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TUBE FAILURE PREVENTION OF HEAT EXCHANGER

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Abstract

This paper presents an overview on the remedial solution for the problem of tube failure in Heat Exchanger. In HOCL, a shell and tube heat exchanger is used in the production line of phenol. Hot oil at 328°C and 10.5 kg/cm^2 is passing through the exchanger tubes. SS316 material is used in the tubes. 120 tubes at the top of the heat exchanger fails regularly and hence the plant have to be closed down for at least 2 days on each failure. The failure causes loss of hot oil (Therminol) which cost approximately Rs 850 per litre. About 1cm drop in oil level costs about 5 lakhs. In order to overcome this problem, the failure analysis of Heat Exchanger is done, from which the various reasons behind the failure are found and remedial solution is suggested for the problem. The remedial solution includes the use of Incoloy tubes instead of Stainless Steel tubes, use of Kettle type of Heat Exchanger with hot oil inlet at bottom and the use of DTS strip in the tube bundle.

Keywords:

Failure;

Heat;

Exchanger;

Prevention;

Tube.

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1. Introduction

Heat exchanger may be defined as equipment which transfers the energy from a hot fluid to a cold fluid with maximum rate and minimum investment and running cost. The heat exchanger is used to reduce the temperature of one process fluid which is desirable to cool, by transferring heat to another fluid which is desirable to heat without inter mixing the fluid or changing the physical state of the fluid.

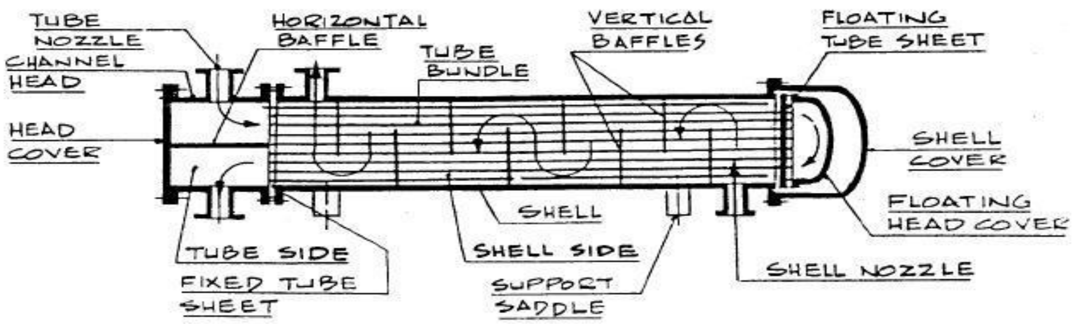


Fig.1 Components of Heat Exchanger

2. Problem identification

In HOCL a shell and tube heat exchanger is used in the production line of phenol. Hot oil at 328°C and 10.5 kg/cm^2 is passing through the exchanger tubes.SS316 material is used in the tubes. 120 tubes at the top of the heat exchanger fails regularly and hence the plant have to be closed down for at least 2 days on each failure. The failure causes loss of hot oil (therminol) which cost approximately Rs 850 per litre. About 1cm drop in oil level costs about 5 lakhs.

3. Causes of failure

Various causes behind the failure of heat Exchanger are given below:

(i) Vibration

Damage from the tube vibration has become an increasing phenomenon as heat exchanger sizes and quantities of flow have increased .The shell side flow baffle configuration and unsupported tube span are of prime consideration.

(ii) Overheating of 120 tubes at the top

In the shell and tube heat exchanger at the inlet (bottom of the shell) hydrocarbon is in liquid state. The inlet temperature of hydrocarbon is 217°c and outlet temperature is 229°c. The heating fluid hot oil called Therminol passes through the tubes. The inlet of hot oil is at top of the bundle and outlet is at the bottom. The inlet temperature of the hot oil is 320 °c and the outlet temperature is 270°c. If there is any obstruction or processing delay in the production line it causes the shortage of hydrocarbon supply in to the heat exchanger. During when the hot oil will be passed through the tubes and this converts the top hydrocarbon in bundle to vapor state. In the vapor state convective heat transfer (h) is less. This causes the top 120 tube to become overheat.

(iii) Lack of availability of heat transfer area

The actual area available for heat transfer is 148.36m^2 and the area required for heat transfer by the Heat Exchanger with Stainless Steel tubes is 150.1m^2. As the Heat Exchanger requires more area for heat transfer than the actual area available, so the failure occurs frequently.

4. Remedial solution

The remedial solution for this problem is found considering the various causes of failure as mentioned in the previous section. This remedial solution includes:

(i) Replace the Stainless Steel tubes by Incoloy tubes

Replace the Stainless Steel tubes by Incoloy tubes in which the chance of failure is less. The thermal conductivity of the Incoloy is 19.6w/mk but thermal conductivity of the Stainless Steel is 13.6w/mk, so the heat transfer area required is high in the case of Stainless Steel which is around 150.1m^2 but using Incoloy the heat transfer area required is around 147.6m^2. The actual area available for heat transfer is 148.36m^2. As the actual area available for heat transfer is more than the area required for the heat transfer by the Incoloy tubes, so the use of Incoloy tubes decreases the chance of failure.

