Analysis of Erosion formation in Boiler Tube Using CFD

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***Abstract*— The phenomenon of corrosion is directly associated with the production of magnetite on the waterside surface of boiler tubes. Corrosion may first be manifested by the sudden, violent rupture of a boiler tube, such failures being found to occur predominantly on the fireside surface of tubes situated in zones exposed to radiant heat where high rates of heat transfer pertain. In most instances, a large number of adjacent tubes are found to have suffered, the affected zone frequently extending in a horizontal band across the boiler. In some instances, pronounced local attack has taken place at butt welds in water-wall tubes, particularly those situated in zones of high heat flux. To prevent corrosion an adequate flow of water must occur within the tubes in the susceptible regions of a boiler. Corrosion products and suspended matter from the pre-boiler equipment should be prevented from entering the boiler itself. Also, it is good practice to reduce as far as possible the intrusion of weld flash and other impedances to smooth flow within the boiler tubes**

***Index Terms*— corrosion, boiler tubes, water-wall tubes, high heat flux, pre-boiler equipment**

I. INTRODUCTION

Corrosion is one of the main causes of reduced reliability in steam generating systems. It is estimated that problems due to boiler system corrosion cost industry billions of dollars per year. Many corrosion problems occur in the hottest areas of the boiler-the water wall, screen, and super heater tubes. Other common problem areas include deaerators, feed water heaters, and economizers. Methods of corrosion control vary depending upon the type of corrosion encountered. The most common causes of corrosion are dissolved gases (primarily oxygen and carbon dioxide), under-deposit attack, low pH, and attack of areas weakened by mechanical stress, leading to stress and fatigue cracking. Menu Boiler feed water heaters are designed to improve boiler efficiency by extracting heat from streams such as boiler water blow down and turbine extraction or excess exhaust steam. Feed water heaters are generally classified as low-pressure (ahead of the deaerator), high-pressure (after the deaerator), or deaerating heaters. Regardless of feed water heater design, the major problems are similar for all types. The primary problems are corrosion, due to oxygen and improper pH, and erosion from the tube side or the shell side. Due to the temperature increase across the heater, incoming metal oxides are deposited in the heater and then released during changes in steam load and chemical balances. Stress cracking of welded components can also be a problem. Erosion is common in the shell side, due to high-velocity steam impingement on tubes and baffles. Corrosion control techniques vary according to the type of corrosion encountered. Major methods of corrosion control include maintenance of the proper pH, control of oxygen, control of deposits, and reduction of stresses through design and operational practices. Control is achieved through feed of the proper type of phosphate to either raise or lower the pH while maintaining the proper phosphate level. Increasing blow down lowers both phosphate and pH. Therefore, various combinations and feed rates of phosphate, blow down adjustment, and caustic addition are used to maintain proper phosphate/pH levels. Elevated temperatures at the boiler tube wall or deposits can result in some precipitation of phosphate. This effect, termed "phosphate hideout," usually occurs when loads increase. When the load is reduced, phosphate reappears. Clean boiler water surfaces reduce potential concentration sites for caustic. Deposit control treatment programs, such as those based on chelants and synthetic polymers, can help provide clean surfaces. Where steam blanketing is occurring, corrosion can take place even without the presence of caustic, due to the steam/magnetite reaction and the dissolution of magnetite. In such cases, operational changes or design modifications may be necessary to eliminate the cause of the problem. Acid corrosion can also be caused by chemical cleaning operations. Overheating of the cleaning solution can cause breakdown of the inhibitor used, excessive exposure of metal to cleaning agent, and high cleaning agent concentration. Failure to neutralize acid solvents completely before start-up has also caused problems.

