DESIGN & DEVELOPMENT OF AIR RELEASE VALVE/ANTI VACUUM VALVE FOR HIGH PRESSURE

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Abstract: Filling and emptying pipeline systems involve the movement of large volumes of water and air. Water transients occurring during these operations can originate large pressure peaks that can severely damage distribution networks. Unfortunately, too often, the complexity of the phenomenon makes it difficult to obtain a fully reliable prediction on when air pockets will mitigate or accentuate water transients. During initial filling of penstock, the water which flows into the empty penstock, displaces the air & pushes it to be higher elevation. If the air at this location is not removed from Penstock the flowing water compress the air to such a extent that penstock pipe may burst. Similarly during emptying of penstock pipe , the penstock pipe has to be filled with air at a rate equal to emptying rate. In the absence of air supply, vacuum is created & the penstock pipe collapses. Hence all Hydro power plants irrespective of the power generating capacity is compulsorily required to use Air Release valve to protect penstock pipe. Present limitation of the Air release valve manufactured in India are up to a size of 300mm in Dia. and pressure rating of PN 20 bar. Objective of this thesis is to develop and arrive the outline dimension & sizing of the air release valve body and components for pressure above 40Bar with the size ranging from 50 mm to 500 mm. Static Structural analysis, Design validation & Design verification of the using CFD analysis, Pressure and velocity distribution by CFD Analysis by using Ansys.
Keywords: Air Release Valve.

I. INTRODUCTION

Hydropower is one of the most cost-effective and reliable energy technologies to be considered for providing clean electricity generation. Hydro-turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, or other machinery. The power available is proportional to the product of head and flow rate. Safety is the most important factor in designing a process system. Some undesired conditions might happen leading to damage in a system. Control systems might be installed to prevent such conditions, but a second safety device is also needed. One kind of safety device which is commonly used in the power plant and processing industry is the relief valve. A relief valve is a type of valve to control or limit the pressure in a system by allowing the pressurised fluid to flow out from the system. The pressure in a system can build up by a process upset, instrument or equipment failure, or fire. When considering safety factors to minimizing the damage in industrial plant, it is important to properly select the pressure relief valve to be utilized. Pressure relief valves controls the pressurised fluid by direct contact, hence it should be designed with materials compatible with the process fluids. Air Release Valves are hydro-mechanical devices which automatically vent small pockets of air as they accumulate at high points in a system while the system is operating and pressurized. As a function of physics, entrained air will settle out of the liquid being pumped and collect at high points within the system. If provisions are not made to remove this air from high points, pockets of air will collect and grow in size. Air pocket growth will then gradually reduce the effective liquid flow area, creating a throttling effect as would a partially closed valve. In extreme cases it is possible for an enlarging pocket of air collecting at a high point within a system to create an air block to a degree where the flow of fluid virtually stops. In this severe case an air problem is easily detected and installation of ARV's at the high points will remove the restrictive pockets of air to restore system efficiency. The design engineer should prevent accumulation of air by installing ARV's on all high points of a system. The presence of trapped air in a pressurized pipeline can have serious effects on system operation and efficiency.

II. PENSTOCK PROTECTION VALVE

Air release valves are required to drive out the air from the pipeline during initial filling. The valve is situated on the downstream side of the penstock protection valve. The pressure rating of the air release valve should match the penstock protection valve. The flow rate should be finalized in consultation with the customer. In the absence of any data, the thumb rule for bypass assembly can be used. A penstock protection valve is a butterfly valve used for isolation during penstock inspection without having to de-water the entire length from dam to penstock protection valve and to act as emergency closing device in the event of penstock rupture on the downstream of the valve. Two nos. of air valves for evacuating the air while filling the penstock and for admitting the air when the penstock is being emptied shall be provided and installed on the downstream side at suitable locations between the Penstock Butterfly Valve and Turbine Main Inlet Valve. Apart from usual electrical interlock, the butterfly valve and by-pass valve shall be supplied with independent mechanical locking devices provided on valve bodies as additional safety devices to guard against accidental opening or vice-versa accidental closure. The valve should also close if the velocity in the penstock exceeds the 30% of normal velocity. The Penstock rupture safety device shall be complete in all respect including all Controls Relays, Velocity sensors etc. Along with these controls additional safety valve i.e. Air Release Valve is used to protect process industry and Hydro Power plants.