(ii) Change the oil flow direction

As mentioned in the previous section that one of the cause of failure of Heat Exchanger is the overheating of the top 120 tubes of Heat Exchanger. This overheating of tubes is mainly due to the wrong direction of flow of the hot oil. Here the hot oil flow direction is changed. In existing condition hot oil is given at the top of the tube but in the changed condition hot oil is given at the bottom of the tube.

In the existing condition, the hot oil is given at the top of the tube. In this condition, the temperature difference at the top side is high. In the top side of the Shell and Tube Heat

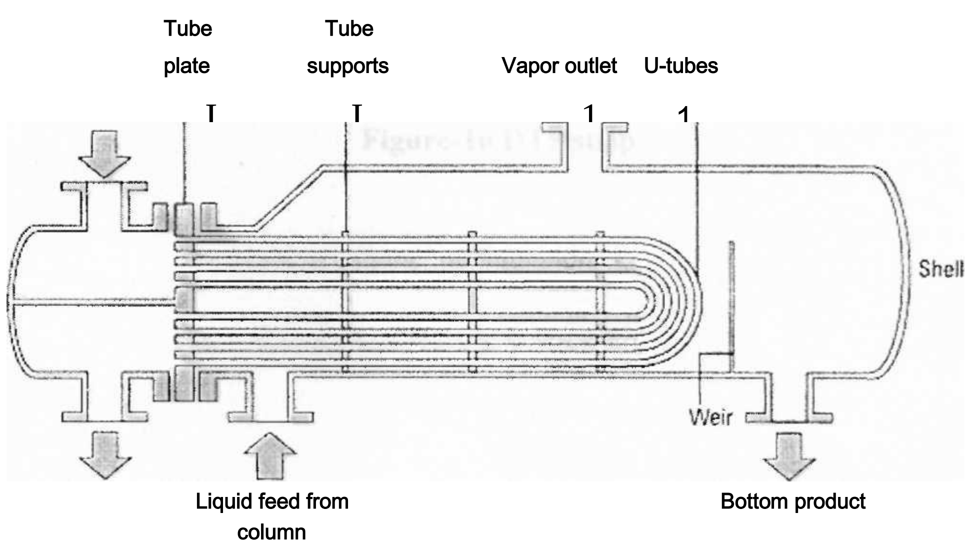
Exchanger vapor is present and the convective heat transfer coefficient of the vapor is less due to which the heat transfer rate is less and so, the overheating of the top 120 tubes takes place.

In the changed condition, the hot oil is given at the bottom side of the tube, due to this reason the temperature difference in the top side is decreased but the temperature difference in the bottom side is increased .The bottom side has the aromatic hydrocarbon in the form of liquid and the convective heat transfer coefficient of the liquid is high due to which the heat transfer rate is high and so, the high temperature difference in the bottom side does not affect the tube.

(iii) Use Kettle type Heat Exchanger

Shell and Tube Heat Exchangers are among the most widely used types of Heat Exchangers. Various Shell and Tube heat exchangers are designed for vapor generation on the shell side. They are widely applied in chemical, process, and energy power industry, in refrigeration and air-conditioning equipments, and they are applied as re-boilers, steam generators, and evaporators. It has been estimated that more than 50% of all Heat Exchangers employed in process industries are used to boil fluids and involve two-phase flow on the shell side. In process industry they are known as re-boilers, while kettle re-boilers are one of the most common re-boiler types. Also, some developments of horizontal steam generators for nuclear power plants are based on the kettle re-boiler design.

A typical design of the kettle re-boiler applied in the process industry is shown in fig.2. The evaporating fluid flows on the shell side, across a horizontal tube bundle. The heat is transferred to the boiling two-phase mixture from a hot fluid that circulates inside the tubes. The



liquid level is controlled by a weir, so that the bundle is always submerged in liquid. The gap between the bundle and the shell allows internal recirculation of liquid .The liquid enters the bundle at its bottom only. The mass velocity of fluid across the bundle is increased by the recirculation of liquid, affecting the global heat transfer coefficient.

Fig.2 Kettle type Heat Exchanger

(iv) Prevent vibration by using DTS strip

DTS Technology consists of dimpled and corrugated straight metal strips that are inserted into a heat exchanger bundle to reduce vibration by stiffening the bundle, as shown in figure, the corrugations on each strip act as a wedge to slightly deflect the tubes The dimples on each end of each thin strip provide a locking mechanism to hold the strip in place.