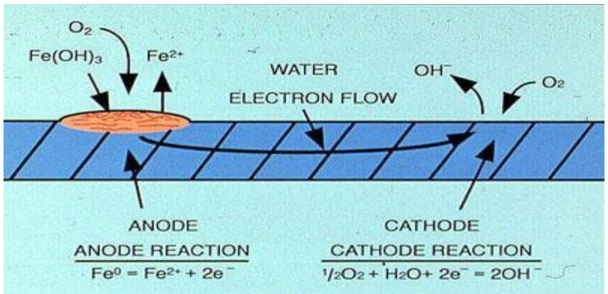


Figure: 1 Simplified corrosion cell for iron in water.

Without proper mechanical and chemical deaeration, oxygen in the feed water will enter the boiler. Much is flashed off with the steam; the remainder can attack boiler metal. The point of attack varies with boiler design and feed water distribution. Pitting is frequently visible in the feed water distribution holes, at the steam drum waterline, and in down comer tubes. Oxygen is highly corrosive when present in hot water. Even small concentrations can cause serious problems. Because pits can penetrate deep into the metal, oxygen corrosion can result in rapid failure of feed water lines, economizers, boiler tubes, and condensate lines. Additionally, iron oxide generated by the corrosion can produce iron deposits in the boiler. Oxygen corrosion may be highly localized or may cover an extensive area. It is identified by well defined pits or a very pockmarked surface.

Fig: 2 Oxygen pitting of a boiler feed water pipe.

II. CORROSION CONTROL FACTORS

A. Steel and Steel Alloys

Protection of steel in a boiler system depends on temperature, pH, and oxygen content. Generally, higher temperatures, high or low pH levels, and higher oxygen concentrations increase steel corrosion rates. Mechanical and operational factors, such as velocities, metal stresses, and severity of service can strongly influence corrosion rates. Systems vary in corrosion tendencies and should be evaluated individually

B. pH Control

Maintenance of proper pH throughout the boiler feed water, boiler, and condensate systems is essential for corrosion control. Most low-pressure boiler system operators monitor boiler water alkalinity because it correlates very closely with pH, while most feed water, condensate, and high-pressure boiler water requires direct monitoring of pH. Control of pH is important for the following reasons:

- corrosion rates of metals used in boiler systems are sensitive to variations in pH
- low pH or insufficient alkalinity can result in corrosive acidic attack
- high pH or excess alkalinity can result in caustic gouging/cracking and foaming, with resultant carryover
- speed of oxygen scavenging reactions is highly dependent on pH levels

The pH or alkalinity level maintained in a boiler system depends on many factors, such as sys-tem pressure, system metals, feed water quality, and type of chemical treatment applied. The corrosion rate of carbon steel at feed water temperatures approaches a minimum value in the pH range of 9.2-9.6. It is important to monitor the feed water system for corrosion by means of iron and copper testing. For systems with sodium zealot or hot lime softened makeup, pH adjustment may not be necessary. In systems that use deionizer water makeup, small amounts of caustic soda or neutralizing amines, such as morph line and cyclohexylamine, can be used.

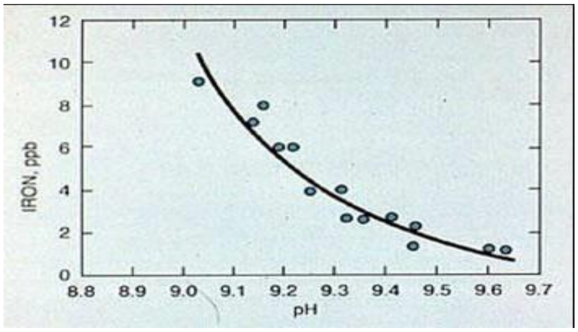


Fig: 3 Iron corrosion product release from carbon steel in boiler feed water.

