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STRUCTURAL AND CFD ANALYSIS OF AIR RELEASE VALVE FOR HIGH PRESSURE HYDRO-POWER PLANT

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Abstract - A mechanical air escape valve is mounted to avoid fluid from passing into the penstock without air. Hydraulic air release valves do not require external activation, but contain a mechanism moving through the penstock as fluid flows. Hydraulic exhaust valves are zero machine water leakage and can be used as protection mechanism in hydraulic systems. As the fluid moves into the tube, the device tends to reduce water head pressure on the turbine blades, and when the fluid starts moving the system blocks the valve opening such that the air passes into this pipe. This project will analyses the air release valve under dynamic fluid load conditions.

This type of valve is mainly used as safety valve, turbine inlet valve, and pump valve for low to medium design pressures. They are operated by oil hydraulic systems for opening and closing or by closing weight and hydraulic pressure for opening. For turbine inlet valves, oil pressure can also be taken from the governor hydraulic oil system. The sealing system is of flexible, adjustable rubber/metal type to reduce leakage to a minimum. Water flow through the valve is possible in both directions.

The main objective of this work is to analyses the option of fabricated variant for door & body in place of casted, reduction in the material of valve body & door by structural design & FEM analysis & optimization in the material of valve component. The 3D modeling to be performs for butterfly valve by using CAD software. Further the stress & displacement FEM analysis of the butterfly valve to be performed by using ANSYS WORKBENCH 19.2 software tool to evaluate the optimized result. CFD analysis

***Key Words* - Hydro Power Plants, Air Release Valve, Ansys workbench**

1. INTRODUCTION

Small hydropower plants (SHP) use energy production without problems and interruptions. Therefore, SHP architecture studies concentrate on secure and efficient service. A SHP's steady activity is the best condition as there is no improvement in the system's mechanical variables including discharge and pressure eye. Nevertheless, if the disrupted flow varies during hydropower production, a disruption may arise, triggering a rapid shift in system status. In the hydraulic conveyance device, including the penstock, flow parameters shift with time. It can cause severe high or low pressure in the penstock, and extremely high pressure may do considerable harm. Turbines, valves and other penstock equipment can be impaired. Even penstock can burst or collapse. There are major hydropower disasters triggered by water hammer, resulting in severe historical harm and loss of life. At Bartlett Dam and Oneida Hydroelectric Power Plant in the U.S., severe faults resulted in five deaths. Lapino SHP's penstock in Poland ruptured in 1997 after his new clearance tests. Finally, the penstock burst as a result of rapid valve closure at Oigawa Hydropower Station in Japan and three employees died. Load rejection, immediate load rejection and load acceptance conditions, turbine wicket or valve mechanical failure and abrupt shifts in front bay elevation will cause water hammer in small hydropower plants. To produce energy at a constant pace, a hydraulic turbine attached to a generator feeding a power grid must run at a constant rotational speed. Some frequency changes may affect generator and turbine velocities. Disruptions that alter turbine speed are regulated by the governor action that aims to hold the turbine at a synchronous rate by controlling the wicket gates in a Francis type turbine or by adjusting the position of the jet deflector and shutting or opening the needle valves in Pelton turbines. Both these immediate behaviors trigger turbine flow and other flow parameters, resulting in hammer pressure. The following fig shows: the tank airflow stops air lock & hydro-power plant configuration

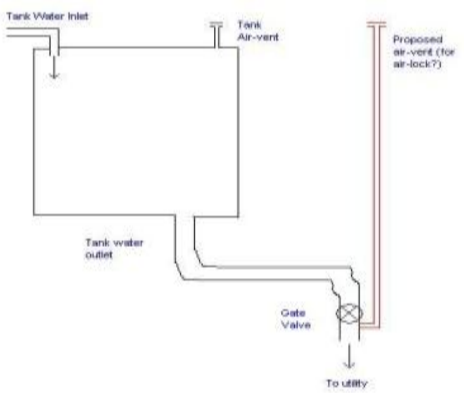

Fig -1: The vent on the tank prevents air lock

2. METHODOLOGY

FE analysis is used to find the behavior of the structure under the loading condition. The perfection in model is one of the factors influencing the accuracy of the solution.

