Fatigue life estimation of turbine bypass valve

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Abstract - *The turbine bypass system is a basic component of a power plant that has evolved over the years to increase operational flexibility and plant life by protecting its components during transient mode operation. The turbine bypass system enables independent activity of the steam generator and the turbine during start-up, load rejection, shutdown and variable pressure operation. Fatigue life of component is highly dependent on the thermal behavior of the component. Thermal stress generated in the component is much higher than the structural loads. Present work deals Study of thermal analysis Temperature distribution of the component & needs to be applied along with mechanical loads such as internal pressure. Stress intensity from ANSYS is used to estimate the fatigue life using EN 12952-3. It can be seen that max stress occurs at the location of max thermal gradient. As per standard, the stress from ANSYS is increased using several factors like weld factor, component's operating regime, temperature factor & safety factor. As per miner's rule, damage index should be less than 0.4, for which the pre heating temperature is found to be 350°C.*

***Key Words*: Thermal power station, turbine, turbine bypass valve, temperature zones.**

1. INTRODUCTION

A thermal power station is a power plant in which the prime mover is steam driven. Water is heated turns into steam and spins a steam turbine which drives an electrical generator. After it passes through the turbine the steam is condensed in a condenser and recycled to where it was heated this is known as a Ranking cycle. The greatest variation in the design of thermal power stations is due to the different fossil fuel resources generally used to heat the water. Some prefer to use the term energy center because such facilities convert forms of heat energy into electrical energy. Certain thermal power plants also are designed to produce heat energy for industrial purposes of district heating, or desalination of water, in addition to generating electrical power. Globally fossil fueled thermal power plants produce a large part of man-made CO2 emissions to the atmosphere and efforts to reduce these are varied and widespread. During startup shutdown and load disturbances in a power plant the boiler and steam turbine need to be isolated from one another. This is to protect the turbine from any water carry over, but also protect additional plant equipment from large thermal transients. By isolating the boiler and steam turbine it is also possible to reduce fuel consumption during startup and shutdown. In the event of a load rejection, reloading times can also be improved through the turbine bypass system. The turbine bypass system is designed to provide the quickest startup time by controlling both boiler pressure and temperature. Bypassing the steam around the turbine allows the steam to attain the desired qualities before being routed through the turbine. If the turbine bypass system were not used the firing rate of the boiler would have to be reduced which could lead to tube failures. The bypass system allows the boiler to be fired at full capability without introducing large thermal gradients in the thick walled components such as the boiler drum and any separators or flash tanks. In order to protect the re heater tube banks from overheating, the high pressure steam is routed around the high pressure turbine into the cold reheat piping. The steam flows through the re heater tube banks and is then routed through the low pressure turbine bypass valve to the condenser. Turbine bypass valve routes high pressure, high temperature steam around the HP/LP Turbine from the main stream line typically to the cold reheat line. In doing so the HP/LP turbine bypass valve must perform both pressure reduction as well as temperature control.

P. Karthikeyan et.al [1] Investigated about the High Pressure Bypass System and a new control station for monitoring and controlling the High Pressure Bypass Valve. Dr. P.V.J. Mohan Rao et.al [2] Analyzed The flow pattern inside the The HP bypass valve using CFX-5.7.1.Flow coefficient was calculated for the given HP bypass valve from CFD analysis, and the percentage of error was estimated to be 2& when compared with the actual test conditions. Ron Adams et.al [3] Investigate the reliable performance of turbine bypass systems are made. These are based on recent experiences in a number of cycling power stations. The root causes were traced through analysis of failed components, reviews of plant layout and operation, analysis of DCS data, additional measurements at the site and finite element analysis. Swanekamp et.al [4] Studied the admission of bypass steam into a water cooled condenser are substantially different from that for an air cooled condenser. Francesco et.al [5] Analyzed with the modelling and simulationof fast start-up transients of a combined-cycle power plant. The study is aimed at reducing the start-up time while keeping the life-time consumption of the more critically stressed components under control.

