Field report: cleaning of shell & tube heat exchangers

Looking at some ways to clean heavily soiled shell & tube heat exchangers, with an assessment of the advantages and disadvantages of these methods.

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Heat exchangers are essential components in many process systems. In order to realise the maximum potential of the processes using heat exchangers, an optimal design and construction, as well as a perfect selection of all relevant components during the manufacture of the heat exchangers are essential [1, 4].

The majority of exchangers that are used are plate heat exchangers (PHE) and shell & tube heat exchangers (STHE) [2]. STHE are robust in structure. They allow large volume throughputs and they function optimally with larger temperature differences, and are preferred over PHE when these conditions are met.

Soiling in heat exchangers reduces heat transfer rate

In heat exchangers, physical and chemical processes such as sedimentation, crystallization [3], chemical reactions, corrosion, biofouling and a combination of these processes lead to soiling. These factors reduce the heat transfer rate [4] and can become extremely critical by forming hard crusts and clogging to the inner tubes.

The degradation of the heat transfer rate leads to technical problems in the processes, which finally result in financial disadvantages. Despite this, system diagnostics to determine when to clean a heat exchanger are not common.

To improve the current situation Prof. Dr.-Ing. Bernd Sankol of the Department of Mechanical Engineering and Production Management at Hamburg University of Applied Sciences (HAW), and of the Fraunhofer Institute for Factory Operation and Automation (IFF) in Magdeburg propose to evaluate methods to analyse the efficiency of the heat transfer units during operation [5].

This approach allows the performance of different cleaning systems for heat exchangers to be compared.

The company, Algorithmica Technologies GmbH has produced a method, which is able to predict the operating time of a shell & tube heat exchanger before a critical degradation takes place. After undertaking a sample of measurements, the method derives the degradation of the heat transfer and provides an estimated operating time before a cleaning is absolutely required. He intends to cooperate with Univ. Prof. Dipl.-Ing. Dr. Techn. Michael Harasek from the Technical University of Vienna, Austria, Research Department on Thermal Process Engineering and Simulation.

In this context, the method produced by the Hexxcell Studio™ [6] is of interest. This method guarantees extended monitoring, predictive analytics and prescriptive maintenance for industrial heat transfer systems.

Measures to ensure the required heat transfer rate

In many cases, a critical degradation in a heat exchanger system cannot be permitted and an overhaul or cleaning is required. The cleaning methods preferred for cleaning STHE are described in detail in the literature [1, 4, 7].

It is not possible to clean soiled STHE during operation. The use of special technical solutions can reduce the tendency towards soiling.

This can be achieved, for example, with the use of ultrasonic heat exchanger clean-in-place technology [8], but

$$\dot{Q} = k * A * \Delta\vartheta_m = \dot{W}_1 * (t'_1 - t''_1) = \dot{W}_2 * (t''_2 - t'_2)$$