i. Pre-processor

Pre-processor involves the choosing the materials that are involved in the analysis and entering the material data which are missing the engineering data. Meshing the model is another important process in the FEA, where certain condition has to be followed like aspect ratio and skew angle. Assignment of the material to the structure and parts, in case if the different part has different material. The predetermined boundary condition and the loading condition are imposed on the FE model.

ii. Solver

Solver is fully automated. It's split into pre-solver and post-solver. Pre-solver reads pre-processor code and formulates concept in mathematical representation. All the pre-processor process must be satisfied to create the mathematical model, and then the mathematical engine proceeds to form the elemental stiffness matrix for the given problem. Solver engine solves the problem and calculates to give the required result like stress, strain, displacement, temperature and frequency etc.

iii. Post-processor

In post-processor results obtained by the solver is read and interpreted. Animation and graph describe the effects in terms of deformation, pattern forms, and natural frequency. Stress obtained are analyzed by the stress plot which used know the maximum and minimum stress is present and by this we can conclude, weather the design is safe or not. Design modification can have carried out in those areas where the attention is required. It gives the representation of the stress, strain and deflection in any direction or in required direction also at any angle to the coordinate axis.

Fig - 2: CAD model

The above shown valve model can have made with the help of Uni-Graphics software and it is in 3 dimensional cad model. Dimensions for the above model can be given below in the form of three dimensional geometrical model dimensions.

i. Meshing using by ANSYS software

Meshing can be done by use of ANSYS software. Here we used in meshing tetrahedral meshing can be used, Meshing is done by ANSYS software. In that meshing here we used tetrahedral elements. Linear tetrahedral elements are also steady stress elements with 4 nodes or linear stress elements with ten nodes. These elements are formulating in 3 - dimensional freedom with 3 degrees of freedom per node, these are the translational degree of freedom in the X, Y and Z directions, correspondingly. Here we done meshing it has 125187 nodes and 73623elements.

C. Solver Packages Used

1) Unix Graphics Software

UG software is modeling software. By the use of this Unix Graphics software we modeled air release valve.

ii. ANSYS *Software* The meshed geometry in imp‟ file format is imported to Ansys solver for execution. The appropriate boundary conditions are applied and problem is executed for the given loads. The results are represented for Vanishes stress consideration. By the use of Ansys software we done meshing and analysis can be done. In meshing tetrahedral mesh is used.

3. Terminology of valve system

People associated with control valves, instrumentation and accessories often encounter unprecedented terms and definitions. Some terms from ISA standard, Process Instrumentation Terminology, ISA 51.1. Some are also common in the valve control industry.

a) **Automatic Control System:** A control system that operates without human intervention.

b) **Bode Diagram:** A log amplitude ratio map and step angle values for a transition feature (Figure 1-15). This is the most popular method of graphically displaying answer results.

c) **Calibration Curve:** Calibration diagram (Figure 1-15). A machine plotted based on its secure results. The curve is usually defined as output period vs. percent input time.

d) **Calibration Cycle:** Applying established values of the calculated component and reporting related output readings in ascending and descending directions (Figure1-15). Calibration curve from varying device input in both increasing and decreasing directions. This is typically percentage of output time versus current input time.

