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# Fouling Detection in Heat Exchanger and Methods to Mitigate its Effect

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**Abstract -** A Heat Exchanger may be defined as an equipment which provides sufficient surface area to transfer energy between hot and cold fluid But this transfer of energy is often resisted by a layer of impurities on the tubing which reduces it effectiveness and ultimately there is power /pressure Drop known as fouling. It is difficult to ascertain its thickness and causes. We will study the factors causing fouling in different HE and methods of detecting the thickness and to make efforts to reduce fouling.

***Keywords***-*fouling, pressure drop, effectiveness.*

## 1. INTRODUCTION

Heat exchangers are extensively used all over the world basically to transfer heat energy in between flow of two fluids. The flow of fluid can be separate or it can be mixed together in a single unit. The heat exchanger which has a separate fluid flow where only energy transfer takes place are known as indirect contact heat exchanger and the one in which the fluids are mixed together where energy as well as mass transfer takes place together are known as direct contact heat exchanger. We are mostly going to focus on indirect contact heat exchanger in this paper. This transfer of energy is often hampered by a layer of deposition; often corrosion, ash, soot, etc and this deposition is known as fouling. This formed layer of deposits eventually increases the thermal resistance between the two fluids and reduces effectiveness of heat exchanger by increasing fuel consumption as well as there is a considerable amount of pressure loss along the fluid pipe. This additional thermal resistance is represented by a term known as fouling factor and is denoted by $R_f$ which indicates the thermal resistance. As time passes the fouling factor increases, whereas for a new heat exchanger the fouling factor is zero.

## 2. FOULING

Fouling has been gaining a lot of focus in today's power-plant industries and energy firms where energy loss posses a huge impact to energy generation. Fouling depends on the fluid which is in contact with the pipe. If the fluid carries impurities the rate of fouling predominantly rises. Just like saline water leads to heavy fouling when used without water treatment. Calcium Carbonate and Calcium Sulphate being the main fouling category in water based systems. It has been found from experiments that even a layer of 2mm thickness can reduce heat transfer efficiency by 47%.

### 2.1 Classification of fouling-

According to mechanisms of fouling formation, fouling is classified in 6 types-
1-Crystallization Fouling
2-Chemical fouling
3-Particulate fouling
4-Corrosion fouling
5-Biological fouling

***Crystallization Fouling-***Crystallization fouling basically consist of separation of materials from liquid solution and it results in deposition on the solid and liquid interface. Crystallization fouling is essentially a layer formation of the solid particles on the walls of the tubes. This type of fouling is further divided into three stages.

a)***super-saturation phase-*** The mechanism of crystallization fouling start with nucleation of surface by local super saturation. This stage last for an average period of 40 hrs in a SS tube.
b) ***crystal core conformation phase-***When the core becomes stable in super saturation phase; crystals will grow and form visible crystals.
c) ***growth phase***-This phase include surface reaction and diffusion.

***Chemical Fouling***-When the chemical fluid inside the tubes changes it causes a fouling layer formation on tube surface. Sometimes the fluid also reacts with the material of the tube leading to scale formation. If the fluid varies from the one normally used, it is beyond the control of heat exchanger designer.

***Particulate Fouling***-This type consist of particles suspended in the fluid flow gets deposited on walls of tubes when the fluid velocity falls below a critical level. This is within the designers control as critical velocity can be designed by considering the fouling effect.

***Corrosion Fouling-***This happens when a corrosion layer builds upon the walls due to oxidation of metals and increases the resistance. This type is mostly common

where the heat exchanger material consist of majority ferrous constituents. This possibility can be eliminated by using stainless steel or using any type of nickel alloys.

## 3. FOULING DETECTION

Different types of method are prefer to detect the fouling in pipes among them most preferable are as follow-

1] Utrasonic technique

2] Extended filter to detect fouling

3] Slope method

- ***Utrasonic technique-***

Ultrasonic testing require transducer as a sensing medium which detect the impurities in the pipes. Pulse echo technique is one of the most common technique in this method.In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the pipes being inspected. In pulse-echo mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device.This technique gives a preferable idea to measure the fouling film between the fluid and pipe walls.

Due to differ in time of returning of pulse we can identify the thickness of various film in pipeline. But it consist of one drawback that this approach requires the velocity of sound in the materials to be known. As the pulse passes through the film it will scattered and scattered light will impact on transducer which will identify the film.The match of reflection of film with respect to pipe material will recognise the location of film.

