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A Review on Dynamic Analysis Of Pelton Wheel Turbine

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Abstract

Pelton wheel turbine is generally used for mechanical power generation in hydroelectric power plant. Vibration produced in the system is forced vibration. The dynamic characteristics of a hydro turbine power depend heavily on changes in load disturbances. Thus the hydro turbine exhibits highly nonlinear, non-stationary system whose characteristics vary significantly with the unpredictable load. When the Natural frequency of the turbine coincides with actual frequency of the turbine causes the formation of the resonance. This resonance forms the increase in chances of failure of the turbine by buckling of deformation of the shaft. So, the Theoretical, Numerical and Experimental Analysis method to find out the dynamic characteristics of Pelton Wheel Turbine is reviewed in the present paper.

Keywords: *Dynamic Characteristics, Forced Vibration, Numerical Analysis, Natural Frequency.*

1. INTRODUCTION

Pelton Turbines has been widely used in hydro-electric plants around the country. The study of dynamic behavior of pelton wheel turbine has been of great importance in order to understand the operating and the failures related with the machines. Machines are set to vibration under several excitation modes. So, accurate prediction of vibration characteristics is important in the hydraulic machinery considering the requirements of quality, performance and safety. This system of Pelton Turbine operates at high rotational speed. So, there is a need to develop methodologies for dynamic analysis of Pelton turbines because prototyping and testing cost are exceptionally high and failure is generally causing great damage in the practical applications and testing of these systems. However, very less work has been done in the field of the dynamic behavior of pelton wheel turbines and their effects in operation and design.

Rotating machinery consists of many structural elements such as shaft, disk, blade, bearing/seal/damper, casing and foundation. The whole machine as an assemblage of part structures has global dynamic characteristics. The dynamic properties of most important in rotating machinery typically include the critical speeds, forced response and stability of modes. The critical speeds of a rotor are defined as the rotational speeds at which the speed-dependent modal (natural) frequencies. So find out of natural frequency of the system it's important for safety operation of system.

2. LITERATURE REVIEW

The dynamic behavior of flexible rotor systems subjected to base is investigated theoretically and experimentally by **Aman Rajak et al. [1].** They have developed a mathematical model for total energy of the system and the equation of motion has been derived using energy method. They assume the pelton wheel turbine as a simple rotor disk system. The assembly of a rotor disk system as shown in Figure 1. Dynamic behaviour is then studied by developing a mathematical model for rotor disk system. They also have done the FEA analysis using ANSYS 14.5. Campbell diagram is used to find out the natural frequency of system. The study focuses on bending phenomenon near the critical speeds of rotation.

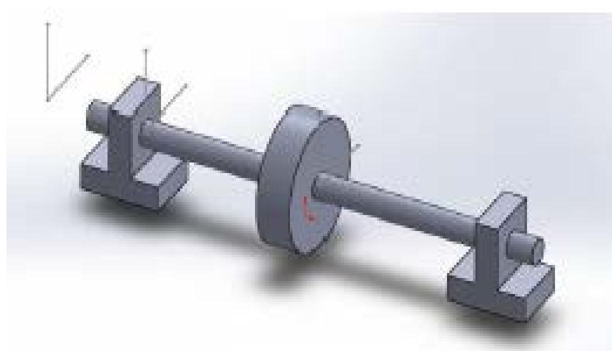

Figure 1 simple rotor disk system

Lixiang Zhang et al. [2] have studied ANSYS finite Element software to model the main shaft system in the hydro-turbine generating unit. On this basis, it takes the Modal analysis and using Campbell diagram calculates the critical speed of rotation. The modal analysis is done for find out the first five mode shapes. As the working speed of rotation increases, due to the gyroscopic effect, the natural frequency of the positive whirl will increase while the negative whirl decrease. When the speed of the rotation equals the angular frequency, it is the critical speed of rotation. The results can provide a reference for dynamic analysis and a foundation for the design or improvement.