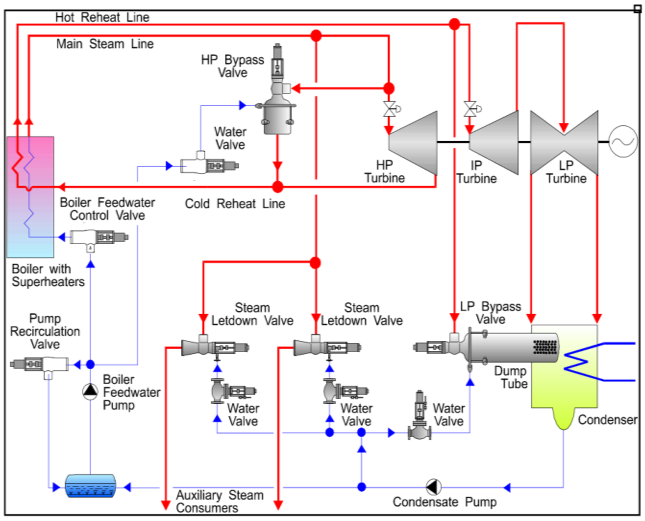

Fig.1.1: Typical Conventional reheat steam turbine

1.1 Operating Conditions of Power plant

Due to the severe thermal cycling over operation, a fatigue failure can occur in the valve body of the bypass valve. So, it is necessary to estimate the fatigue life of the given bypass valve for the operating conditions like cold start, warm start & hot start. What are the operating conditions of these valves.

Usually three generic operating conditions are found for a power plant

1. Cold start (>72hrs of plant shutdown)

2. Warm start (<=45hrs of shutdown)

3. Hot start (<=8hrs of shutdown)

Among these three conditions, hot start is the most prevalent & necessary operating condition. Fatigue life requirements can be from 5000 cycles to 15000 cycles & varies for different plants.

Essential characteristics of bypass valve

- Resistance to thermal shock and fatigue: The Bypass Valve will be subject to severe thermal shock (>200degC). Valve body and trim must be designed to assure reliable operation.

- Maximizing Power Output and reduced Maintenance: Repeatable seat tightness is required to prevent steam leakage that can otherwise be used to generate electricity and therefore revenue. Excessive seat leakage also results in excessive maintenance and plant shutdown.

- Must handle severe pressure drops: The Bypass Valve will have to throttle or control pressure drops of greater than 100 bar (2500psi). The valve trim should have sufficient Pressure reducing stages and control trim exit velocity to prevent premature erosive wear, excessive damaging vibration and noise.

2. METHODOLOGY

This section describes the structural flow of work from initial stage to final stage. Primary objective of the current study is to estimate the fatigue life of the bypass valve for the given operating conditions & improve the fatigue life.

2.1 OBJECTIVE OF THE CURRENT STUDY

This section discusses about the major objective of the project.

- Primary objective of the current study is to estimate the fatigue life of the bypass valve for the given operating conditions & improve the fatigue life.

- A detailed transient thermal analysis is necessary to understand the thermal scenario of the component during the given start condition (hot start).

- Structural analysis at discrete points can hint us the time vs. stress scenario.

- Fatigue life can be estimated using industry standards like (ASME/EN12952).

- Thereafter, optimization of iterations can be performed to improve the fatigue life.

- ANSYS software is used for this analysis purpose.