- ***Kalman filter-***

Kalman filter was first publish in 1960 by R E Kalman, since then the kalman filter has been subject of research and application. By implementation to mathematical equation we can estimate the state of noise filter consist of number of inputs and outputs. It support estimate to past, future and present because it is powerfull in various aspects. As per Gaussian white noise the value is 0 for the mean the kalman filter assume the noise as measurement. The kalman filter filters the noisy measurements that are given to it to estimate the desired state. Due to the statistically optimal the mean-square estimation error minimizes.

It can be seen by inspecting that new observation is given the kalman filter does not look directly on any previous observation. Kalman filter is use to estimate the temperatures inside the heat exchanger.

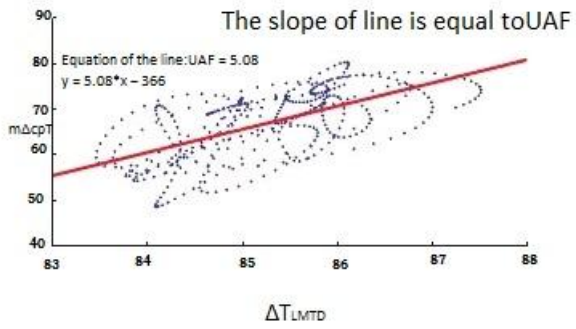
- ***Slope method-***

If the heat exchanger being investigated operates in a condition close to a steady state the most of the method may not work since they need frequent variations in the inputs to estimate the parameter of the model. therefore to overcome this drawback the method is specially design to monitor heat exchanger. The company Hitaveita Sudurnesja has the heat exchanger which works at almost steady state operation through there whole operating time. Such heat exchanger works at constant pressure and flow due to which usually cold side has constant temperature,but mass flow has some variations.

The heat transfer rate for parallel flow and counter flow heat exchanger in a steady state is

$Q=UAT_d$ LMTD=ṁkC_pT_dk

Where the subscribe k indicate either hot or cold side. For the cross flow heat exchanger it is necessary to calculate the value of F for the log mean temperature difference, T_dLMTD.




This method finds the fouling by calculating the slop AUF over a sliding window of size N from the plot in ΔT against ΔTLMTD. A typical plot can be seen in figure below by viewing the figure it can clearly be seen that there are strong correlations between observations by monitoring the slop for changes from the slop of a reference operation it is possible to find out when the heat exchanger start to build up fouling. As the slop decreases the more foul the heat exchanger is. Because of the correction it is necessary to have relatively long windows when estimating the slop to minimized the effect of the correct reference slop because the detection is done by comparing how the slop is changing with time to the reference slope.

## 4. FOULING REDUCTION

The degradation of heat transfer performance due to fouling in heat exchangers occur due to poor design. The general process to reduce the fouling is through proper design of heat exchangers and then through on-line reduction technique.

- ***Reduction of heat exchangers fouling by design-***

Heat exchanger fouling may reduced at design state through following steps:-

1- Selecting suitable heat exchanger type and geometry.

2- Design with adequate velocities that avoids hot spots, bypass flow or dead zones.

3- Design with proper cleaning.

These option can be extensively used to reduce fouling at the design stage.

***Compact Heat exchangers-***
For eg:- Plate and frame heat exchangers, Fin tube heat exchangers, etc have been found to experience reduced fouling due to increased level of turbulence, reduced surface temperature, and homogenous flow distribution.
***Scraped-surface heat exchangers-***
where rotating installations continuously keep the pipe internal surface free from deposits and their complex geometry and maintenance results in very less foiling.
***Fluidized-bed heat exchangers-***
is very effective which reduces or even eliminate the scale formation on many types of applications.

- ***On-line Reduction of heat exchangers fouling-***

The purpose of on-line reduction is to keep the heat transfer in a state of proper cleanliness to maintain high operating efficiency. The on-line reduction includes technique such as chemical, mechanical physical and change of operating conditions.