Uzma Nawaz et al. [3] have studied the differential equations for hydro system and based on the differential equations, a transfer function is obtained. The analytical method for calculating the flow of water through the penstock uses equation of motion and continuity. These equations used arithmetical and graphical methods for solving transient stability problems. They have proposed a mathematical model of the hydro sub-system of a micro hydroelectric scheme for the transient and steady-state responses operating in frequency-control mode. It can be used during design, testing and commissioning as well as forming the basis for contractual agreement on performance during normal operation.

Chong-Won Lee [4] has studied Frequency-speed diagram, often known as Campbell diagram that has long been an important tool in the design and operation of rotating machinery. The construction of the conventional frequency-speed diagrams are discussed in relation to the desired rotor dynamic properties of complex rotor systems.

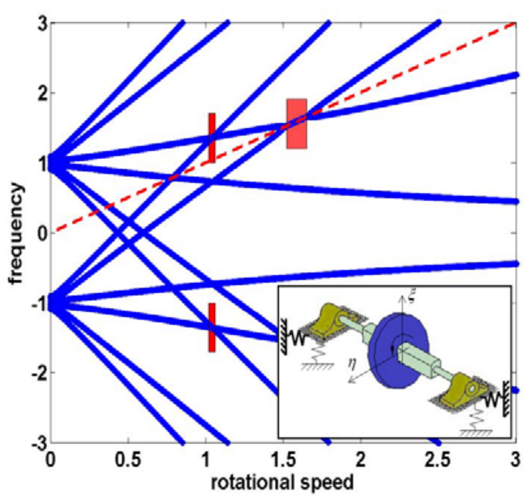

Figure 2 Conventional Campbell diagram for the simple general rotor [4]

The Campbell diagram for simple general rotor system shows in figure 2. This rotor model is very simple, yet it generally contains all the essential characteristics of practical rotors. The Campbell diagram for the general rotor as the rotational speed is varied. In the figure, the shaded areas indicate the instability speed regions. The Campbell diagram is crowded with an infinite number (only twelve modes are shown in the figure) of modes, which may all cause, at least in theory, resonances depending upon the type of external forces. For example, we can finds possible resonant modes due to the unbalance excitation (marked by broken line) only, even for this simple general rotor model.

Jiaqi Liang, et al [5] has suggested the detailed dynamic modeling of pumped storage hydro-plants for system dynamic studies. Both rigid and elastic dynamic models for different water tunnel penstock configurations are presented. The results show that a rigid model is sufficient for system transient dynamic studies, while an elastic model is more accurate for long-term dynamic studies. Particular attention is paid to the dynamics of an elastic water model for the case of a common water tunnel connected to multiple penstocks. Different plant operating conditions with different system contingencies are considered.

Prakash K. Dhakan AND Abdul Basheer Pombra Chalil [6] have presented the design of casing for four jet vertical pelton wheel turbines is carried out considering the size and shape of the casing. Casing should have enough strength to meet the mechanical/structural requirements such as to withstand the dead weight of the generator, forces developed in the manifold/branch pipes, load due to the four jets in different combinations and load due to various actuation mechanisms. After satisfying above aspects, the casing should be checked for vibration behavior by modal analysis. Through the structural analysis using ANSYS Mechanical software, casing design is optimized and a weight reduction of around 12% is achieved. Vibration behavior of the casing is analyzed through the model analysis and ensured the natural vibration of casing is well above the operating frequency of turbine unit.

