OPTIMISED HEAT EXCHANGER MANAGEMENT - ACHIEVING FINANCIAL AND ENVIRONMENTAL TARGETS

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ABSTRACT

The Cleaning System:

An advanced cleaning system, named RTC, achieves high efficient inner tube cleaning of heat exchangers. It uses a drilling process, predestined for careful removal of all kinds of fouling up to shiny inner tube surface – even, from tubes fully blocked. It works fast without manual effort and without danger for the operating personnel. It achieves efficient tube cleaning, short cleaning time, easy handling and low cleaning costs. Therefore it will be more economically to clean in shorter intervals than usual.

In this way it is possible to enhance exchanger function by reducing production losses, corrosion failure, pump pressure, tube repairs, and to exceed heat exchangers life time and to reduce plant emissions.

The Software:

The simplest way to reduce operating costs is to reduce efficiency loss by fouling due to economic cleaning interval. In cooperation with the Technical University of Vienna, a program was developed for fouling prediction by computing most economical interval of cleaning. Losses of tube efficiency become immediately apparent in monetary terms. It advises short cleaning intervals to avoid high efficiency losses.

1. COST ISSUES AND TECHNICAL PROBLEMS IN CONNECTION WITH FOULING

Reduced exchanger performance due to deposits

Fouling always leads to a reduced heat exchanger performance, even if deposits are thin. Studies carried out at a combined heat power plant have proofed that limestone deposits of 1 mm double the normal energy consumption. New deposits are often built up after only 3 to 5 days.

If the pipe cross section is reduced, the pump pressure will increase to achieve the desired throughput rate. Both the lower thermal conductivity of the exchanger pipes, caused by deposits and the increasing pump pressure, reduce the contact of the medium with the pipe walls. More heat in the system causes a rise of jacket temperature, which leads to accelerated fouling and exponentially efficiency losses.

Maintenance costs

The maintenance costs are determined by the specific costs of cleaning (equipment, labour and service charges), the downtime costs and costs of purchase and disposal of cleaning and conditioning agents (acids, bases) if used.

These costs can be reduced by using high quality cleaning methods which completely remove fouling, at least for some time.

The RTC cleaning method (Fig. 1-4) works significantly faster even if tubes are badly blocked with very hard deposits. With conventional cleaning techniques e.g. high pressure cleaning often it is not possible to clean such tubes.

Figure 1. Fully blocked tube, going to be recovered

Figure 2. End of tube – after efficient tube cleaning
A comparison test at LENZING AG, later on described, showed a reduction of cleaning time of almost 90%.

Figure 3. End of tube, showing drill bit before breaking through

To optimise cleaning intervals means determining the time at which the cleaning costs correspond to the accumulated performance loss of the exchanger unit. If cleaning is postponed beyond this point, the operating costs rise significantly. In general, heat exchangers should be cleaned according to economical calculations and not to a given date like time of repairs or insufficient operation. A long interval causes high energy losses. The usual approach to extend cleaning intervals as long as possible to reduce downtime is not reasonable if cleaning time is short.

Another argument for frequent cleaning is the easy and safe operation with the RTC.

The later on described optimisation programme allows predicting energy losses caused by fouling and shows that short cleaning interval for exchanger is more reasonable.

The possible reduction of emissions for environmental and cost reasons is also an important issue in the EU. To reduce energy demand is contributing to the implementation of the Kyoto Protocol for the reduction of greenhouse gas emissions.

Industry may contribute to the reduction of emissions by improving the performance of heat exchangers.

Figure 4. Cleaning equipment in operation: Upper part cleaned, lower part showing deposits

No need for heat exchangers for chemical pre treatment with acids or bases.

In order to eliminate blockages in heat exchanger tubes, the units are often treated with chemical solutions for a time of several days up to some weeks. Afterwards remaining layers have to be removed conventionally.

The RTC drilling process removes any tube blockage within a short time and without leaving residues. Chemicals do not need to be purchased, stored and disposed of, and no dangerous chemicals have to be handled at the plant further. This is a real cost benefit.

Smooth exchanger tube surface postpones start of fouling.

Tubes treated with chemicals or high pressures cleaning remain with a rough inner tube surface. This leads to early growing of tube layers. The RTC not only totally removes blockages, it also provides special brushes to polish inner tube surfaces. So it is possible to regain smooth surfaces (Fig.6).

Efficient cleaning end up with over dimensioning

It is very usual to design oversized exchangers of 30% to 40%, or even more. Purchasing cost of heat exchangers are increased up to 25% and higher by this.

Some reasons for managers to order oversized exchangers are;
1. To hold a reserve on capacity for peak of performance.
2. To hold a reserve on capacity to compensate reduced capacity caused by fouling layers.
3. To compensate capacity losses by blocked tubes or by tubes with corrosion failure.

Choosing an efficient and cost effective cleaning system, oversized exchanger design can be reduced to minimum requirements. Hereby the investment for exchangers could be reduced. Best option would be to decide on a cleaning system in the planning process.

