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ELECTRO-HYDROMECHANIC CLEANING OF HARD DEPOSITS IN TUBULAR EXCHANGERS – FAST, SAFE AND EFFICIENT SISACO APPROACH

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ABSTRACT

Heat exchangers, quite often, are prone to fouling which requires them to be shut down from time to time for off-line cleaning. This must though be fast and efficient thus they can be put back into operation without a major stoppage as otherwise the plant in question will be subject to huge financial penalties. If the formed deposit is hard then mechanical objects such as inserts and drills or physical means such as ultrasound would be used to clean the tubes that have been clogged by deposits. This paper presents a new and innovative technique of using mechanical tools in combination with water hydro-jet for a quick and efficient cleaning. The advantages of the technique with respect to other off-line cleaning techniques such as those mentioned above will be discussed in terms of cost effectiveness, energy and time. An industrial case study is also presented in which the new cleaning technique is compared with combined approaches of chemical cleaning and water jet.

INTRODUCTION

Heat exchangers are the workhorse of most chemical, petrochemical, food processing and power generating processes. The global heat exchanger market is estimated to top a total of $12.7 billion in 2012 with an increase of 3-5% per annum [1]. Among many types of exchangers, approximately 55-60% of the heat exchanger market is still dominated by the shell and tube type heat exchanger (see Figure 1). It is largely favored due to its long performance history, relative simplicity, and its wide temperature and pressure design ranges.

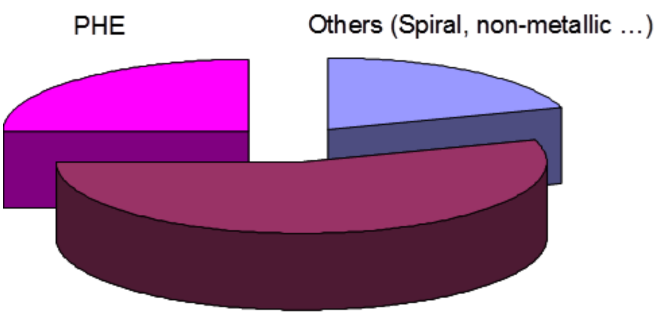

Figure 1 Various heat exchangers in industry.

Heat exchanger manufacturers are presently under increasing pressure to produce heat exchangers which are more efficient in terms of heat recovery and use of material, while at the same time being faced with fluids which are increasingly difficult to process. One major problem directly related to these requirements is the deposition of unwanted materials on the heat transfer surfaces, which occurs in the majority of heat exchangers [2]. Conservative studies estimated that heat exchanger fouling leads to additional costs in the order of 0.25% of the GDP of industrialized countries, and that it is responsible for 2.5% of the total equivalent anthropogenic emissions of carbon dioxide [3]. Moreover, The worldwide costs of fouling is estimated to be approximately B$60 per annum [3]. Therefore, efficient mitigation and cleaning methods must be available to safe-guard the operation of heat exchangers.

Figure 2 Typical clogged tubes of a S&T exchanger.

Cleaning techniques in general can be divided into on-line and off-line techniques. While the former is preferable in order make sure continuous operation of exchanger but off-line cleaning may be necessary in periodical basis, even if the heat exchanger is well-designed and the fluid treatment is satisfactory (see Figure 2). Furthermore, conditions in the heat exchanger may deviate from the design conditions due to changes in flow rates and temperatures, plant failures, and changes in the fluid composition or up-stream corrosion, which all may promote fouling. Therefore, efficient off-line cleaning methods must be available to safe-guard the operation of heat exchangers. For efficient off-line cleaning of heat exchanger the following general criteria must be considered before attempting any specific cleaning technique:

- Dominant fouling mechanism
- Severity of fouling
- Type of heat exchanger
- Extent of required cleanliness
- Cleaning costs
- Time intervals between cleaning cycles

The present paper reports on an innovative US patented technique of using the Sisaco electro-hydromechanic tool to clean the inner tube side of a partially or clogged tubular exchanger. The method is fast, efficient and safe especially designed to combat hard formed deposits. The device is also compared with other present off-line cleaning techniques.