In the boiler, either high or low pH increases the corrosion rates of mild steel The pH or alkalinity that is maintained depends on the pressure, makeup water characteristics, chemical treatment, and other factors specific to the system. The best pH for protection of copper alloys is somewhat lower than the optimum level for carbon steel. For systems that contain metals, the condensate and feed water pH is often maintained between 8.8 and 9.2 for corrosion protection of both metals. The optimum pH varies from system to system and depends on many factors, including the alloy used

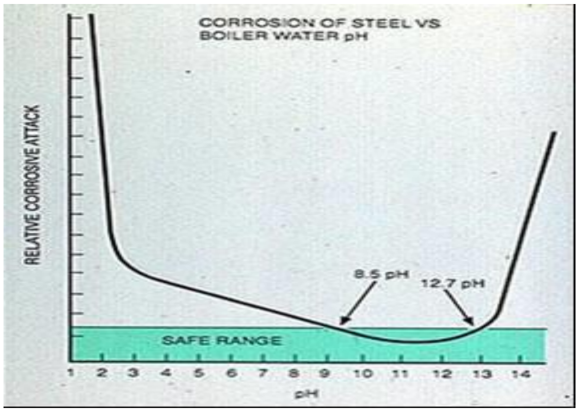


Fig: 4 High or low boiler water pH corrodes boiler steel.

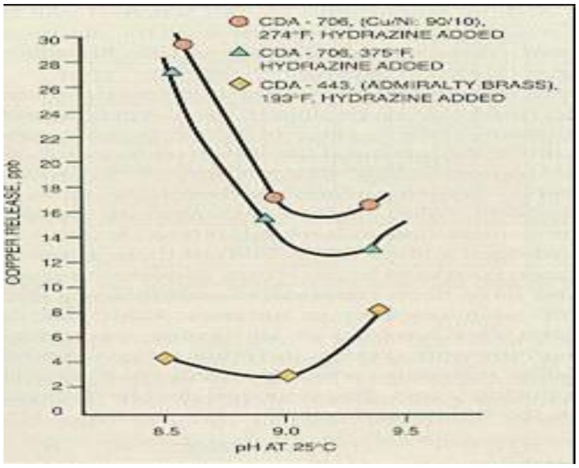


Fig: 5 Average copper release as a function of pH shows optimum pH in range of 8.8 to 9.2 for different copper-based alloys.

III. CORROSION PROTECTION DURING

Oxygen corrosion in boiler feed water systems can occur during start-up and shutdown and while the boiler system is on standby or in storage, if proper procedures are not followed. Systems must be stored properly to prevent corrosion damage, which can occur in a matter of hours in the absence of proper lay-up procedures. Both the water/steam side and the fireside are subject to downtime corrosion and must be protected. Off-line boiler corrosion is usually caused by oxygen in-leakage. Low pH causes further corrosion. Low pH can result when oxygen reacts with iron to form hydro ferric acid. This corrosion product, an acidic form of iron, forms at water-air interfaces. Corrosion also occurs in boiler feed water and condensate systems. Corrosion products generated both in the pre boiler section and the boiler may deposit on critical heat transfer surfaces of the boiler during operation and increase the potential for localized corrosion or overheating. The degree and speed of surface corrosion depend on the condition of the metal. If a boiler contains a light surface coating of boiler sludge, surfaces are less likely to be attacked because they are not fully exposed to oxygen-laden water. Experience has indicated that with the improved cleanliness of internal boiler surfaces, more attention must be given to protection from oxygen attack during storage. Boilers that are idle even for short time periods (e.g., weekends) are susceptible to attack.

Boilers that use undefeated water during start-up and during their removal from service can be severely damaged. The damage takes the form of oxygen pitting scattered at random over the metal surfaces. Damage due to these practices may not be noticed for many years after installation of the unit. The choice of storage methods depends on the length of downtime expected and the boiler complexity. If the boiler is to be out of service for a month or more, dry storage may be preferable. Wet storage is usually suitable for shorter down-time periods or if the unit may be required to go on-line quickly. Large boilers with complex circuits are difficult to dry, so they should be stored by one of the wet storage methods.