**1-CHEMICAL FOULING REDUCTION METHOD**
During On-line inspection, the most wise spread technique of reduction of fouling of heat exchangers is use of chemicals agents or inhibitors with complex geometries. Commercial anti-foulants are usually poly-functional and hence more versatile as they can be designed to combat various types of precursors that may be present in any given system. It is design to prevent equipment surfaces from fouling but are not effective in removing already formed deposits. Hence it should be start after equipment is cleaned. Continuous Chlorine used at 0.1 mg/l can reduced the aluminium tube fouling. The chlorinated Copper Nickel tubes shows a fouling Factor lower than chlorinated aluminium.
On line chemical reduction is effective but they contain substance like chorine, hypochlorite, polyphosphate, etc which are harmful to the environment. Fouling and corrosion inhibitors contain amount of chlorine, bromine, chromium, zinc etc which their concentration has to be mounted carefully. Higher concentration may lead to overdosing and have negative effects.

**2-MECHANICAL FOULING REDUCTION METHOD**

This method is boardly classified into two types such as

1. Brute force methods such as high-pressure jets, lances, drills etc.

2. Mild methods such as brushes and sponge balls. The following mechanisms predict the modern methods:-

a- Increasing shear stress at the fluid interface.

b- Reducing stickiness of the heat transfer surface.

c- Mechanical vibration of the heat transfer surface.

Mechanical reductionhave some advantages over chemical reduction methods, which involves materials which are difficult to handle and also to control. The utlilization of on-line mechanical fouling reduction may lead to reduce maintenance downtime, avoid of antifouling chemicals and more efficient plant operation.

**3- PHYSICAL REDUCTION TECHNIQUE**
It is used to reduce the fouling without changing heat exchangers layout, operation, or chemical additives by modifying the interaction of deposit forming precursors and heat transfer rate.
***Surface modification-*** Due to the environmentally friendly features there is increase in surface modifications . To reduce Fouling surface coatings with organic materials such as polytetrafluoroethylene (PTFE) have been used to reduce fouling.
***Sonic technologies***:-High- and low-frequency sound has used in heat exchangers for gases to dislodge and weaken particulate deposits which can be carried away by the process gas stream. But this can be very cost effective option.

**4-CHANGE OF OPERATING CONDITION**
***Filtration***- Fouling can be reduced by removal of contaminants. Therefore removal of materials such as sodium, sulfur, or vanadium from fuels prior to combustion and contaminant removal from combustion gases are two approaches to reduce gas-side fouling.
**Thermal Shock**- Overheating of the heat transfer surfaces leads to brittle deposit layers to crack due to the different thermal expansion of tubes and deposits.
***Intermittent changes in flow direction or velocity***:- There is increase of the flow velocity (flow pulsation) which is used to reduce the formation of weakly adhering deposits by regular reversal of flow direction and also at higher speed better performance is obtained.

**5. CONCLUSIONS**

As this paper throws a light on fouling detection and its reduction techniques; we have gone through a various number of fouling detection method and their usage;which totally depends on the application of heat exchanger. Also the methods by which its effect can be brought to a

minimal level has been exercised. At present, industries largely focus on their power losses in energy conversions and different related processes; also the economics associated with it, which can be a crucial factor in avoiding a considerable amount of losses. This paper gives an overall picture of fouling and can help further researchers by giving them a concrete information.

## 6. REFERENCES

[1] Pamela Springer, ``Measurement of thermal resistance due to fouling on heat exchanger."

[2] Ping Xu,Yajun Zhang, Xiadong Liu,Ting Liu,"Fouling in circulating cooling water system." 2012 Beijing.

[3] S N Kazi, "Fouling and fouling mitigation on heat exchanger surfaces."March 2012

[4] Er R.K Rajput,"Heat and Mass transfer".

[5] Jianhua Zhang, Luyao Zhang, Rui Wang, Guolian Hou,"Detection in heat exchanger using a billinear model-based parameters estimation method." 2015.

[6] Kern D Q,Seaton R E(1959)," A theoretical analysis of thermal surface fouling."

[7] Oddgeir Gudmundsson, Olafur Petur Palsson, Halldor Palsson, Sylvain Lalot," Methods to detect fouling in heat exchangers".

[8] Jonsson, G.R., S. Lalot, O.P. Palsson and Bernard Desmet. "Use of extended Kalman filtering in detecting fouling in heat exchangers." International Journal of Heat and Mass Transfer.

[9] Bott T R 2000."The fouling of heat exchanger."Heat transfer engineering.

[10] Peter M. Withers “Ultrasonic acoustic and optical techniques for non invasive detection of fouling in food processing equipment.”