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Numerical Simulation and Design Optimization of Intake and Spiral Case for Low Head Vertical Turbine

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Abstract: *The Spiral casing usually consists of a trapezoidal cross section made of concrete. The effects of the pairs on the distribution of velocity and pressure in the spiral case, outlet angle and hydraulic loss of the spiral case are studied. The design of the spiral case has important position in the design of turbine .The design have direct effects on turbine performance. The purpose of this research subjects is numerical analysis of flow field within the spiral case is a main tool to optimize the spiral case .Based on the Reynolds-average N-S equations and the non-structural grid, CFD analysis of three –dimensional flow through a semi –spiral case is presented in this paper. A complete optimization of hydraulic design content mainly four parts, the process of initial hydraulic design, flow field analysis, performance prediction and optimization design. Basic equation Spiral flow can be described by Navier-stock equation; calculation of water head at 15.8m, 1050m3/s discharge import and export of the spiral case were given flow as a boundary condition. , for this research Ds is 11.5m. This paper aims to study how the flow behaves in spiral case of Kaplan turbine in order to achieve hydraulic loss.*
Keywords: *Hydropower, Kaplan Turbine, Spiral case of Kaplan Turbine.*

I. Introduction

Axial flow turbine is usually used in heads ranging from 1m to 70m .Axial flow turbine have adjustable runner blade and fixed blades. The advantage of using adjustable runner blades is that the efficiency is higher over a wider operating range. Inside the spiral casing the water flow is more or less uniformly distributed to stay vanes and guide vanes, some of static energy of a swirling flow component after the guide vane passage .The swirling flow enters the runner, where the water power is extracted Logarithmic spiral provides an axial symmetrical potential flow and is therefore characterized by rotational free vortex flow .The circumferential velocity in this case will increase from the inlet section to the spiral tooth .Constant velocity spiral is where the circumferential velocity V_u is kept constant .Constant velocity spiral has larger sections for the same inlet sections as compared to the sections of logarithmic spiral .Selection of the type of spiral casing would be from the above two methods . The spiral case is an important component of the turbine which distributes water from penstock to the runner .The spiral case should bear internal water pressure and imposed loads by units. It should be making construction more convenient and lower cost. The spiral casing for low heads 25-30 meter is made of concrete. To make this type of scroll casing with required accuracy, wooden models are used against which the concrete is poured. The function of the spiral case is to supply water from the intake to the stay vanes, directly to the upstream portion of the turbine and the turbine and through a unique shape of cross sectional area reduction to the downstream portion of the turbine, maintaining a near uniform velocity of water around the stay vanes and wicket gates. Concrete spiral casing are generally used for low head and the allowable velocities are low. Where used of higher head steel lines should be provided to later for higher velocities and water –tightness. The concrete spiral casing do not normally envelope the guide apparatus fully and the angle of envelopment used from 0^0 to $200^{0.}$. The sections of concrete spiral casing are generally of trapezoidal shapes because they are easier to form compared to circular or elliptical shapes. The research scope is to run the numerical simulation for both intake designs with different pier end shape. The research is to find the pressure and velocity field difference the geometrical design .The distance from the pier end to the unit centre is 18.5 m.

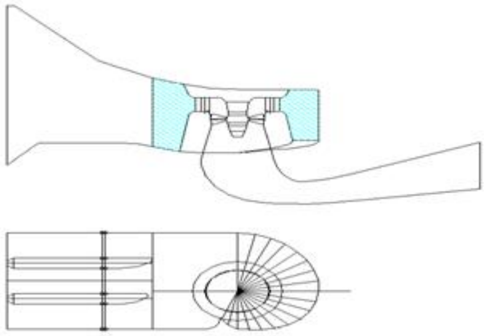


Figure 1: Spiral case of Kaplan turbine.

II. Design Of Spiral Case Of Kaplan Turbine

The selection or adoption of concrete or steel spiral casing depends upon the Techno-Economic considerations .The following gross heads may serve as guide for selecting the type of spiral casing.

Concrete Spiral casing – up to 40m
Steel spiral casing –above 30m

The shape of the spiral case is represented by a variable number of Cross sections each cross – sections can have a different location, orientation and shape. Each section has given outer radius Ra, and height Hd and Hs.

