ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 6, Issue 9, September 2019

Performance Enhancement in Water Cooled Condenser by Fouling Treatment

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Abstract: Any unwanted material deposition on heat transfer surfaces is called fouling. Fouling causes significant impacts on the thermal and mechanical performance of water cooled condensers. The deposition imposes an additional resistance to heat transfer. Due to the presence of deposit, the flow area gets narrow which results in an increased velocity for a given volumetric flow rate. Fouling increases the overall thermal resistance and lowers the overall heat transfer coefficient of water cooled condensers. Fouling also effects fluid flow, accelerates corrosion and increases pressure drop across water cooled condensers. Therefore, the consequences of fouling are, in general, a reduction in condenser efficiency and other associated operating problems across the condensers. It is only in the recent years that the problem of water cooled condenser fouling has attracted scientific and theoretical treatment and many aspects remain yet to be investigated even today. This research paper deals with different fouling mechanisms, environmental and economical impacts caused by fouling and some controlling measures for overcoming it.
Keywords: Fouling, Water cooled condenser, Thermal resistance, Heat transfer coefficient.

I. Introduction

Water-cooled condensers and chiller barrels are specialized heat exchanger. They exchange heat by removing heat from one fluid and transferring it to another fluid. A water-cooled condenser is a heat exchanger that removes heat from refrigerant vapour and transfers it to the water running through it.

The time period for a fouling problem to become apparent may be different for different water-cooled condenser. It mainly depends on the particular fluid and the conditions under which the condenser operates. The nature of deposits is also extremely variable. In some examples, deposits are hard, tenacious and difficult to remove. Other accumulations are soft and friable that allows themselves for easy removal.

It is found that the deposits are made up of different components. The deposits associated with cooling water, for instance, may include: corrosion products, particulate matter, crystals and even living biological material.

The extent of each of the components in the deposit will depend on many factors including the origin of the water, its treatment and the processing conditions. It is possible that one component is dominant resulting in either scale formation or corrosion. Because of this extremely variable quality of deposits, it has become common practice to consider different fouling mechanisms in the development of techniques to mitigate the problem.

II. Fouling With Water

Both scaling and corrosiveness of the **condenser** tubes in the Water cooled condensers is due to the influence of the flowing water. Some factors like alkalinity, hardness, pH value, the quality of tube material and the presence of oxidizing agents like carbon dioxide causes scaling. The

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dissolved solids can further add up for corrosion. In general, corrosion is the result of low pH of water.

Acidic water has a large number of Hydrogen ions to react with the electrons at the cathode leading to corrosion. But in contrast, water with a higher pH reduces the solubility of calcium carbonate which results in the calcium carbonate being precipitated out as scale.

Hard water contains calcium compounds which causes the formation of calcium carbonate precipitate. If the hardness in the water is reduced by noncarbonation, the chlorate and sulfate ions will tend to maintain the calcium in solution and will help to reduce scaling.

The other most commonly found chemicals and compounds in water like oxygen, carbon dioxide, and dissolved solids results in the corrosion process.

So it can be concluded that water with a high alkalinity is more likely to form scales and that with low alkalinity lacks the buffering capacity to deal with acids thus making it more acidic and corrosive.

The relationship between pH, alkalinity, and water stability is as shown in figure 1.

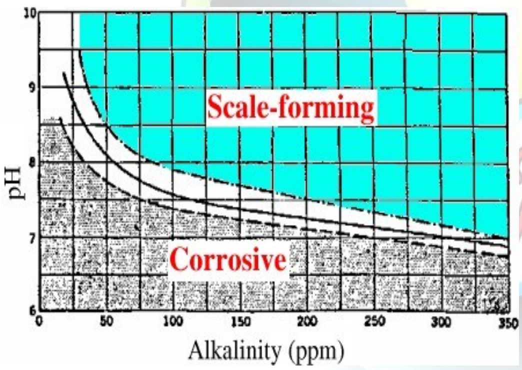

Figure 1. Relationship between pH, alkalinity, and water stability

III. Fouling Mechanisms

Fouling mechanisms are of different types. They may occur individually but often occur simultaneously. The most common fouling mechanisms are described below:

A. Scaling or Crystallization Fouling

The most common type of fouling is scaling .Scaling is commonly associated with inverse solubility salts such as calcium carbonate (CaCO3) found in water. These reverse solubility salts become less soluble with increasing temperatures and get deposited on the water cooled condenser surface. Mechanical and chemical cleaning methods may be required to remove scale as it is in a crystallized form.