III. PROBLEM DESCRIPTION AND OBJECTIVES

Currently the Air release valve/ Anti vacuum valve manufactured in India are up to a size of 300mm in Dia and pressure rating of PN 20 bar. Any size & pressure rating beyond this have to be imported from companies like ARI0 (Israel) OR DOROT (Israel). Since these are the only companies in the world manufacturing high pressure Air release valve/ Anti vacuum valve, they are0not only very expensive but also take considerable time 12 to16 weeks) to deliver. Hence it has was proposed to develop these valves for pressure beyond 40 bar & above, size ranging from 50 mm to 500 mm.

The main objective of the work is

- Outline dimension & sizing of the air releases valve body, Sphere, spring & stiffeners by considering existing catalogue & Reverse engineering.
- Identification of international governing standards & codes for design calculation for various calculation of the valve
- Material of construction, suitable hardware's of various components of the valve.
- Geometric modeling, meshing and applying boundary condition.
- Static Structural analysis.
- Design validation of the orifice using CFD analysis
- Pressure and velocity distribution by CFD Analysis
- Design verification.
- Revision of design based on CFD analysis result.
- Conclusion & future scope of work.

IV. METHODOLOGY

The project consists of design & validation of Air release valve/ Anti vacuum valves for pressure rating PN102 and for a size of 200mm valve. The size and pressure rating of the proposed valve is selected as this is normally supplied to many of the hydro power plants in Himachal Pradesh, Nepal, Vietnam & Latin American countries.

The following steps are in involved in project:

- Project planning preparation of list of activities and then arrive at the time schedule for completion.
- Identification of international governing standards for design manufacturing & testing
- Design & calculation of various components of the valve
- Design validation of the orifice using CFD analysis.
- Pressure & velocity distribution shown in CFD analysis.
- Conclusion & future scope of work.

A. Design parameter details

The parameters which considered are the dimensions of actual bus given below.

TABLE I: DESIGN CONSIDERATIONS FOR AIR RELEASE VALVE

Internal design pressure	102bar
Body /shell material	S G Iron
Body bore	200 mm

V. MODELLING AND SIMULATION OF AIR RELEASE VALVE

Air Release Valve modeling is carried out in PRO-E. This chapter discusses the detailed three dimensional modeling of a Air Release Valve and simulation of the model.

A. Modeling

The 3D model is created using Pro-e wildfire 4.0 software as per the design specifications discussed in the above. This chapter discusses the detailed three dimensional modeling of a Air Release Valve and simulation of the model. The Air Release Valve is made with S.G Iron of circular forged section.

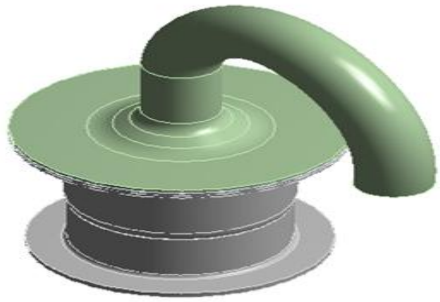

Fig.1. 3D Model of Air Release Valve

B. Meshing

The meshing of 3D model of the Air Release Valve is done in ANSYS 14.5 workbench. The mesh influences the accuracy, convergence and speed of the solution. Tetrahedral mesh elements are used while meshing of the Air Release Valve. In ANSYS 14.5 Workbench, Tetra mesh method provides:

- Support for 3D inflation
- Built-in growth and smoothness control. The mesh will attempt to create a smooth size variation based on the specified growth factor.

The TET elements are used for meshing with number of nodes and elements are listed near the image.

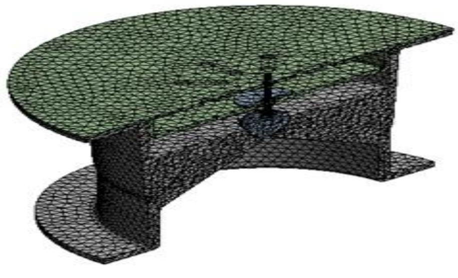

Fig.2 Mesh Model of Air Release Valve

C. Boundary and loading condition

The boundary condition used in the analysis is different according to the operating circumstances of the valve. During the static loading case the main loads that are considered are pressure of 102bar with fixed supports. And also CFD analysis is performed to know the fluid flow at the set pressure.