EVALUATION OF PRESENT OFF-LINE CLEANING TECHNIQUES

If the formed deposits are hard then the utilization of off-line cleaning would be inevitable. Various off-line methods are available as categorized in Figure 3. Traditional intense mechanical and chemical cleaning technique may not only remove the deposit but also part of the protective oxide layer on the pipe surfaces. Under certain circumstances, this may create a corrosion problem. Regular cleaning removes deposit and avoids flow conditions, which promote corrosion due to chemical reaction or stagnant flow. On the other hand, in some techniques, i.e. drilling, the positioning of the tool is imperative which small deviation may result in tube damage. This may eventually require re-tubing or tube replacement. For very severe fouling problems, a combination of chemical and mechanical cleaning may be recommended.

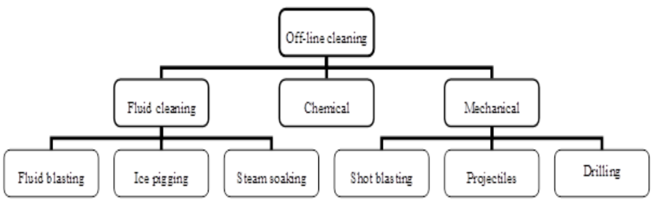

Figure 3 Categorization of various off-line cleaning systems.

Off-line cleaning is most pertinent to petroleum and chemical processing industries and mainly involves manual or semi-automatic cleaning at predetermined maintenance intervals. Although generally effective, these techniques do not mitigate the gradual performance degradation (due to fouling) between physical cleaning intervals. As a result most heat exchangers will operate at significantly less than peak efficiency.

In off-line chemical cleaning, problems may also arise due to the danger of handling chemical (burns, toxicity), due to elevated application temperatures, due to the costs of cleaning agents, due to the chemical attack on the heat exchanger material (over-cleaning, uneven cleaning, corrosion) and due to disposal problems. Acids and alkalis must be neutralized, organic materials may be burned and fluorides must be reacted to inactive solid residues. Some of the organic acids, such as citric acid and gluconic acid are biodegradable. Research on the mechanisms of chemical cleaning of heat transfer surfaces is far less developed than research on fouling mechanisms, even though similar approaches may be used.

SISACO ELECTRO-HYDROMECHANIC CLEANING TECHNIQUE

The present water jet blasting devices may require enormous amount of water and energy to clean an exchanger. It is also unable to clean the totally blocked tubes. The drawbacks also include inability to reach U-shape parts of bended tubes. Due to the applied high pressure, it may also damage the tubes. The Sisaco electro-hydromechanic cleaning technique contains a flexible tube with a rotatory tool to scrap and remove the deposit. The device comprises of various parts such as a power transfer shaft, a power generator, a power transmission means attached to the power generation part and the power transfer shaft, an electrical unit to generate a dynamic force, a liquid guidance system integrated to the power transfer shaft, a movement conditioner for the power transfer shaft; and at least one cleaning tool which is removable and is attached to the power transfer shaft. Furthermore at least one cleaning tool includes a predefined structure to convert a turning movement of the cleaning tool into a rotational movement of the power transfer shaft for cleaning of the deposits in the tubes without any damage to an internal body of the tube. The advantages of the technique include:

- Affordable - initial outlay is minimal and the cost of consumables is reasonable.
- Simple to use - little training or expertise is required.
- Requires only one operator (to reduce labour).
- Tubes are left thoroughly cleaned for better heat transfer.
- There are many models to choose from; ranging from simple, no-drilling machines to more advanced units incorporating mechanical shaft feed, bi-directional rotation, and variable speed.
- Most effective method for cleaning the newer chillers that use internally enhanced tubes (more on this later).

The cleaning device uses an electric motor to rotate a flexible shaft, which is encased in a plastic casing that transports water to the cleaning tool. Figure 3 shows the flexibility of the tubing while Figure 4 shows the removed deposits are disposed while the device is in operation.

Cleaning tools range from a variety of brushes to buffing tools, hones and scrapers. They can clean almost all types of deposits including hard scale. The specifications of the technique are enlisted in Table 1. The operator simply feeds the flexible shaft through the tubes to brush and flush in one operation.