Figure 2. Scaling or Crystallization Fouling

B. Particulate or Sedimentation Fouling

Particles like dirt, sand or rust in the solution settle and deposit on the heat transfer surface causing sedimentation. These sedimental deposits, like scale, may be difficult to be removed by mechanical methods depending on their nature.

Figure 3. Particulate or Sedimentation Fouling

C. Corrosion Fouling

The surface material of the water cooled condenser may get involved in some chemical reaction which gives rise to corrosion. When the water cooled condenser is made of metals like copper, aluminium etc., an adherent oxide coating forms on the surface. This metal oxide coating may prevent

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further corrosion. But these corrosion products even in small amounts may result in reduction of thermal conductivity and also it may significantly affect the overall performance of the water cooled condenser.

Figure 4. Corrosion Fouling

D. Chemical Fouling

The chemical reactions that occur in the fluid stream may result in some materials that may get deposited on the water cooled condenser surface hence causing fouling. Some chemically sensitive materials when heated to temperatures near its decomposition temperature is the common reason for this type of fouling. A good example for this type of fouling occurrence is coking of hydrocarbon material on the heat transfer surface.

Figure 5. Chemical Fouling

E. Freezing Fouling

Freezing fouling is caused when a part of the hot stream is cooled to near the freezing point of one of its components. Some prominent examples for freezing fouling occurrences are when paraffin solidifies from a cooled petroleum product and freezing of polymer products on the water cooled condenser surface.

Figure 6. Freezing Fouling

F. Biological Fouling

When biological organisms grow on heat transfer surface, biological fouling is said to occur. If untreated water is used as a coolant then biological organisms ranging from algae to other microbes such as barnacles and zebra mussels may grow on the water cooled condenser. During the blooming season microbial colonies of several millimeters depth may grow across the surface within hours, impeding circulation near the surface wall and impacting heat transfer.

Figure 7. Biological Fouling

It is of great importance to consider fouling and the mechanism of fouling that may occur while designing a water cooled condenser.

Different methods may be adopted to account for the expected fouling and to maximize runtime between cleaning. Fouling factor is a common method for use in shell and tube

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water cooled condensers. Excess heat transfer area is used for other types of water cooled condensers. However, the selection of fouling factors or excess area must be done carefully because fouling is a self-fulfilling prophecy and it has its own impact in the overall performance of the water cooled condensers.

IV. ENVIRONMENTAL IMPACT CAUSED BY FOULING

The environmental impact of Water cooled condenser fouling is equally as important as the economic impact. Consciousness on reduction of environmental pollution has made a sharp turn in addressing the issue.

A. The cost of fouling

If this fouling problem is ignored at the design stage of the water cooled condenser , the production cost will surely rise up .It may result in an emergency shut down as the water cooled condenser may rapidly lose its heat transfer efficiency or an excessive pressure drop may be caused which would it turn reduce the flow pressure. This would be the reason behind the frequent failure of joints and packing, and increased wear and tear on the associated pumps. And to add up, the fouling deposits may increase the corrosion of the underlying metal making it liable to early replacement, thereby increasing the capital cost. Fouling is the main culprit for increased maintenance costs.

The economic penalties faced due to fouling in water cooled condenser are:

1. Increased capital costs, i.e., additional heat transfer
2. Additional energy requirement to allow for reduced energy recovery.
3. Labour costs associated with additional maintenance, cleaning and mitigation.
4. Cost of any antifoulant chemicals.
5. Lost income resulting from lost production.
6. Equipment replacement costs.
7. Additional costs associated with low labour morale.

IV. NEED FOR FOULING TREATMENT

Fouling if addressed in the right method will be of great advantage to the industry.
Some interesting advantages are

- Reduction of carbon footprint as result of reduced consumption of electricity or fossil fuels.
- Extension of equipment lifetime (less corrosion in tubes)
- Downsizing of equipment footprint (no overdesign)
- Reduction of water consumption.
- Reduction of environmental pollution.