A. Dry Storage

For dry storage, the boiler is drained, cleaned, and dried completely. All horizontal and non-drainable boiler and super heater tubes must be blown dry with compressed gas. Particular care should be taken to purge water from long horizontal tubes, especially if they have bowed slightly Heat is applied to optimize drying. After drying, the unit is closed to minimize air circulation. Heaters should be installed as needed to maintain the temperature of all surfaces above the dew point. Immediately after surfaces are dried, one of the three following desiccants is spread on water-tight wood or corrosion-resistant trays the trays are placed in each drum of a water tube boiler, or on the top flues of a fire-tube unit. All manholes, hand holes, vents, and connections are blanked and tightly closed. The boiler should be opened every month for inspection of the desiccant. If necessary, the desiccant should be renewed.

B. Storage of Feed water Heaters and Deaerators

The tube side of a feed water heater is treated in the same way the boiler is treated during storage. The shell side can be steam blanketed or flooded with treated condensate. All steel systems can use the same chemical concentrations recommended for wet storage. Copper alloy systems can be treated with half the amount of oxygen scavenger, with pH controlled to 9.5. Deaerators are usually steam or nitrogen blanketed; however, they can be flooded with a lay-up solution as recommended for wet lay-up of boilers. If the wet method is used, the deaerator should be pressurized with 5 psig of nitrogen to prevent oxygen ingress.

C. Cascading Blow down

For effective yet simple boiler storage, clean, warm, continuous blow down can be distributed into a convenient bottom connection on an idle boiler. Excess water is allowed to overflow to an appropriate disposal site through open vents. This method decreases the potential for oxygen ingress and ensures that properly treated water enters the boiler. This method should not be used for boilers equipped with non drainable super heaters.

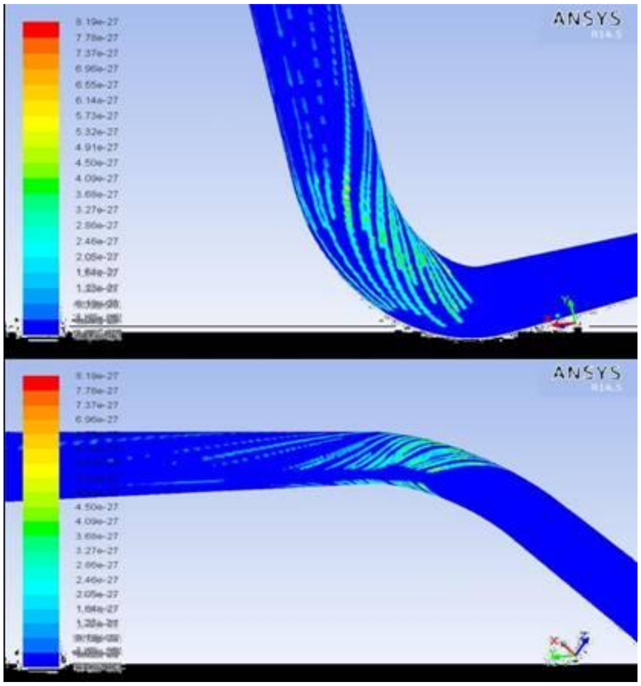
D. Cold Weather Storage

In cold weather, precautions must be taken to prevent freezing. Auxiliary heat, light firing of the boiler, cascade lay-up, or dry storage may be employed to prevent freezing problems. Sometimes, a 50/50 water and ethylene glycol mixture is used for freeze protection. However, this method requires that the boiler be drained, flushed, and filled with fresh feed water prior to start-up.

E. Fireside Storage

When boilers are removed from the line for extended periods of time, fireside areas must also be protected against corrosion. Fireside deposits, particularly in the convection, economizer, and air heater sections, are hygroscopic in nature. When metal surface temperatures drop below the dew point, condensation occurs, and if acidic hygroscopic deposits are present, corrosion can result. The fireside areas (particularly the convection, economizer, and air heater sections) should be cleaned prior to storage. High-pressure alkaline water is an effective means of cleaning the fireside areas. Before alkaline water is used for this purpose, a rinse should be made with fresh water of neutral pH to prevent the formation of hydroxide gels in the deposits (these deposits can be very difficult to remove).Following chemical cleaning with a water solution, the fireside should be dried by warm air or a small fire. If the boiler is to be completely closed up, silica gel or lime can be used to absorb any water of condensation. As alternative, metal surfaces can be sprayed or wiped with light oil. If the fireside is to be left open, the metal sur-faces must be maintained above the dew point by circulation of warm air.