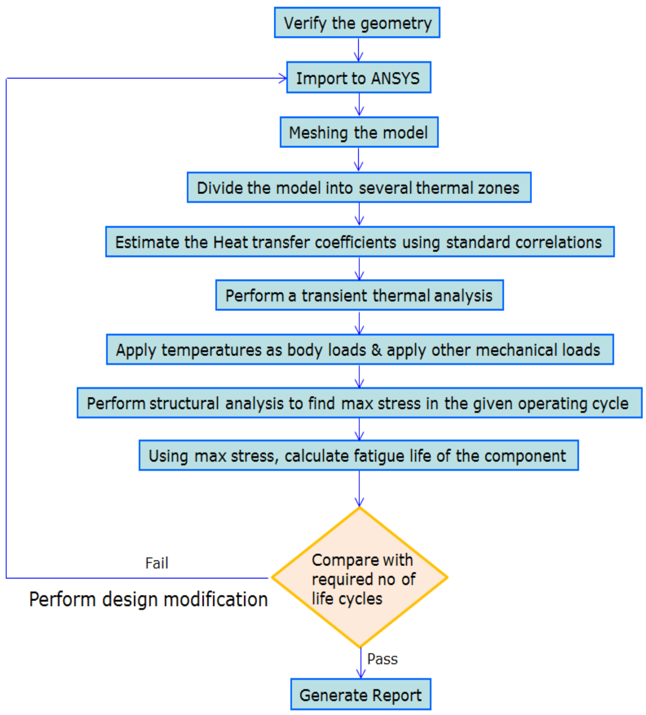

Fig.2.1: Structural flow of work from initial stage to final stage.

3. RESULTS AND DISCUSSIONS

Below is the geometry that is used for the current analysis. Due to symmetry of the model and ease of handling, only 180 ˚C model is considered for the analysis.

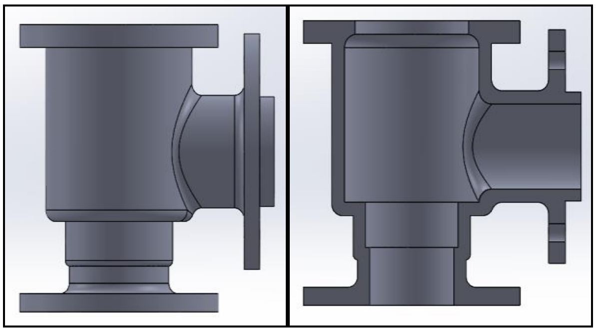

Fig.3.1: Full Model and 180˚C model of the geometry.

3.1 FE Modeling

FE modeling of valve is carried out in Ansys preprocessor module, due to complexity involved in the model both hexahedral and 2nd order tetrahedral elements are use to mesh the model. The FE model is as shown in the below fig.

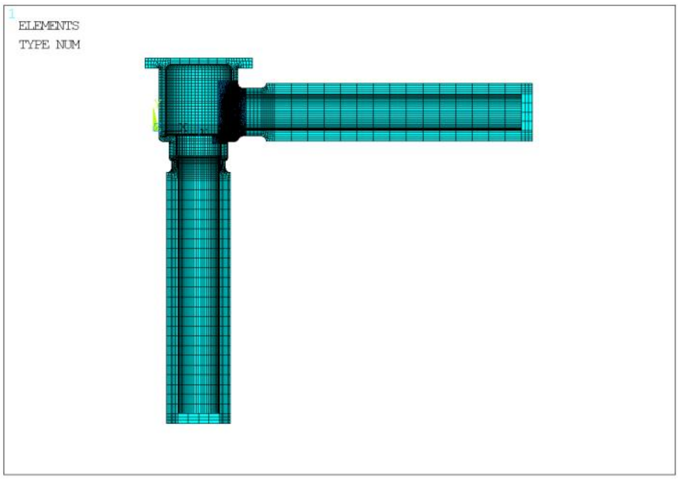

Fig.3.1.1: FE Model of complete assembly.

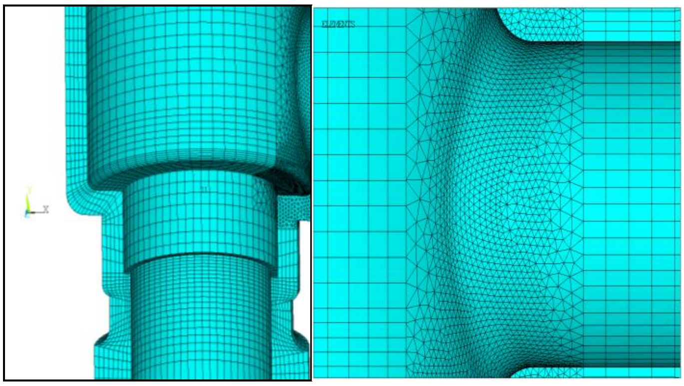

Fig.3.1.2: FE Model with zoom in view.