Table 1 Specifications of Sisaco electro-hydromechanic cleaning device

Specification	Range
ID of fouled tubes	10 – 100 mm
Deposit thickness	clogged tubes
Power	3 kW
Tube substrate	SS, Cu
Max. length of fouled tube	20 m
Weight of device	170 kg
Cleaning rate of fouled tube	0.5 – 5 m/min

Figure 3 The Sisaco electro-hydromechanic cleaning device in operation highlighting the device flexibility

Figure 4 The Sisaco electro-hydromechanic cleaning device in operation highlighting the disposal of removed deposits.

CASE STUDY

An industrial case study was attempted to examine the functionality of the Sisaco electro-hydromechanic cleaning technique. In the study, the device was used to clean a totally clogged E101 exchanger in Arak petrochemical complex. The deposit was polymeric and very hard. To rigorously characterize the functionality of the device, its performance was compared to previously attempted technique of combined chemical and water jet cleaning. As for the combined chemical cleaning with water jet, benzene was selected as chemical solvent with known detrimental impact on the environment, in the quantity of 4000 liter. The solvent was applied along with hot steam to transform firstly the rigid and hard deposit into a soft one. The following time span was required to clean the inner surface of the tubes.

Hot steam to soften the hard deposit	8 days
Mechanical perquisites for water jet application	2 days
Water jet cleaning	4 days

Under such circumstances not all tubes were even cleaned and some had to be replaced. The Sisaco electro-hydromechanic cleaning device was managed to clean the tubes only in 15 hrs with a price of 30% compared to the combined technique of chemical and water jet cleaning.

COMPARISON TO OTHER OFF-LINE CLEANING TECHNIQUES

An efficient off-line cleaning approach is ideally characterized by the following criteria:

- Simple operation
- Maximum cleanability
- Minimum damage to the tube
- Low labour intensive
- Safety issues and minimum risk
- Easy portability
- Easy maintenance
- Low consumption of utility resources i.e. water and energy
- Environmentally-friendly feature
- Flexibility to clean partially blocked or clogged tubes
- Flexibility to clean tubes of various diameters
- Flexibility to clean U-shape tubes
- Low costs

Mechanical cleaning systems such as water jet systems, pneumatic hydro milling and abrasive bullet are contrived for cleaning blocked pipes/tubes. However these methods have several potential drawbacks. Faults/defects of these methods include impossibility of direct cleaning completely or half blocked pipes with bends thereby causing probable damage of pipes/tubes and water jets with higher pressure. Also these methods are not flexible for the existence of rigid pipes/tubes transmitting force, the breakage of drill and damage of internal casing of pipe/tubes are more likely during the smashing of stiff/hard or elastic sediments.

In the meantime, as the size of water vents is too small, the vents are immediately blocked with the increased volume of sediment or fouling so that the increased in the friction and the thermal tension at the tip of means contributes to the breaking speed of the drill and damages the pipes/tubes. Since the kinetic force system could not be controlled, a small conflict, occurred at the tip of the cleaning drill with sediment, imposes a considerable tension to the tip of the instrument and causes breaking of the tip leaving it inside the pipe/tubes, thereby distorting the cleaning function. Moreover, these tools are by no means applicable in case of half-blocked and completely-blocked pipes/tubes, hard and dendrite sediments. The functionality of the Sisaco technique compared to other methods is presented in Table 2 while environmental comparison is made in Table 3.

Table 2 Comparison of mechanical functionality of the Sisaco technique with respect to other off-line cleaning methods.

Methods	Mechanical	SISACO Technology	Chemical
Equipment	Water jet	Hydro mechanics	....
Cleaning quality	Average	Excellent	Average
Cleaning rate	Average	High	Low
Equipment safety	Average	Excellent	Low
Equipment damage	Yes	No	Yes
Energy consumption	High	Low	Average
Possibility of cleaning U-shape tubes	No	Average	Yes
Water consumption	Too high	Average	High
Cleaning of blocked tubes	No	Excellent	No

Table 3 Environmental Comparison between Sisaco technique and other methods

Methods	**Mechanical**	**Sisaco Technology**	**Chemical**
Machine	Water Jet	Hydro mechanic	……
Pollution of Surface and Ground Water	No	No	Yes
Human Resources Health and Safety	Low	High	Low
HSE Total Technology Advantages	70%	95%	10%

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Declaration: The Sisaco electro-hydromechanic cleaning technique is a US patent under US 2010/0263140 A1