IV. ANALYSIS OF EROSION FORMATION IN BOILER TUBE USING CFD



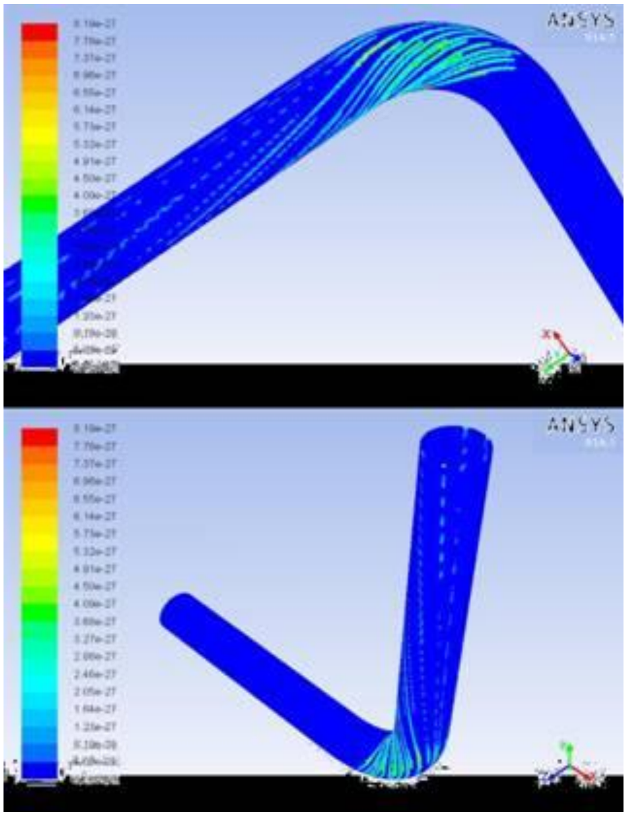


Fig: 6: Contours of DPM Erosion Rate (kg/m2sec)

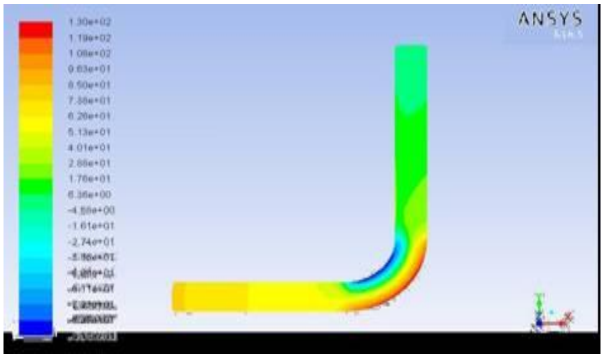


Fig: 7 Contours of Static Pressure (Pascal)

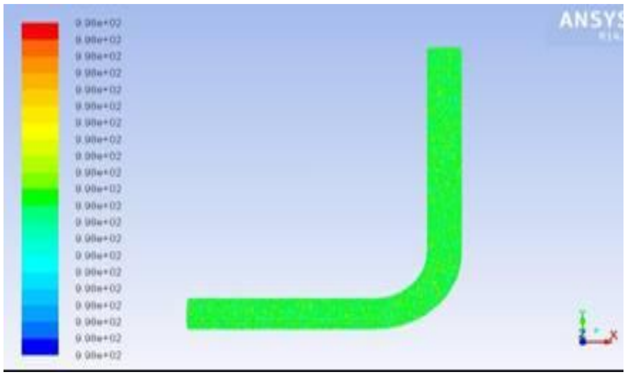


Fig: 8 Contours of Density (kg/m3)