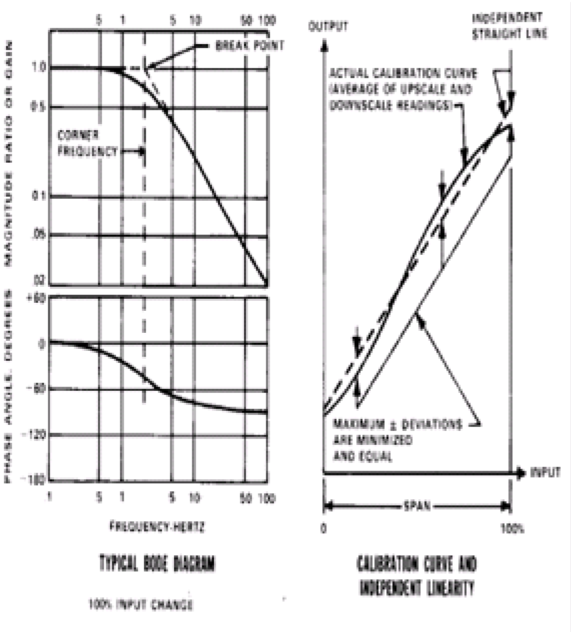

Fig - 3: A calibration curve

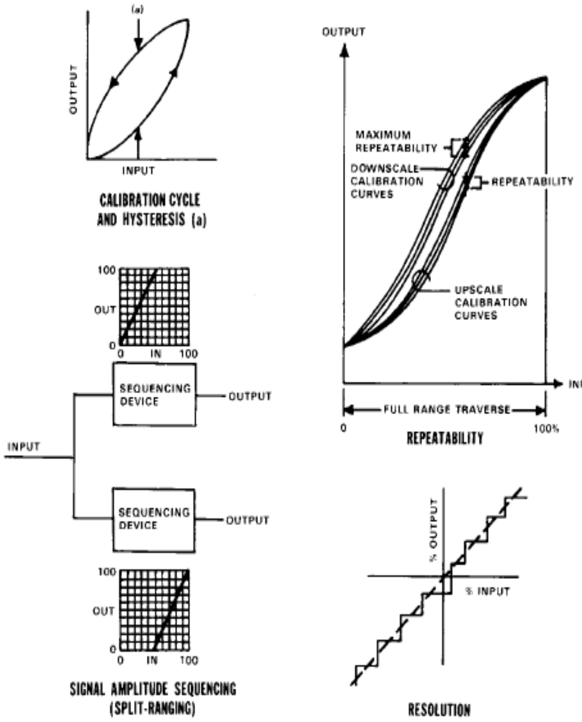

Fig - 4: Graphic representation.

4. ANALYTICAL STUDY

4.1 MODEL ANALYSIS

Modal analysis is conducted to evaluate system vibration properties, i.e. normal frequency and modal forms. It's one of design's significant facets. Determining normal frequency, we may estimate how much the system may malfunction. This measures free mode vibration to identify displacement trends. Mode shapes suggest growing structure automatically displaces. Lateral displacement is more significant. Lower order mode structure is the primary contributor to the systemic reaction as the order rises. Mode form depends on equality. N degrees of freedom form N types. A mode is a condition of deformed shape where the system constantly transfers kinetic-energy and stain-energy and the normal frequency at which the phase formation exists. In an unreformed state, kinetic energy is at its highest, and the energy of strain is negative. Deformed strain energy is optimum and kinetic energy zero.

4.2 Material properties

The material selected for the design depends on the various factors such as, strength, ductile property, cost, availability and many more. Generally, aluminum alloy type of steel is used for the construction of the structure of air release valve as it can high strength to weight ratio and it has good corrosion resistance property compared to cast iron. In our design structural steel is used for the analysis and its material properties is show in the below table 1.

Case: Carbon Steel

Yoke: Carbon Steel

Diaphragm: EPMM + Nylon

Valve Trim	ANSI Class	Seat Type	Bonnet Type		Seat Leakage
			Standard	Extended	
1/2"~4"	#150 through #900	Soft	-30C ~ 230C	-196C ~ 230C	VI
	#150 through #2500	Metal	-30C ~ 300C	-196C ~ 565C	IV, V
6"~20"	#150 through #600	Soft	-30C ~ 230C	-196C ~ 230C	VI
	#150 through #2500	Metal	-30C ~ 300C	-196C ~ 565C	IV, V