It might be worth considering installing two heat exchangers parallel with the total capacity of a single unit. Whereas one exchanger is doing its operational work, the other can be cleaned. Although the investment costs for two exchangers are higher than for one, the extra costs will easily be compensated by the gain of efficiency. Exchangers regularly cleaned at short intervals show less corrosion, and less efficiency losses. Efficiently operating heat exchangers contribute to improved operational work of connected equipments like pumps and others.

2. CLEANING TECHNOLOGY

The RTC technology is based on a drilling process with hydraulic forwarding and pneumatic rotation (Fig.5). The drill bit is a real alternative to high pressure cleaning, or
cleaning with rigid lances. Our company was primarily motivated to create a new technology by serious accidents to personal using high pressure and damages to pipes caused by lances.

Figure 5. RTC cleaning system with guide for easy and safe handling

This system replaces the cleaning lance with a pneumatic drilling process that chips away all deposits from inner tube walls without damaging them. Pressurised water (12 bar) is used for the hydraulic operation of the cleaning probe and for cooling the drilling process. The work does not require any manual force and does not cause any danger to operation staff.

The water pressure of 12 bar of the RTC do not stress the tubes mechanically as known from high pressure cleaning, which sometimes lead to hairline cracks.

The chipping process removes all deposits, including hard and caked residues, viscous fouling layers and quickly opens up tubes which are 100% blocked.

Figure 6. Full efficiency with shiny tube surface, right tube lightened

The technical equipment consists of the following parts:
1. Positioning and guiding device for horizontal and vertical installation (Fig.5, Fig.7)
2. Cylinder, hydraulic tube, main part for cleaning
3. The probe which can be equipped with a drilling bit or with brushes (steel, copper or polyvinyl) for removal of layers and/or for tube polish.

Application:
1. Direct horizontal or vertical positioning at heat exchanger unit or at a separate cleaning station
2. Suitable for pipe diameters from 12 to 55 mm
3. Suitable for exchangers from 1 m to 12 m length
4. Space required in front of or above the exchanger: Length of exchanger tubes + 1 m
5. If there is only little space near the exchanger, specially parted probes can be ordered
6. If it is necessary to clean several exchangers of different lengths the job can be done with the same device. In such cases, we recommend a length of cylinder that suits the length of the most common units at the site and using accessory equipment to adjust it to shorter or longer exchangers.

Operation Energy:
1. Compressed air (8 bar) for the rotation of the cleaning probe
2. Electric power (3.5 kW/h) for the water pump
3. Water Consumption (6 l/min for cleaning), total water consumption 16 l/min

Advantages:
1. Low consumption of; water, air, electricity
2. Extremely safe for employees due to low water pressure
3. Cleaning work is done in normal work clothing and without any physical force
4. Cleaning operation is done by the equipment without manual effort
5. Workplace remains clean, as the removed particles are collected in a container.
6. All kinds of residues are smoothly removed like hard and viscous deposits, biological fouling and micro deposits

Figure 7. Vertical cleaning of evaporators (producing Milk Powder)

3. EXPERIENCES
The RTC manages to remove any kind of contamination easily, like micro deposits using brushes, or hard deposits and blockages using a drill bit. The drilling head diameter corresponds to the inside diameter of the exchanger tubes minus 0.2 to 0.5 mm. The precision drilling head ensures that the tool is automatically centred in the tube and is
guided by the tube itself. Exchanger tubes bended out of shape up to 10° can be cleaned without any difficulties. The drilling head is guided well by the tube without damaging the tube wall.

Examples of operation:
Thanks to this cleaning system, the oil refinery SLOVNAFT in Bratislava, Slovakia, has been able to clean blocked heat exchangers which had been already written off. The exchanger was working again at full capacity. The company was saving about EUR 400,000 per year. This was only the price for not ordered new exchangers.

The SALINE WATER CONVERSION CORPORATION in Jeddah, which operates a number of desalination plants in Saudi Arabia, was able to recover a titanium exchanger that had become unusable. It was successfully cleaned with the RTC, and the extremely hard deposits (mainly consisting of calcium sulphate) were completely removed in short time without any chemical pre-treatment.

The Austrian fibre producer LENZING AG was able to reduce cleaning time for a mother liquid pre heater from 72 hours (cleaning with high pressure equipment) to 8 hours cleaning time with the RTC.

At BOLIDEN AB, a Swedish copper electrolysis plant, the graphite exchangers had become unusable due to deposits. As no suitable cleaning method could be found, the company decided to demolish and rebuild the plant. A test cleaning series with the RTC was so successful that the company changed its plan. Prior to the first cleaning procedure, the exchanger performance was measured and analysed with a computer. The unit's steam consumption was 10 tons per hour at a jacket pressure of 2.5 bar before cleaning. After cleaning, the steam consumption dropped to 1 ton per hour, at a jacket pressure of only 0.5 bar. Low jacket pressure prolongs the life of graphite exchangers. In this way the exchanger who has been successfully recovered was in operation for another 18 years. Also the cleaning interval due to more viscous residues was reduced from 2 months to each 14 days. This was possible because cleaning can be done quickly and easily by a single worker.