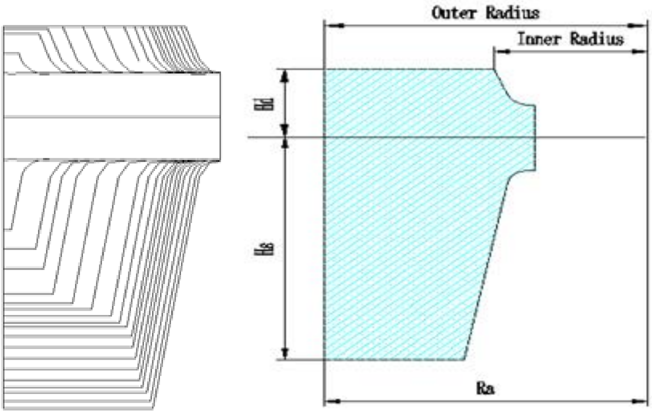
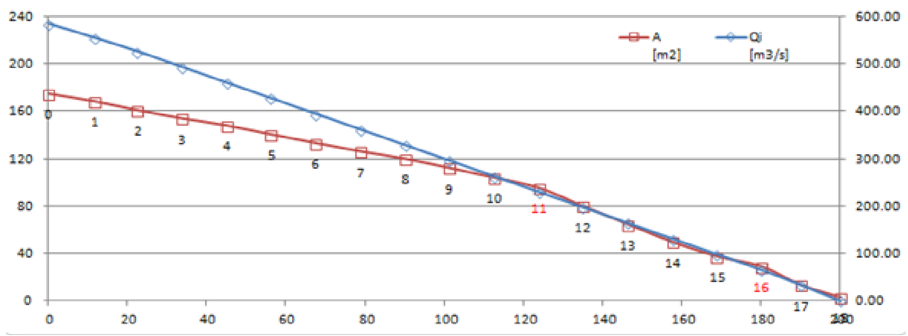


Fig 2: Construction of Cross Section of Spiral case.



Graph: 1 Different Design of Cross-section Area and discharge for the Concrete Semi Spiral Case

From Graph :1 The cross section area is rapidly falling down which makes straight line .In Graph the cross section area from 10 to 18 which is co-inside with discharge at cross section 10-18.

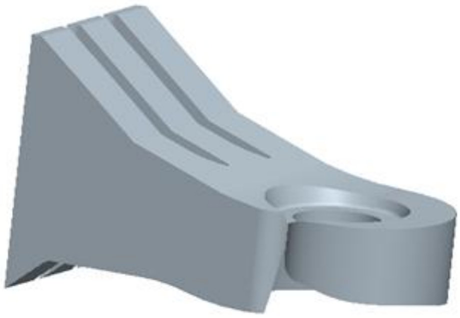


Fig 3: 3D view of Spiral case of Kaplan turbine.

According to design principle of the spiral case, the warp angle is set at 200 degrees based on the basic parameters of the hydraulic turbines. The average flow velocity in spiral section must be larger in order to induce the size of the spiral case and head loss. Velocity in the inlet section of the spiral casing which may be taken as the design velocity depends on the rated head and may be competed from the following formula $V= K\sqrt{H}$

V = design velocity m/s
K= coefficient, depending on rated head and type of turbine
H= rated head (m)
Values of K vary for different head and also on type of turbine used .the Values of k for different values of head and different turbines.

The following data should be collected for design of spiral case

- Net Head
- Discharge of water
- Maximum pressure in spiral casing including water hammer
- Maximum permissible velocities (in case of concrete spiral)
- The hydraulic design of spiral casing may be done by any one method

Logarithmic speed, in which the moment of velocity is kept constant that, is where,
$V_u \times R= C$
Where,
V_u= Circumferential velocity in m/s at the point where radius is r.
R = radius in m of the spiral casing and C= Constant

The 3D structured mesh is generated using ICEM-CFD/HEXA .Which both deliver high quality block –structured meshes for geometrically and topologically complex domains. After the meshing process, pressure inlet and mass flow rate boundary conditions are given for all component simulations in CFX module. The mesh of the models includes 868876 nodes and 4978590 elements as shown in figure: 4.The mesh of the given model is Tetrahedral.

Fig 4: Mesh Model of Spiral Case.

The equation for flow in spiral case can be described by Navier-stock equation, $1050 m^3/s$ discharge of water is import from inlet of spiral case which given as flow as a boundary condition. In figure: 5 pressure counters is of water is seen in different color. The highest pressure is at cross section 17 and 18 which is 1.390e+005 Pa.

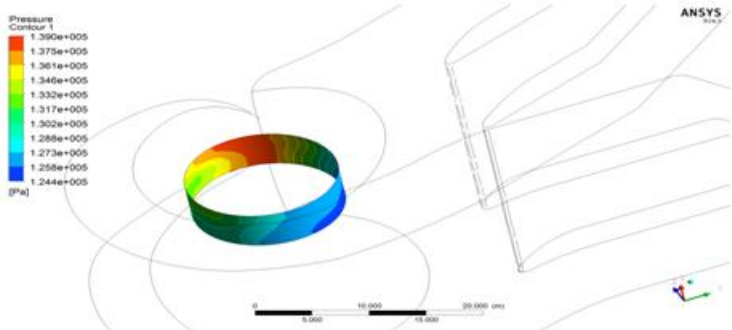


Fig 5: Pressure at Inlet of Spiral Case.

