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Report

Scaling in heat exchangers for wastewater from pulp production– solutions for Asia Symbol, Rizhao, China

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Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
United Nations Building
Rajadamnern Nok Avenue
Bangkok 10200, Thailand

Edited by:
Dipl.-Ing. Peter Renz, Dr.-Ing. Marius Mohr
Fraunhofer-Institute for Interfacial Engineering and Biotechnology (IGB)
Nobelstrasse 12, 70569 Stuttgart, Germany

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1 Background

Asia Symbol (Shandong) Pulp & Paper Co., Ltd. is operating a large pulp and paper factory in direct vicinity to the city of Rizhao, Shandong province. Pulp and paper production has a great demand for water and heat, therefore a sustainable management of these streams is an economic and ecological necessity. Part of this sustainable management is the utilization of heat in wastewater streams. As pulp wastewater often contains high concentrations of salts which precipitate when the water is cooled down, scaling in heat exchangers is a common problem.

There are two wastewater streams coming from the bleaching process in the pulp production line, an acid one and an alkaline one. They are cooled down by heat exchangers from 55°C to 40°C. After that these streams are mixed together and treated in an aerobic wastewater treatment process followed by a Fenton process.

Basic data:

Acid water: 20,000 m^3/d, pH 1.8-2.5

Alkaline water: 20,000 m^3/d, pH 10.5-11

COD (Chemical Oxygen Demand) in both streams: 2000 mg/l

Currently, plate heat exchangers are used (figures 1 and 2), but the precipitating salts ($CaCO_3$, $Ca(OH)_2$) regularly form a compact and resistant layer on the surface of the heat exchangers (scaling). As a result the effectiveness of the heat exchangers is reduced, so they have to be cleaned up to four times per month.

Figure 1: Plate heat exchangers in Asia Symbol Pulp and Paper factory in Rizhao

Figure 2: Plate heat exchangers in Asia Symbol Pulp and Paper factory in Rizhao

2 Main parameters affecting scaling in heat exchangers

Fluid velocity

The higher the fluid velocity in a heat exchanger the lower are the Fouling rates, due to increasing shear stress and appearing eddies. Both, deposition and removal rates are affected [1].

Temperature and pH

Scaling is a result of fluid supersaturation of inorganic salts. If the saturation ratio is reached precipitation appears. In case of scaling the main components are salts of calcium. An increasing fluid temperature causes a lower carbon dioxide concentration in the fluid and consequently the pH rises. With an increasing pH the supersaturation of calcium salts is at a lower value. Consequently precipitation appears earlier [2].

Surface roughness

A greater surface roughness is supposed to provide "nucleation sites" where initial deposits can lay down more easily. Areas with deviating flow velocities and turbulences occur that strengthen this effect. A better surface finish has been shown to influence the delay of fouling and also ease cleaning [1].

Impurities and suspended solids

Solids can either act as a promoter for fouling by initiating the deposition process by seeding or have a scouring effect by reducing or removing the deposits. This is depending on the kind of solid and often forms the basis of antifoulant chemicals [2].

Design

In case of tube heat exchangers the fluid with higher risk of scaling should be placed on the tube side because flow velocities are higher and cleaning is easier. Plate heat exchangers should have a high rate of turbulences, absence of stagnant areas, and a homogenous flow velocity [1].

3 Operation of heat exchangers under scaling conditions

If strong scaling in the heat exchangers is expected the choice of a proper construction of the heat exchanger is an important point. In case of plate heat exchangers the distance between the plates should be large enough to tolerate a distinct fouling rate. The same tolerance for fouling has to be applied for tubular heat exchangers by increasing the diameter. The resulting loss of heat transfer capacity must be compensated by additional heat transfer surface. As mentioned above the conduction of flow is also important and should provide turbulences and an absence of stagnation areas in order to impede depositions.

Generally scaling cannot be prevented completely. Eventually a chemical cleaning with acid has to be conducted. In order to organize the cleaning process as efficient as possible an accurate timing is crucial. On the one hand chemical cleaning should not be performed until it is necessary and on the other hand the required cooling capacity has to be granted. Costs for chemicals and for the shutdown of the heat exchanger can be reduced to a minimum if the right point in time for the beginning of a cleaning process and its minimum duration is detected. In order to achieve this, the process has to be automated. The control variable which controls the start and the finish point of a cleaning process has to be the pressure difference between intake and outtake. The pressure difference constitutes a measure for the degree of scaling inside the heat exchanger. As soon as this pressure difference exceeds a defined value, the cleaning process starts automatically and as soon as it decreases to a defined value the cleaning process stops. The applicable value for the pressure difference is different in each system and generally depends on the flow rate, the minimal necessary cooling capacity and the performance of the pump which has to transport the medium against the pressure difference.