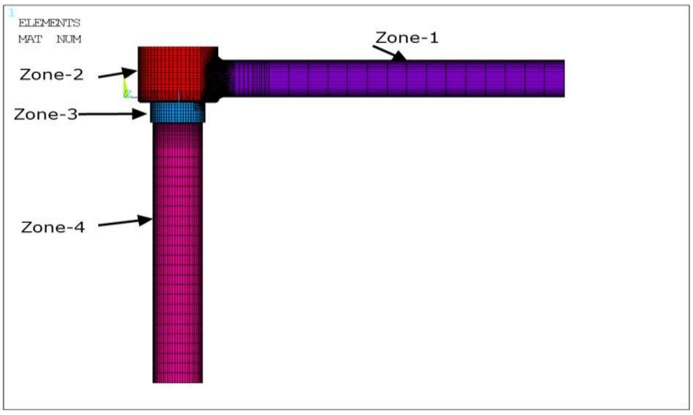

Fig.3.1.3: Different zones used in the analysis.

Operating Curves or Service Loads Below are the operating curves of hot start load case. Steam temperature, Pressure & Flow Rate curves are given as per the valve operating conditions in the plant.

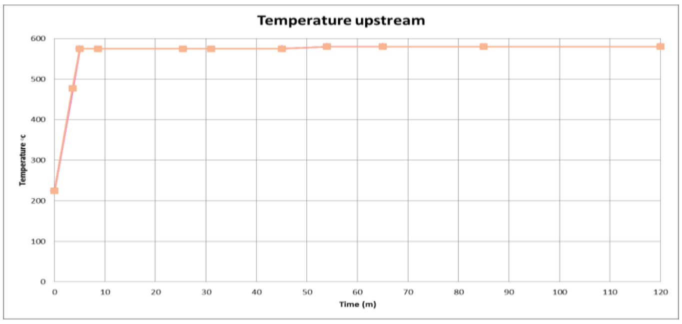

Fig.3.1.4: Temperature vs. Time History Plots.

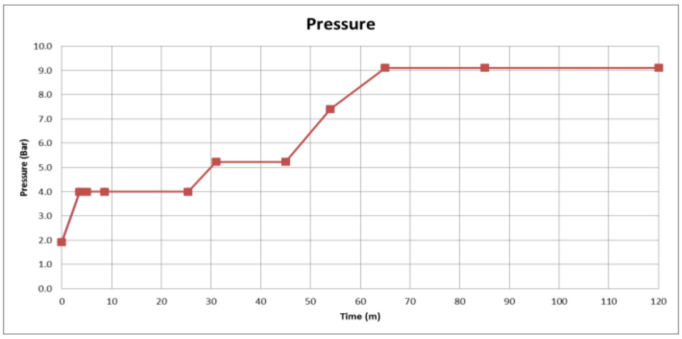

Fig.3.1.5: Pressure vs. Time History Plots.

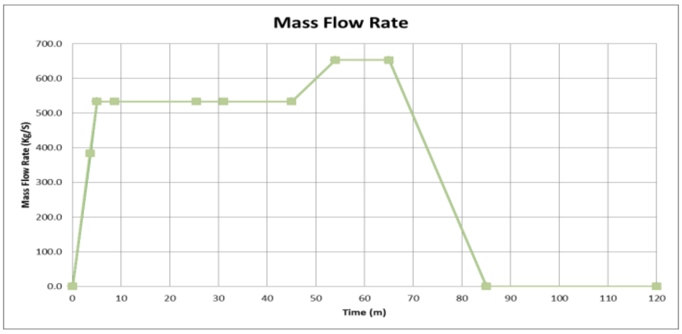

Fig.3.1.6: Mass Flow Rate vs. Time History Plots.

3.2 Thermal Analysis

After thermal zones are created according to the diameter of the pipe, HTC values are calculated. Thermal analysis is composed for complete service load i.e. from 0 sec to 120 min and the thermal results obtained are plotted for different points as shown in the below figs.