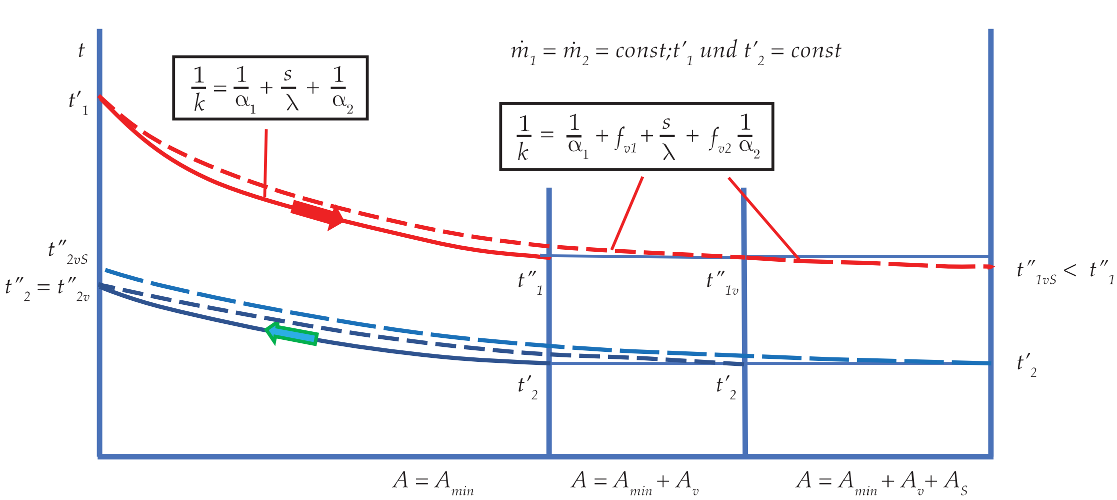

Fig. 1. The influence of soiling and the temperature profile in heat transfer units. (Photo courtesy of Hamburg University of Applied Sciences, Prof. Dr.-Ing. Sankol.)

Fig. 2. Scheme of ultrasonic cleaning of a shell & tube heat exchanger. (Photo courtesy of ORANGE Cleantech Inc.).

also with other precautions [7]. Solutions implemented on a standing STHE also gives very good results [9]. Taking into account the different flows that work within a STHE, as well as the different flow velocities and the prevailing temperatures, the use of vibrating fixtures in the inner pipes and the use of wash-out balls during operation is also possible [1, 7, 10].

The cleaning of soiled STHE requires a shutdown of the STHE and often also interrupts plant operations.

One way to clean a STHE without having to dismantle it, is to flush the pipes inside and outside with cleaning fluids. These cleaning fluids work biochemically [11] or chemically as well as physically [8, 12].

Fig. 3. Cleaning with (HPCT). (Photo courtesy of Hamburger Abendblatt / Jörg Riefenstahl).

A selection of methods for cleaning dismantled STHE are described below. The cleaning of the STHE is very often carried out by external service providers, who are often contractually bound to the operator in a long-term contract.

Most cleaning service providers use high pressure cleaning technology [HPCT] to clean contaminated STHP.

The outer surfaces of the tube bundles are mostly successfully cleaned with HPCT. If there are hard crusts and clogging in the inner tubes of the STHP, cleaning with HPCT is a challenge.

Usually HPCT uses water, or in some cases, chemical additives dissolved in the water. Other methods use dry ice or special granules for cleaning [13]. These methods are very useful when water has a negative impact on the cleaning process. The methods also take a long period of time in which to achieve acceptable cleaning results. The workload of those performing the cleaning task is similar for that of those who apply the HPCT cleaning process.

Because of the poor cleaning performance with the HPCT in the presence of hard soiling and blockage,s and other disadvantages, a drilling method has emerged as a way out.

An alternative cleaning process for heavily soiled inner pipes of the STHE

There has been a great deal of concern expressed about the use of drilling solutions to clean the inner tubes because of the possibility of damaging them. With the Rädler Tube Cleaning process (RTC) [14], this negative effect can be completely avoided.During cleaning, the drill bit, inserted into the pipe, is kept away from the inner surfaces of the pipe by a guide ring and the water emerges from the guide ring at 2 bar. This absorbs the detached dirt. The water and the dirt are forced to flow between the guide ring and the inner surface of the tube in an opposite direction to the movement of the drill [15]. The friction between the inner tube surface and the guide creates a very clean surface for the inner tubes.

Fig. 4. Cleaning the inner tubes of two dismantled tube bundle heat exchangers using the RTC cleaning method. (Photo courtesy of AC Rädler Umwelttechnik GmbH.)

In practice, the high cleaning quality achieved with the use of RTC leads to an increase in the operating time between overhauls.

The remaining sediments on the surfaces of the inner tubes and unremoved closures from a less effective cleaning result in a rapid increase in pollution and an increase in the number of closures. This leads to a situation where cleaning the pipes at shorter time intervals is required. This is followed by a total thermal breakdown and finally scrapping.

When using the RTC method, the environmental impact and the workload of operators are significantly lower. There are no safety risks. Because this drilling process can only be used to remove hard crusts and clogging in straight pipes, the pipe elbows connecting the pipes or the hoods (chambers) of the STHE must be cleaned by other cleaning processes.