A further important aspect in order to prevent a shutdown of the complete process is the installation of a redundant heat exchanger. In case of a cleaning process of a heat exchanger the medium is redirected to a redundant heat exchanger. There are two alternatives to realize this concept. Either the redundant heat exchanger is connected in series to the main heat exchanger with the possibility to bypass one of them in the case of cleaning, or the redundant heat exchanger is deployed in parallel to the main heat exchanger. In order to save investment costs it is reasonable in both concepts to design the redundant heat exchanger in a smaller dimension. The redundant heat exchanger is only intended as backup capacity in case of cleaning the main heat exchanger and is operated only temporary. It is crucial to keep the redundant heat exchanger operational at any time.

4 Inhibition and reduction of scaling

Besides the operation of a redundant heat exchanger there are different approaches to inhibit and reduce the extent of scaling. In general chemical or mechanical approaches are regarded. Chemical approaches are either the addition of antiscalants, which interfere with the molecular development of scale formation, or the creation of supersaturated conditions at a specific spot, where the lime precipitates and can be removed in a controlled way. The mechanical approach is the circulation of scouring particles in the heat exchanger and thus the prevention and removal of scale formation.

Antiscalants

The addition of antiscalants is a common approach to reduce the extent of scaling. Antiscalants are chemical compounds, mostly phosphonates or polymeric materials. Usually the antiscalants are added in the bleaching plant and at the evaporators, which allows an operation under supersaturated conditions and increases the reusability of water [3]. They work by one or more of the following mechanisms:

- Threshold inhibition: ability to keep supersaturated solutions of soluble salts without crystal formation.
- Crystal modification: ability to distort crystal shapes, which results in non-adherent scale.
- Dispersion: ability of antiscalants to adsorb on crystals or colloidal particles in order to keep the crystals separated.

On the basis of these mechanisms the deposition of scale is largely inhibited. Some products can also remove existing depositions to some extent. It is important to optimize antiscalant treatment with respect to type and dosage. The proper antiscalant for the particular purpose should be identified first [4].

A possible antiscalant for the use in pulp and paper industry is *Baypure DS 100* by Lanxess. It is in use in some applications in the pulp and paper industry. In case of a volume flow of 40,000 m³/d, which has to be treated with Baypure, the consumption of this chemical for the accrued current is about 800 kg/d according to personal communication with staff of Lanxess. This consumption would result in material costs of about 40,000 - 45,000 € per month. In contrast to the material costs the costs of cleaning or even a shutdown must be considered.

Antiscalants can be added in different process steps as long as the composition of the fluid does not restrain the effectiveness of the antiscalant. This allows a selective scale control wherever it is necessary in the process. The implementation of new plant components is limited to a dosing device, which generally requires only little space and causes little investment costs.

On the contrary there is a constant demand for chemicals which generates perpetual operating costs. The antiscalants do remain in the fluid and have to be eliminated. Often antiscalants are well biodegradable.

Company offering antiscalants:

LANXESS Deutschland GmbH
Functional Chemicals
Phosphorous Chemicals Technical Service & Development
Building T 36
D-51369 Leverkusen

Dr. Ralf-Johann Moritz
ralf-johann.moritz@lanxess.com

http://lanxess.com/en/

Self-cleaning heat exchangers

The technology of self-cleaning heat exchangers is based either on the scouring effect of the fluid itself or on the scouring effect of additional particles. By adding solid particles at the inlet of a heat exchanger, a mild scrapping effect on the wall of the heat exchange tubes is achieved, removing deposits at an early stage of formation. The particles can be cut metal wire, glass or ceramic balls [5]. This technology has already been proved in pulp mills in Europe and America. The developer of this technology is the company Kalren BV located in the Netherlands [6]. To ensure the effectiveness of this technology for the particular scaling problem, a pilot plant should be installed which proves over a specific period of time the self-cleaning performance and the best frame conditions. However, the pilot plant has to be paid by the client.

Earlier in the 1980's and 1990's, investigations in the field of pulp and paper industry in the US were conducted and showed self-cleaning effects of tubular heat exchangers if chopped metal wires were used as scouring

particles. For more information about references Klaren international BV should be contacted.