Table 1: shows pre-processing analysis of valve

4.3 Geometry and meshing of model

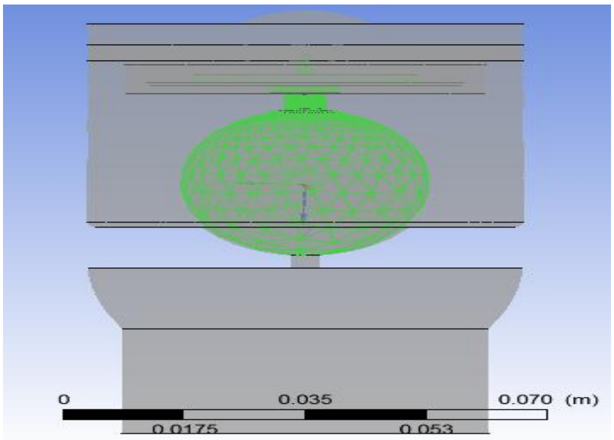

Fig - 5: Geometry

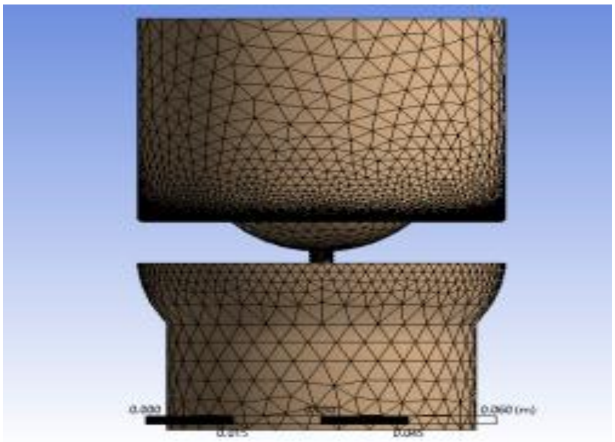

Fig - 6: Meshing of pressure relief valve.

5. RESULTS AND DISCUSSIONS

A. pressure distribution is maximum Around the ball

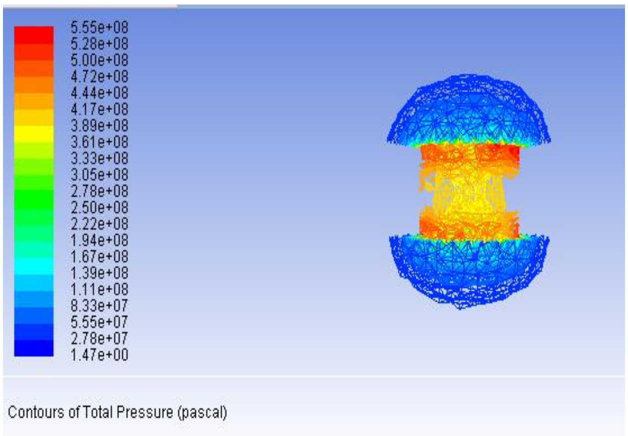

Fig - 7: From the above graph, it is shown the pressure distribution is maximum Around the ball

from the above picture, max pressure variation depends on maximum load acting on the ball or around the ball. it may have varied on different parameters also like size of ball, fluid pressure etc.

B. Reverse flow condition of fluid

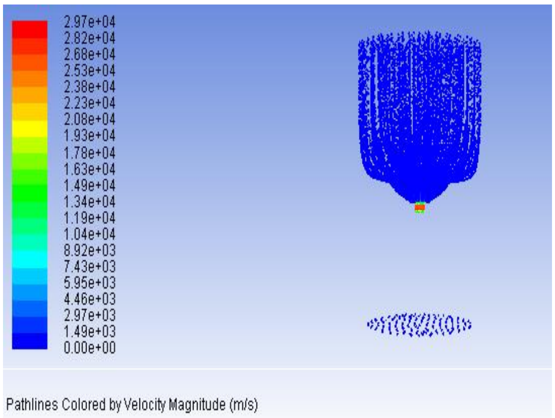

Fig - 8: In the above graph the velocity at which the reverse flow is happening is observed