Another cleaning process is offered under the name Thermo-Clean cleaning process (TCCP) [16] and is characterized by its ability to be applied universally, regardless of the design of the STHE or other apparatus which has to be cleaned.The Thermo-Clean process guarantees a high cleaning quality, especially when organic hard crusts and closures are present. The STHE needs to be disassembled for cleaning by the TCCP method and needs to be transported to a furnace chamber. The STHE are heated in a controlled manner in a low-oxygen environment and slowly heated up to a maximum of 450°C. During this process, any contamination is broken down by chemical and physical processes. The organic components are gasified. After the STHE has cooled down, loose dust may be present on the surfaces, consisting of pigments and inorganic fillers. This is about 1–5% of the original amount of dirt. This dust can be removed easily with compressed air or with other cleaning methods.

Another high-performance cleaning process, developed in Canada is available under the name TECH SONIC'S Cleaning technology [17] and is successfully used in Canada and the US. In this technology it is necessary to remove the tube bundle of the STHE and place it into an external cleaning system.

The tube bundle is completely immersed in a cleaning liquid. The tube bundle and the cleaning fluid are exposed with ultrasound. According to the provider, the contamination is removed very reliably.

Conclusion

Since the cleaning success of the STHE is usually not measured, operators often accept a poor cleaning quality

Fig. 5. The oven chamber can be moved into the STHE for cleaning. (Photo courtesy of JMC Company NV B Thermo-Clean-Group)

Fig. 6. Immersion pool –cleaning the STHE with ultrasound. (Photo courtesy of TECH SONIC.)

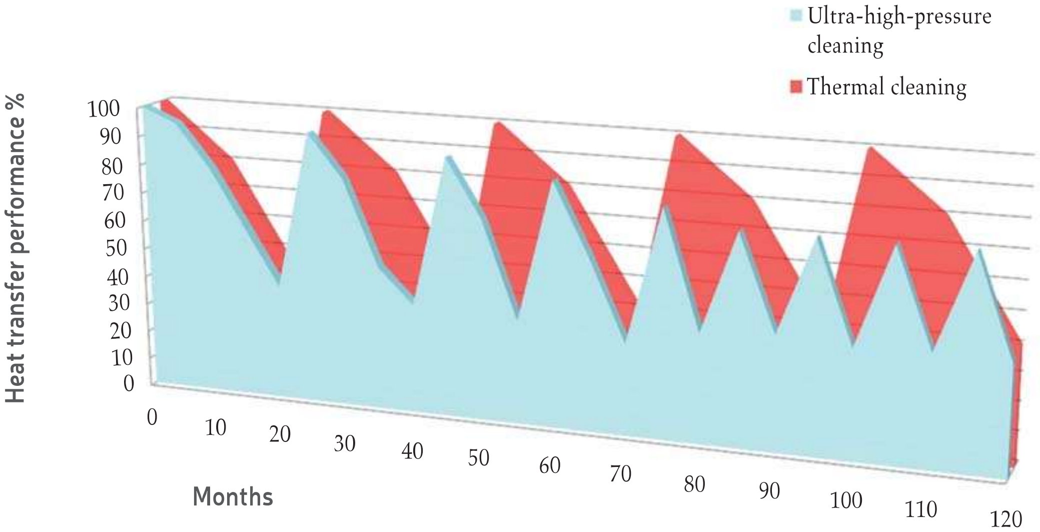

Fig. 7. Representation of the effect of effective cleaning on the service life and the frequency of cleaning – a comparison of thermo-clean and high-pressure cleaning processes. (Photo courtesy of JMC CompanyNV B Thermo-Clean Group.

because of the economic pressure of time. However, poor cleaning shortens the time intervals of periodic cleaning until the STHE is replaced because the required heat transfer is not guaranteed. Qualified cleaning, with a process that guarantees high cleaning quality, has been proven to extend the service life of STHEs.

This Field report enables operators of STHEs to influence the design and execution of the STHE before purchasing it if the process is expected to cause contamination.

Moreover, the reference to available cleaning methods enables the operators of STHE to influence the service providers in terms of providing an economically and technically advantageous cleaning for the operator.

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