VII. CONTROLLING OF FOULING

Mitigation of Fouling

The mitigation techniques for overcoming fouling in water cooled condenser depends on the nature of the fluids being handled, the design of the water cooled condenser and the conditions under which it is operated. The online mitigation techniques generally come under two groups- mechanical methods and the use of chemical additives.

A. Mechanical method

Mechanical methods use physical methods of removal. The mechanical cleaning techniques need the water cooled condenser to be taken offline and dismantled for undertaking the cleaning process. Tube drilling, surface brushing and high pressure water jetting are some conventional cleaning techniques. Steam-blasting using high- pressure steam lines or hydro-blasting are some most common methods employed to remove the surface build-up.

Hydroblasting

A water cooled condenser can be hydro blasted using water at pressures up to 40,000 psi to remove fouling inside the shell, on the outside of the tube bundle, and on the internal surfaces of each tube. Hydro-blasting has to be performed only after dismantling the whole set up which is very tedious and also hazardous.

This is an effective method but has its own disadvantages. Some of them are- use of highly pressurized water, fouling materials being dispersed into the atmosphere, use of mobile lifting equipment, rigging, and potentially generating hazardous waste.

Some more mechanical control techniques that comes handy are tabulated below:

Table 1. Mechanical control techniques

Technique	Application
Circulation of sponge rubber balls	Inside of power station condenser tubes
Brush and cage systems	Inside of tubes in shell and tube heat exchangers
Soot blowers	Outside of tubes in combustion spaces
Sonic vibration	Tubular exchangers
Vibrating springs activated by the fluid flow	Inside of tubes

B. Chemical additives method

The use of the additive is complementary to the shear effects produced by the fluid velocity across the water cooled condenser surface. The additives are selected in such a way that they impart changes either to the depositing particles or the surface so that the particles are held off the surface. The concentration of additive must be kept as low as possible so that it would be cost effective.

Some examples of the use of additives are given in the following table:

Table 2. Chemical additive and their corresponding application

Fouling problem	Additive
Scaling or crystallisation	Dispersant to prevent attachment. Crystal modifier to weaken the deposit structure.
Particle deposition	Dispersant to prevent deposition. Flocculant followed by settling or filtration. Modifiers to reduce the strength of deposits in combustion systems
Biological growth	Biocide to kill the living matter. Biostat to reduce biological activity. Dispersant to prevent attachment to surfaces.
Chemical reaction	Antioxidants to prevent oxidation. Reaction chain terminators to remove free radicals.
Corrosion	Corrosion inhibitors to restrict the opportu - nity for corrosion reactions Chemicals to maintain protective oxide layers. Chemicals that react with acid combustion gases.
Freezing	Crystal modifiers to weaken the deposit structure.

Chemical cleaning process

A five step procedure is followed for chemical cleaning:

1. *Alkaline clean*: Removes organic material build up such as oil and fats leaving the inorganic surfaces exposed and ready for treatment.
2. *Rinse:* Following each step there is a rinse using high flow water flushes which removes loose debris and remaining chemical residue.
3. *Acid cleaning*: The inorganic material is now treated with an appropriate acid blend designed to soften or dissolve the fouling material.
4. *Rinse*: The process of rinsing occurs once more to remove any debris, sludge or residual acid from the water cooled condenser following the acid cleaning process.

5. Design in an easily accessible manner so that cleaning is made easier.
6. During water service, ensure the tube wall temperature is not too high to create salt deposits.
7. Do not throttle water flows in winter time.

VI. CONCLUSION

Fouling is a natural process that occurs during the normal operation of any water cooled condenser. This reduces thermal effectiveness and hydraulic efficiency of the water cooled condenser. Hazardous procedures are taken up to remove fouling in order to restore the water cooled condenser's thermal and hydraulic performance to normal operational conditions. Written procedures and safety standards are to be developed and followed to ensure safety, reduce maintenance costs and hazards. By following these recently developed mechanical and chemical cleaning methods, fouling reduces considerably.