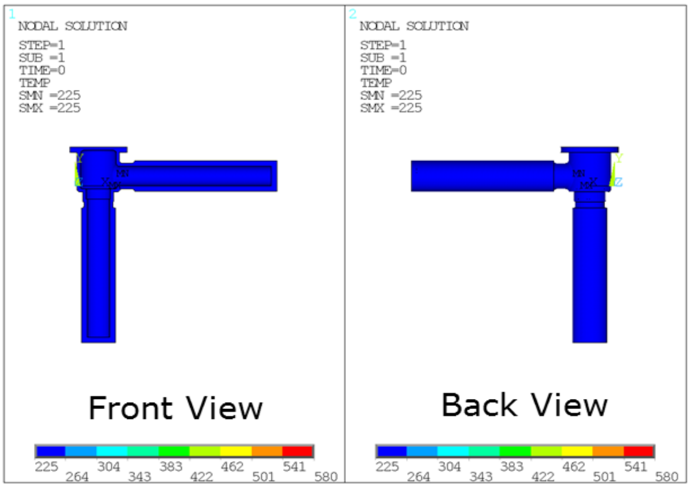

Fig.3.2.1: Temperature plot at 0sec

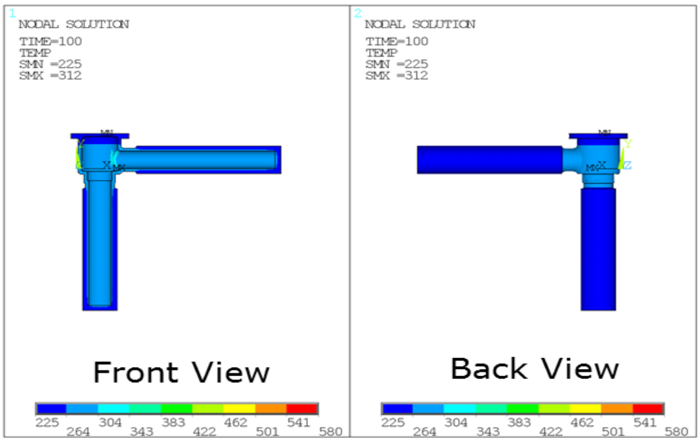

Fig.3.2.2: Temperature plot at 100sec.

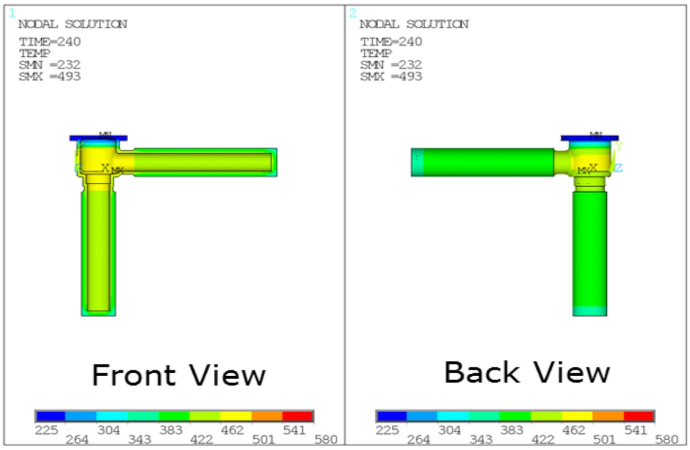

Fig.3.2.3: Temperature plot at 240sec.