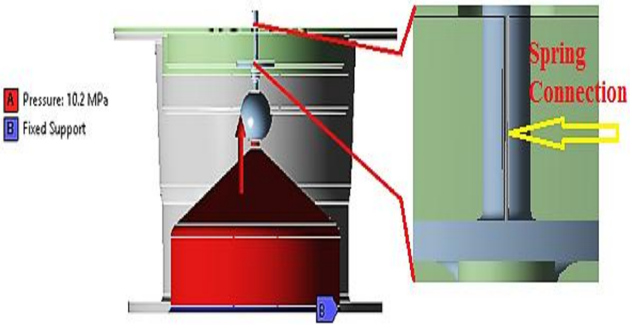

Fig.3 Boundary Condition for Air Release Valve

D. Post-processing

Post-processor contains sophisticated routines used for sorting, printing, and plotting selected results from a finite element solution.

TABEL.II: MATERIAL PROPERTIES FOR ROTOR

Material	Chrome Steel
Density	7300 Kg/m3
Young's modulus	125 x 10^3 MPa
Ultimate strength	540 MPa
Poisson's ratio	0.3
Pressure	102 bar

VI. RESULTS AND DISCUSSIONS

1. Static Structural Analysis of Air Release Valve

A. Equivalent stress on Body

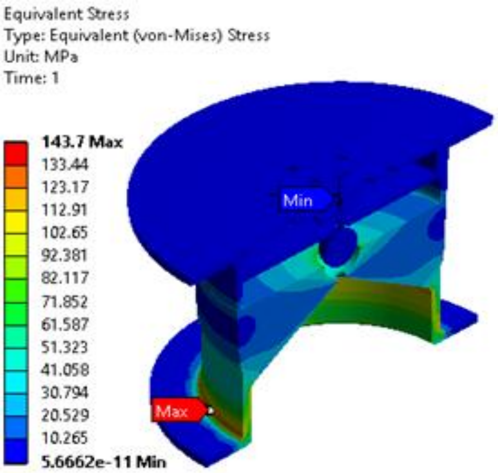

Fig. 4. Equivalent stresses at 102bar

B. Equivalent stress on Floater

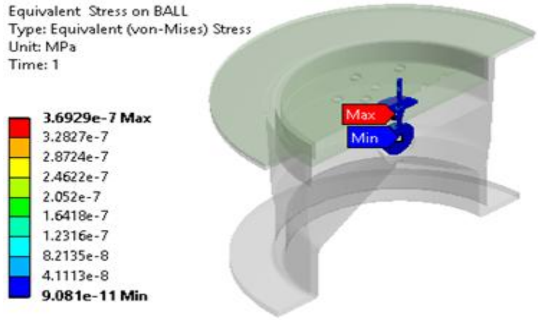

Fig.5. Equivalent stress on Floater at 102bar

C. Total Lift of Floater

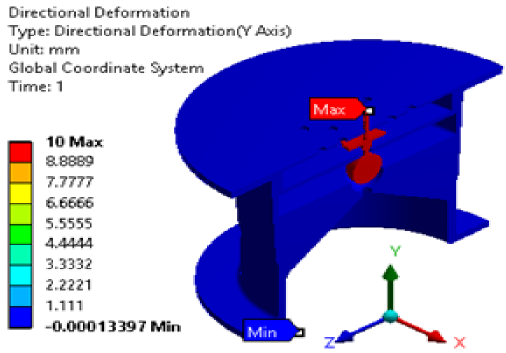

Fig.6. Total lift of Floater

D. Maximum principal stress

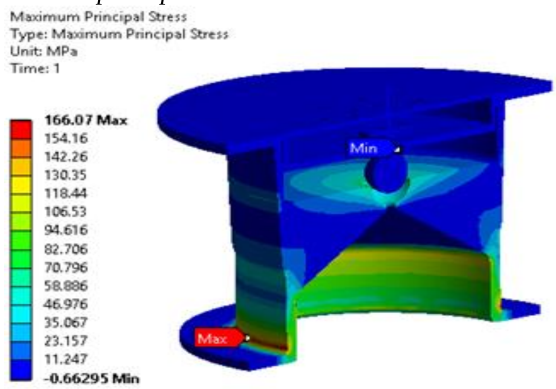

Fig.7. Maximum principal stress

E. Fatigue Life

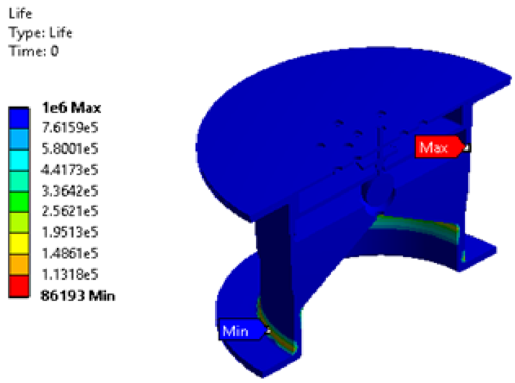

Fig.8.Fatigue Life

2. CFD Analysis of Air Release Valve

A. Pressure Distribution on the system

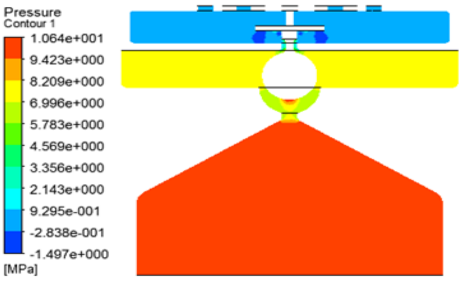

Fig. 9 Pressure Distributions0on the System

B. Pressure Representation in terms of Volume

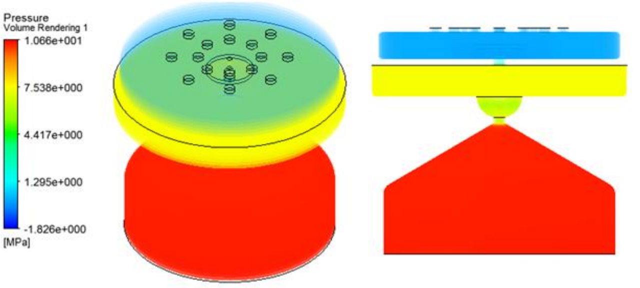

Fig 10. Pressure Representation

C. Stream line Representation for Air Relief

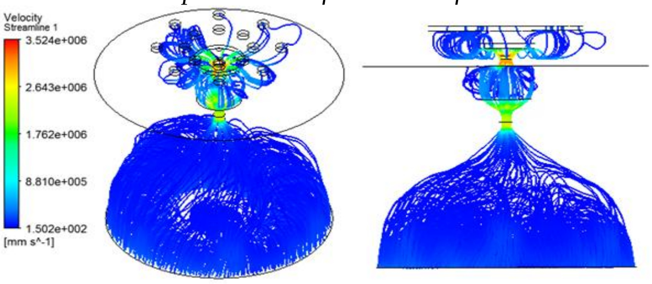

Fig.11. Flow path of the relieving air

D. Stream line Representation for Air Relief

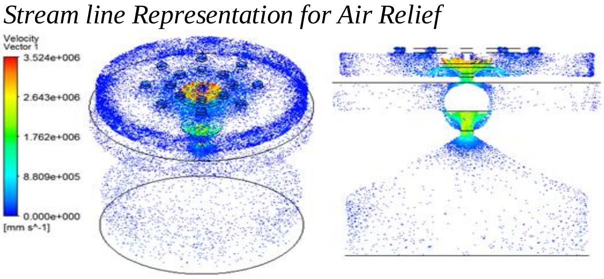

Fig.12. Velocity Vector

TABEL.III RESULTS COMPARISION