C. Equivalent Stress

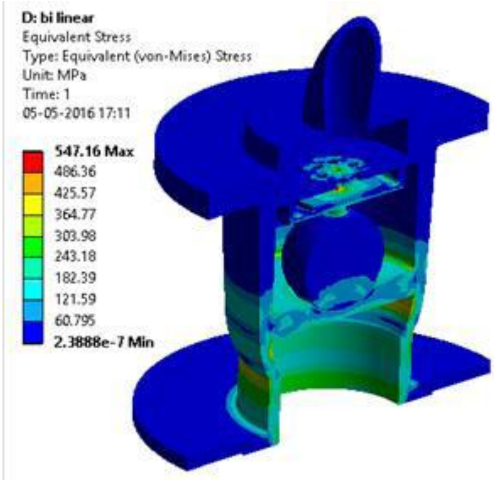

Fig - 9: Equivalent stress

D. Maximum Principal Stress

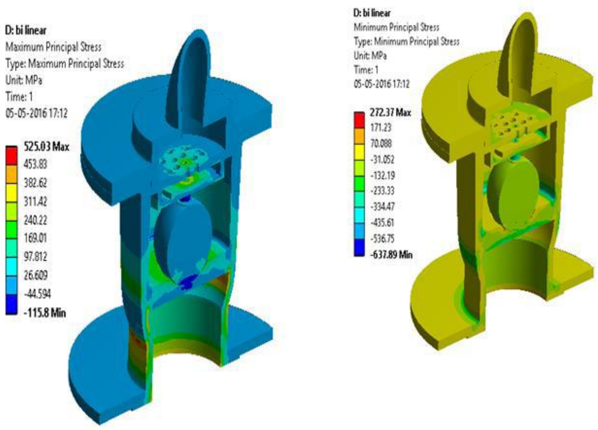

Fig - 10: Maximum and Minimum Principal Stress

The above fig shows the maximum and minimum principal stress values when it is solved in ANSYS software after the application of boundary condition of pressure value 40 MPA. The maximum principal stress value is 525MPA which is shown in red shade in the fig. The minimum stress value is 272MPA.

E. Maximum Total Deformation

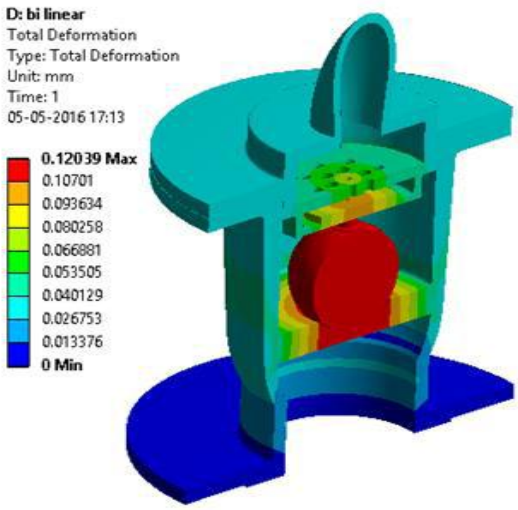

Fig - 11: maximum total deformation

The maximum deformation occurred during the analysis is 0.12mm which is shown in red shade in the above fig.

6. CONCLUSIONS

Design and analysis of air release valve concludes the following points:

 The static analysis of valve had done. The value of equivalent stress in static analysis is 346 MPA which is lower than the yield stress 355 MPA.

 The bilinear analysis of valve had carried out. The equivalent stress value obtained is 547 MPA which is heavier than the yield stress 355 MPA. So the structure is not safe.

 The deformation value obtained is 0.12mm in bilinear analysis which is larger than 0.049 mm, the deformation value in linear static analysis. So the structure is not safe in bilinear analysis.

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