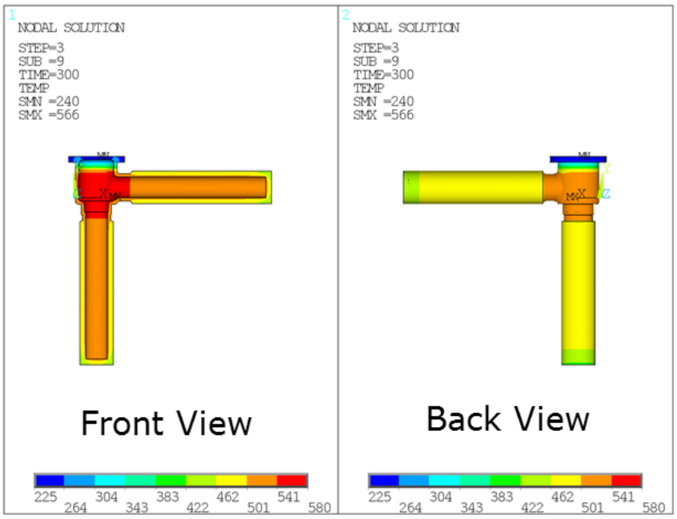

Fig.3.2.4: Temperature plot at 300sec.

Fig.3.2.5: Temperature plot at 450sec

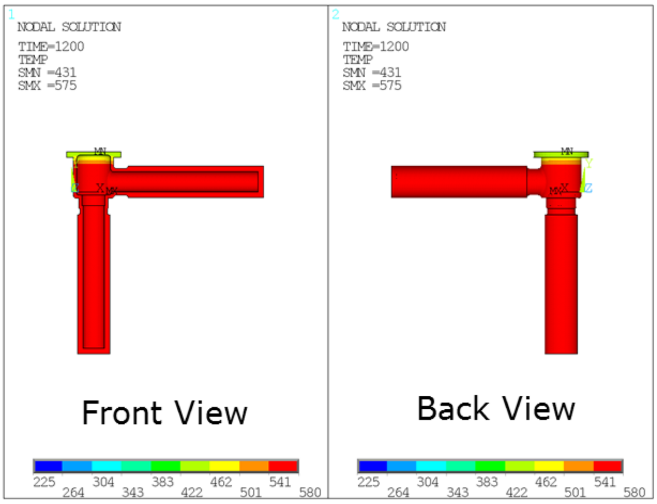

Fig.3.2.6: Temperature plot at 1200sec.

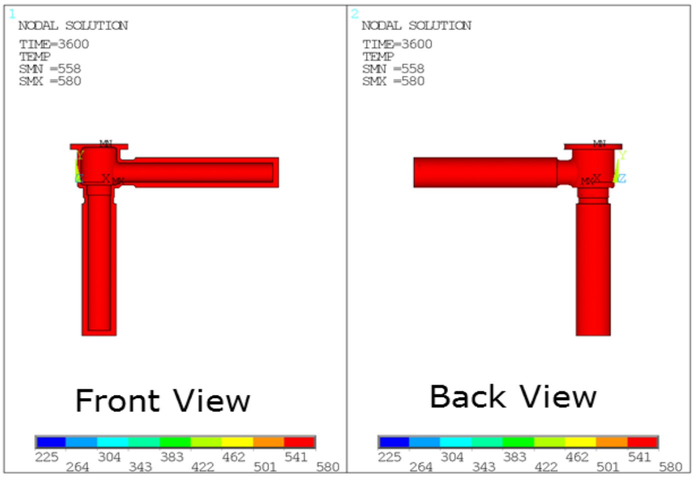

Fig.3.2.7: Temperature plot at 3000sec.

CONCLUSION

After the detailed Study of the analysis fallowing can be drawn. Pressure boundary parts like valve are exposed to severe thermal loads which in turn generates thermal stresses. Failure of this valve body can cause devastating damage both in terms of human & money. It is necessary to estimate fatigue life of the component for the given operating conditions. Fatigue life of component is highly dependent on the thermal behavior of the component. Thermal stress generated in the component is much higher than the structural loads (like internal pressure. A non-linear transient thermal analysis is necessary for each operating condition of valve. Structural analysis should include the transient Temperature distribution of the component & needs to be applied along with mechanical loads such as internal pressure. Stress intensity from ANSYS is used to estimate the fatigue life using EN 12952-3. It can be seen that max stress occurs at the location of max thermal gradient. As per standard, the stress from ANSYS is increased using several factors like weld factor, component's operating regime, temperature factor & safety factor. As per miner's rule, damage index should be less than 0.4, for which the pre heating temperature is found to be *350˚C.*

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