Description	Actual Stresses
Equivalent Stress (Body) in Mpa	143.7MPa
Maximum Principal Stress in Mpa	166.07MPa
Minimum Principal Stress in Mpa	26.766MPa

Table above shows the comparison between normal operation of Steam turbine and Operation under Low Volume Flow condition. Here we can see that Equivalent Stress and Total deformation are more in Low Volume Flow condition.

VII. CONCLUSION

The main objective of the work is focused on the design Air release valve, such as origin of overpressure (to determine the maximum or minimum required valve in such conditions), valid codes, Principles and standards, and general cases of individual relieving rates. Static Structural Analysis of Air Release Valve using Ansys & CFD for pressure and velocity distribution. Here the basic work involved is stress analysis / buckling through analysis, sizing as per existing catalogue & reverse engineering, re-circulation through CFD analysis, design verification & hand calculation. The Air release valve modeled in Pro e and meshed in ANSYS 14.5 Workbench. A methodology to determine Static Structural Analysis for high pressure is illustrated. Equivalent Stresses for valve body & sphere are tabulated. And the results tabulated in table 6.1 show the stresses generated in the Air release body & sphere is within the acceptable limit. Future Work: Further to the above analysis, Prototype model test to be conducted for 200mm, PN 102 bar & results to be tabulated and compared with calculated stress values.

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