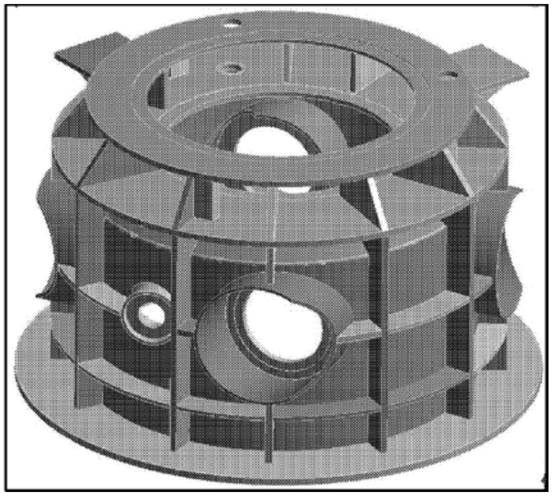

Figure 3 final optimized shape of casing

Ze li and lixiang zhang [7] has presented the numerical method which could simulate the vibration of spiral casing structure that caused by the water flow in turbine flow passage. The numerical simulation of 3-D unsteady turbulent flow through the flow passage of turbine model is accomplished by solving the N-S equations, and the flow fields of flow passage and dynamic water pressure on boundary are obtained. At the same time, the three-dimension finite element dynamic model of solid structure is established shown in figure 4

Figure 4 finite element model of spiral casing.

J.C. Chavez et al. [8] have analyzed of a 16-bucket Pelton impeller from a hydroelectric plant in Colombia, a plant with two turbo generators with a nominal capacity of 2.33MW each. Metallographic analyses were performed on the impeller zones near the cracks; including an analysis of the fracture surface a computational simulation of the fluid dynamics using finite volume software is done. The computational fluid dynamics analysis permitted the identification of low-pressure zones caused by an inadequate geometry for the bucket profile where cavitation is present. The finite element analysis permitted the identification of critical points on the bucket zone neck, coinciding with the crack found. This zone is under tensile stress due to the effects of centrifugal force and compression when the bucket comes in contact with the jet, causing fatigue.

Amod Panthee et al. [9] have presents Computational Fluid Dynamics (CFD) analysis of Pelton turbine of Khimti Hydropower in Nepal. The purpose of CFD analysis is to determine torque generated by the turbine and pressure distributions in bucket for further work on fatigue analysis. The paper describes the methods used for CFD analysis using ANSYS CFX software. 3 buckets are used to predict the flow behavior of complete Pelton turbine. The pressure distribution is found maximum at bucket tip and runner Pitch Circle Diameter (PCD). The torque generated by the middle bucket is replicated over time to determine total torque generated by Pelton turbine. The result showed that SST model is robust turbulence model to conduct CFD analysis of Pelton turbine.

Bilal Abdullah Nasir [10] has explained the Pelton hydraulic turbine with maximum efficiency during various operating conditions the turbine parameters must be included in the design procedure. In this paper all design parameters were calculated at maximum efficiency. These parameters included turbine power, turbine torque, runner diameter, runner length, runner speed, bucket dimensions, number of buckets, nozzle dimension and turbine specific speed. A complete design of such turbines has been presented in this paper based on theoretical analysis and some empirical relations. The maximum turbine efficiency was found to be 97% constant for different values of head and water flow rate.

D Jost et al. [11] have presented a numerical analysis of flow in a 2 jet Pelton turbine with Horizontal axis. The analysis was done for the model at several operating points in different Operating regimes. The results were compared to the results of a test of the model. Analysis was performed using ANSYS CFX-12.1 computer code. The numerical analysis of flow in the Pelton turbine was performed for several operating points. On the basis of the results it can be concluded: Accurate calculation of jet thickness and velocity is crucial for prediction of Pelton turbine efficiency. Numerical results are sufficiently accurate to be used for efficiency prediction in a design process.

4. Conclusions

From the literature review it is seen that, very less work has been done in the field of the dynamic behavior of pelton wheel turbine and their effects in design and operation. Forced vibration is that mode of vibrations in which the system vibrates. Having this mode of vibrations, this may cause a serious damage of the machine.
Aman Rajak et al., Uzma et al., Jiaqi Liang, et al. Author emphasis on dynamic characteristic of system by find out natural vibration of system. The mathematical model for dynamic behavior of the pelton turbine assembly was thus formulated and the analytical solution of natural frequency was performed.
Lixiang Zhang Et Al., Prakash K. Dhakan And Abdul Basheer Pombra Chalil, Ze Li and Lixiang Zhang, J.C. Chavez et al., amod panthee et al. Author emphasis on fea analysis of the pelton wheel turbine system to find out the dynamic characteristics of system

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