young Chul Park, "Numerical Analysis of butterfly valve prediction of flow coefficient and hydrodynamic torque coefficient", world congress on engineering and computer science, October 2007, San Francisco, USA.

[22] Kundu, P., and Cohen, I., 2010, Fluid Mechanics, 4th ed., Academic Press Elsevier, Burlington, MA.

d Valves

[23] IS 7326-1 (1992): Penstock and turbine inlet butterfly valves for hydropower stations and systems, Part 1: Criteria for structural and hydraulic design [WRD 12: Hydraulic Gate and Valves].

[24] IS 7326-2 (1992): Penstock and turbine inlet butterfly valves for hydropower stations and systems, Part 2: Guidelines for design and selection of control equipment [WRD 12: Hydraulic Gates and Valves]

[25] IS 7326-3 (1976): Penstock and turbine inlet butterfly valves for hydropower stations and systems, Part 3: Recommendations for operations and maintenance [WRD 12: Hydraulic Gates an