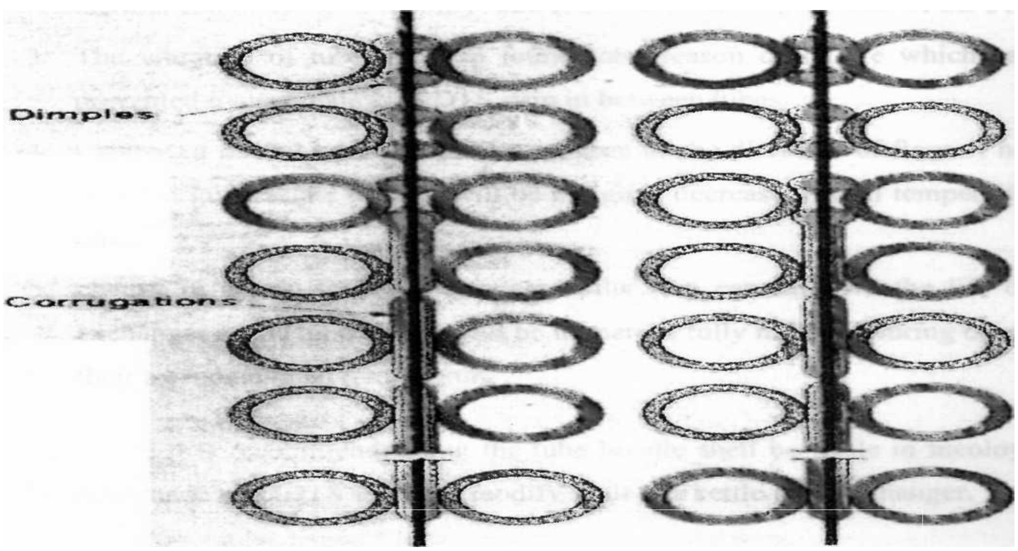


Fig.3 DTS strip installed in bundle

5. Result and discussion

The failure analysis of shell and tube heat exchanger at HOCL is done. From the analysis, various reasons behind the failure of this Heat Exchanger are found which mainly includes the lack of availability of heat transfer area and higher requirement of heat transfer area by the material used in the Heat Exchanger, vibrations in the equipment, and incorrect location of the hot oil inlet in the equipment, corrosion, wear and fatigue failure. Based on this failure analysis, a remedial solution is provided to the problem.

The remedial solution mainly includes the replacement of the currently used Stainless Steel heat exchange tubes by the Incoloy tubes, changing the location of hot oil inlet in the equipment, using Kettle type Heat Exchanger and using DTS strip to avoid the vibrations in the equipment. Comparative analysis is also done in the following tables which show that how these remedial solutions are effective.

Table 1: Comparison between Stainless Steel tubes and Incoloy tubes

Stainless Steel tubes	**Incoloy tubes**
1. Using Stainless Steel as tube material 2. Thermal conductivity = 13.6w/mk 3. Area required for the heat transfer = 150.1m^2 4. Actual area available = 148.36m^2 5. As the available area is less than the area required for heat transfer, so the failure occurs.	1. Using Incoloy as tube material 2. Thermal conductivity = 19.6w/mk 3. Area required for the heat transfer = 147.6m^2 4. Actual area available = 148.36m^2 5. As the available area is more than the area required for heat transfer, so the failure does not occur.

Above table shows that the use of Incoloy tubes in a Heat Exchanger in place of a currently used Stainless Steel tubes eliminates the chances of failure.

Table 2: Comparison of existing condition and changed condition of hot oil inlet

Existing condition of hot oil inlet	**Changed condition of hot oil inlet**
1. Hot oil inlet at top side. 2. Temperature difference in the top side = Hot oil inlet - Aromatic hydrocarbon at outlet = 320-230=90°c. 3.Temperature difference in the bottom side =Hot oil outlet–Aromatic hydrocarbon at inlet = 270-217=53°c 4. Temperature difference in the topside is high which overheat the top 120 tubes. 5. Temperature difference in the bottom	1. Hot oil inlet at bottom side. 2. Temperature difference in the top side = Hot oil out let - Aromatic hydrocarbon at outlet = 270-230=40°c 3.Temperature difference in the bottom side = Hot oil inlet- Aromatic hydrocarbon at inlet =320-217=103°c 4. Temperature difference in the topside is small. 5. Temperature difference in the bottom

side is less.	side is high, but the bottom side has aromatic hydrocarbon in the form of liquid so this temperature difference does not affect the heat exchange tube.

Above table shows that the change in the location of the hot oil inlet in the equipment eliminates the failure, as it avoids over heating of the top 120 tubes.

6. Conclusion

The failure analysis of Shell and Tube Heat Exchanger installed at Hindustan Organic Chemicals Limited (HOCL) is performed successfully. This Heat Exchanger is used in the production line of Phenol. The various reasons behind the failure of this Heat Exchanger are found from the failure analysis and the remedial solution is also provided to this failure. By using Incoloy heat exchange tubes the heat transfer area required is reduced as compared to that of Stainless Steel tubes. The location of hot oil inlet is changed from the top to the bottom of the equipment which eliminates the overheating of top 120 tubes and reduces the chances of failure. Vibrations in the equipment are reduced by using DTS strip in the tube bundle. Use of the Kettle type Heat Exchanger also reduces the chances of failure. Thus, with the elimination of failure, the productivity of the plant is increased as there will be no loss of hot oil (Therminol) and no chance of close down of the plant due to failure.

Therefore, it is recommended that the heat exchange tubes must be made of Incoloy, always use DTS strip in the tube bundle of Heat Exchanger and modify the shell of Heat Exchanger to the Kettle type of Heat Exchanger with hot oil inlet at the bottom.

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