4. APPLICATION IN DISTRICT HEATING PLANTS
Continuous cleaning solutions like the use of cleaning balls which are brought into the media flow to prevent the formation of deposits in pipes for a certain period of time, are sometimes risky as these balls become jammed in the pipes, leading to complete blockage. Therefore, even with continuous cleaning, the exchanger pipes need to be cleaned by a conventional method at least once a year. The balls otherwise cannot move through the system properly. When comparing the initial costs and operational expenses of continuous cleaning systems to the RTC method, it is often the more cost effective solution. Only the space required for the equipment in front or above the exchanger might be considered as a disadvantage.

District heating systems and domestic combined heat and power plants
The transfer capacity of heat exchangers greatly affects the energy efficiency of district heating systems. A reduced temperature gradient, caused by deposits, is often compensated with a higher volume flow in the heating system network. The pumps must be run at a higher output level, consuming considerably more electric power. According to fluid kinetic laws, the electric power consumption of pumps increases by the third power of the volume flow rate.

Generally, the higher return temperature is caused by deposits in the heat exchangers at the transfer stations.

In domestic combined heat and power plants, the demand for heat and energy fluctuates with the seasons and the hours of the day. Deposits occur most often during the times of low demand. In many cases, these deposits grow quickly, forming layers inside the tubes. These layers generally consist of corrosion products; calcium carbonate and other solids contained in the water and can only be removed mechanically or with special solvents.

In district heating systems (e.g. at heat transfer stations) the use of an RTC can help to save money, increasing the energy efficiency of the system. Both the suppliers and the consumers of hot water earns the benefit of lower costs.

5. OPTIMIZATION SOFTWARE
In addition to the cleaning method AC-Rädler provides a simulation program for the prediction of fouling behaviour. By using this program, exchanger efficiency loss due to fouling layer and the increase of fouling during operation time is pointed out. Therefore manager in charge are able to choose a cleaning interval that avoids unnecessary costs due to inefficient heat exchanger operation. With this tool they are enabled to define cleaning intervals based on financial criteria.

Figure 8. Start window of the Optimisation Software

Following specific data are used for calculation:
1. Geometry of exchanger (Fig. 8)
2. Medium: inside and outside
3. Monetary value of production
4. Cost of stand still, time of maintenance
5. Cost of different cleaning methods
6. Cost of investment

**Optimised heat exchanger management, to reach budget and emission targets.**

The program is predicting accumulated exchanger efficiency loss due to fouling as diagram in monetary value. These figures are providing a sound basis for decisions and further calculations like:
1. Economical planning of cleaning interval
2. Comparison of exchangers operation costs of different cleaning methods including costs for downtime and cleaning work.

To maintain heat exchangers according to the fouling prediction - energy consumption, pump pressure, tube corrosion - can be reduced and plant harmonization be improved.

**Example of calculation:**

The example below (Fig. 9) refers to a heat exchanger in a combined heat and power plant, operated as a counter flow unit, with a primary circuit temperature change from 150°C to 110°C, and a secondary circuit temperature change from 70°C to 90°C.

Figure 9. Loss of capacity, reduction of volume flow

**Efficiency loss in Monetary Value:**

Figure 10. Capacity loss in Monetary value according to operation time and increase of fouling.

After 40 days of exchanger operation, losses reached 1500 Euro, which is the prize for a cleaning with the RTC equipment, including all costs of work, amortisation of equipment and costs of stand still. So it is obvious, that cleaning should be done after a period of 40 days, which means in this specific case, 9 times a year.

The calculation shown in Figure 10 makes clear, that too little attention was paid to exchanger operation efficiency. Losses of efficiency rose to the amount of Euro 17.000 in 140 days. This was caused by a fouling rate of 0.01 mm/day of calcium carbonate in a 14 mm tube diameter reduction.

As company success is influenced by direct savings on energy, resources, emissions and indirect savings like plant protection, less repairs, enlarged plant usage, improved plant maintenance become more and more important for company managers.

Efficient cleaned heat exchangers are contributing to the realisation of Kyoto targets too.

**6. CONCLUSION**

The described cleaning solution using a drilling system and the optimisation software gives new advantages for optimised heat exchanger cleaning and management. With these tools managers are able to:
1. maximise the exchanger output rate
2. reduce the operating costs and to save energy
3. increase the service life and reliability of the exchanger and connected equipment
4. reduce emissions

In many cases this cleaning method is more successful and efficient than other methods.

The optimisation program shows clearly, that in most cases, it is efficient to clean in shorter intervals than usual for saving energy and costs. In the EU energy efficiency and low emissions are issues gaining importance, both in relation to costs and to environmental aspects. Efficiently cleaned heat exchangers contribute to the implementation of the Kyoto Protocol.