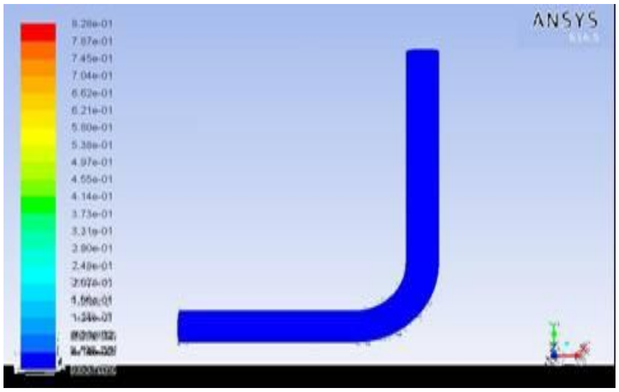


Fig: 9 Contours of Velocity Magnitude (m/sec)

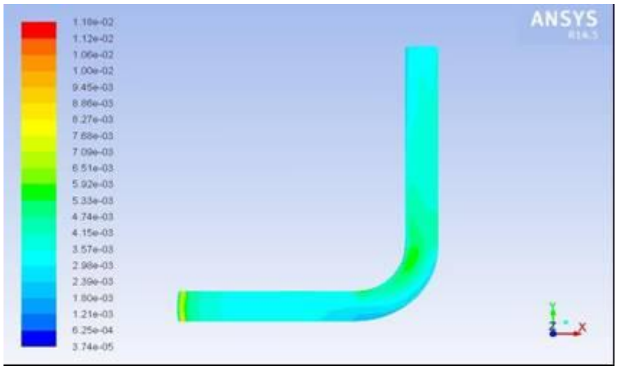


Fig: 10 Contours of Turbulent Kinetic Energy (k) (m2/s2)

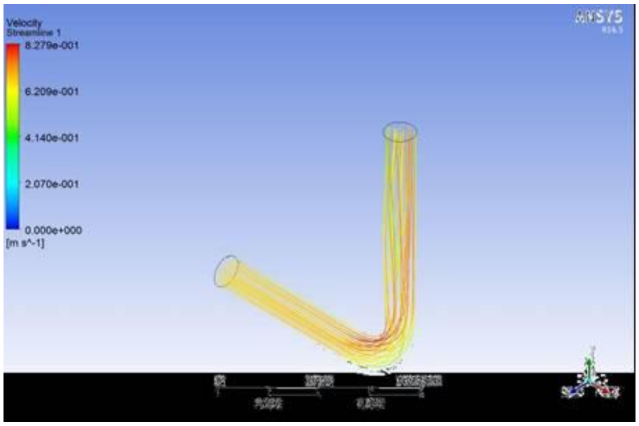


Fig: 11 velocity Streamline

V. RESULTS & SUMMARY

Post-processing the erosion results from FLUENT will help determine, how geometry changes, changes to the fluid properties, or boundary condition changes to the erosion model will impact the DPM erosion in your model. In this project, the post-processing capabilities of FLUENT were demonstrated for analyzing erosion phenomenon due to particles impinging on a 3D elbow bend.

VI. CONCLUSION

The product of corrosion in the feed water system transported into the boiler and gets deposited on the internal surface of water-wall tubes. Proper treatment of boiler feed water effectively protects against corrosion of feed water heaters, economizers, and deaerators. It leads to overheating, corrosion and ultimately tube failure. Heat is transferred through a thin layer of superheated liquid on a metal surface, the temperature gradient rising to about 10oC as the heat transfer rate increases and the boiling point of the liquid is approached failure of boiler tubes by corrosion attack has been a familiar phenomenon in power plants resulting in unscheduled plant shut down. The effects of scales and/or corrosion products in reducing thermal conduction leading to higher temperatures in the underlying metal can lead to other modes of failure.

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