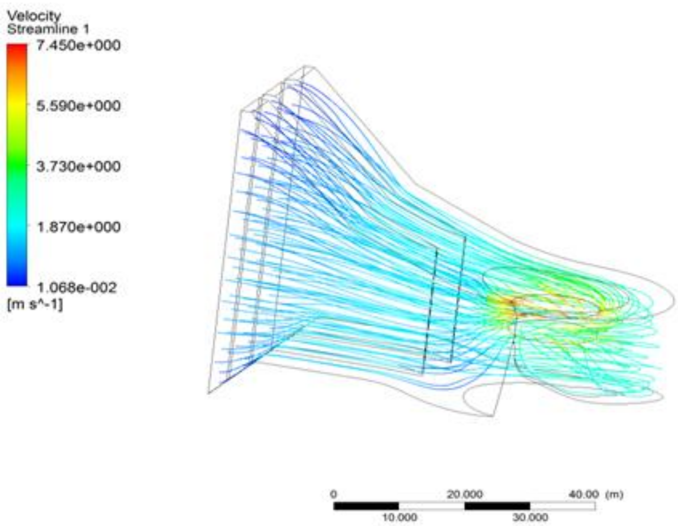


Fig 6: Velocity Streamline in Spiral Case

The hydraulic loss in the spiral case are mainly the friction loss and the minor loss due to geometrical change like bending shape of spiral case, and cross-section shrinking from outer area to inner area.

$$\Delta h_{spiral\ \ case} = k\frac{v_u^2}{2g}$$

The V_u are mainly driven by the discharge and the cross section area; at the spiral case inlet, it is the width B and height H. The frication factor k is calculated from moody diagram which value is 0.031. from this calculation the sum of hydraulic loss is 0.2273697 m.

III. Conclusion

The purpose of this research subjects is to study how the flow behaves in spiral case of Kaplan turbine in order to achieve hydraulic loss. The hydraulic loss for each cross section is 0.2273697 m, based on the Reynolds-average N-S equations and the non-structural grid, CFD analysis of three –dimensional flow through a semi –spiral case. The spiral is designed by solving equation at various mesidinal sections of the spiral. The main advantage of Kaplan turbine are the wide ranges of gate opening and heads which can be granted and because of vertical arrangement .Inside the spiral casing the water flow is more or less uniformly distributed to stay vans and guide vanes. Some of static energy of a swirling flow component after the guide vane passage .The swirling flow enters the runner, where the water power is extracted Logarithmic spiral provides an axial symmetrical potential flow and is therefore characterized by rotational free vertex flow .The circumferential velocity in this case will increase from the inlet section to the spiral tooth . Constant velocity spiral is where the circumferential velocity V_u is kept constant .Constant velocity spiral has larger sections for the same inlet sections as compared to the sections of logarithmic spiral. Kaplan turbine efficiency is typically about 90% and more.

Reference

[1]. Vekue T, An experimental investigation of draft tube flow, doctoral diss, University of Science and technology, Trondheim Norway, Norway. 2004 July

[2]. Schleiss A.J, Hydroelectric power plants, General layout of Schemes. Postgraduate studies in Hydraulic Schemes , LCM,EPFL,2004,128-132

[3]. Krum dieck, Standardization of Civil works for small hydropower plants(UNIDO: Electro watt Consulting Engineers Company. Zürich, 1988.)

[4]. Andaroodi M, Standardization of Civil Engineers works of small Hydropower plant and development of an optimization tool. LCH, EPFL: Switzerland, 2005.

[5]. Kassana L.B, Small Scale Hydropower for Rural Development phase I Unpublished Report of the Nile Basin capacity building Network for River engineering, NBCBN-RE ,Group I :Dar as Salaam ,Tanzania .2004

[6]. Binyam Abate. Desihn of Micro Hydro turbine suitable for most Ethiopian Sites, Msc Thesis. Addis Ababa University. June 2004

[7]. Santos Antonia Forseca dos, Small power plant and social development. They can make difference**, Hydro** 2004, Porto Portugal 2004.

[8]. Siervo F and Leva F, Modern trends in selecting and designing Kaplan turbines. Water power and dam construction. December 1977, PP 57-56 and January, 1978 PP 52-58.

[9]. Oliver Paish, Small Hydro: technology and current status, Renewable and Sustainable energy reviews. 6 Feb 2002, 537-556.

[10]. S.J Williamson, B.H stark, J.D Booker, Low head pico hydro turbine selection using a multi –criteria analysis, World renewable energy congress 2011-sweden. Linkoping Sweden, May 2011,8-11

[11]. Yang Wei, WA yulin and Liu Shu hong, An optimization method on runner blades in Bulb turbine based on CFD analysis , Science China Technological Science 2011. Vol 54, No 2,338-344.

[12]. Nilsson H, A Numerical investigation of turbulent flow in a Kaplan water runner, doctoral diss ,Chalmers university of technology .Gotebong, Sweden.2002

[13]. L Zhu, H.P Zhang ,J.G Zhang, X.C meng and L.liu, Performance of a bulb turbine suitable for low prototype head: model test and transient numerical simulation,26th IAHR symposium on hydraulic machinery and systems IOP conf series: Earth and environment Science 15(2012) 042032.

[14]. Radha Krishna HC, Hydraulic Design of hydraulic machinery (England: Auebury publishing House. 1997).