The main advantage of this concept is that it operates largely autonomously. There is no need for additional chemicals which have to be added to the fluid continuously. Hence the operating costs can be kept quite small. Furthermore, there is no need for new space for the integration of the self-cleaning heat exchanger because the old one will be replaced. However, the design might differ from the one of the installed heat exchanger, whereby space problems can occur.

Adversely the high investment costs and the necessity of a pilot plant have to be considered. Success cannot be granted but if the pilot plant delivers promising results this concept can be superior to antiscalants from the financial point of view in the long term.

If a self-cleaning heat exchanger is used it has to be taken into account that the lime still remains in the wastewater and might precipitate at another spot in the system.

Company offering self-cleaning heat exchangers:

Klaren International BV
Vincent van Goghsingel 40
NL-2182 LP Hillegom
The Netherlands
E-Mail: info@klarenbv.com
http://www.klarenbv.com/framespage.html

Lime Trap

This technology removes the solved lime ingredients at an appropriate spot within the process. By stripping out carbon dioxide and adding sodium hydroxide, precipitation of calcium carbonate is induced. The calcium carbonate either deposits or floats and can be removed from the system. Water with a low calcium concentration is generated [7]. Investigations of the RWTH Aachen showed a reduction of the hardness degree of up to 83% [8]. A reference lime trap is installed at factories of Voith paper Environmental Solutions GmbH & Co.KG.

By eliminating the lime, this process secures the subsequent system components reliable from scaling. By varying the input of carbon dioxide or the concentration of sodium hydroxide, the lime elimination rate can be controlled.

This concept implies significant space requirements. The dimension of the lime trap is comparable to an aeration pond of the wastewater treatment system. Respectively, the investment costs are substantial. The operating costs primarily caused by the carbon dioxide stripping and the sodium hydroxide consumption are to be considered as well.

Companies offering lime traps:

KOWITEC Ingenieurgesellschaft für Wassertechnik mbH
Leonhardstrasse 21a
18057 Rostock
Germany
http://kowitec.de/?babel=en&pg=technologie

Voith Paper Environmental Solutions GmbH und Co. KG
Escher-Wyss-Str. 25
88212 Ravensburg
Germany
E-Mail: info.vpes@voith.com
http://www.vp-environmental.de/en/Paper_Industry/products/Lime-Trap.html

5 Recommendations for Asia Symbol Pulp & Paper

In the previous chapter, three possible solutions for the handling of scaling problems have been described. For more details regarding one of the solutions described above, the companies mentioned can be contacted. If general advice regarding heat exchangers in pulp wastewaters is needed, more companies active in that field are listed in the annex.

The following measures should be taken into account before realizing one of the described solutions:

- It should be considered to mix the two wastewater streams (acid and alkaline) before the heat exchange process, as this would a) lead to precipitations upstream of the heat exchanger where they can be easier controlled and b) to a less aggressive wastewater due to a more neutral pH.
- Heat exchangers should be equipped with pressure control sensors to measure the reduction in pressure over the heat exchangers. The values should be monitored automatically. If the head loss exceeds a certain value, the heat exchangers should be automatically backwashed with chemicals until the head loss is reduced to a certain value.
- During backwashing, an additional heat exchanger should be available to guarantee the continuous operation of the heat exchange process.

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Annex: Companies offering heat exchanger solutions for pulp and paper industry

GEA Ecoflex GmbH
Karl-Schiller-Straße 1-3 ·
31157 Sarstedt
Germany

Mr. Stefan Kaimer
E-Mail: Stefan.Kaimer@gea.com

http://www.gea-phe.com/germany/startseite/

As part of the international GEA Group, GEA PHE Systems is specialized in the plate heat exchanger business. GEA PHE Systems is one of the leading manufacturers of plate heat exchangers worldwide. GEA PHE Systems provides the optimum solution with its full range of gasketed, fully welded and brazed plate heat exchangers (PHEs) for all process stages, applications, temperatures and pressure levels.

WCR Deutschland GmbH
Albert-Pröller-Str. 13
86675 Buchdorf
Germany
E-Mail: info@wcr-deutschland.de
http://wcr-deutschland.de/

The WCR Germany GmbH is a German subsidiary of the world leader for vendor-independent service for plate heat exchangers. In pulp and paper industry their area of application is, for example, hydraulic oil cooling and heat recovery from wastewater.

Bronswerk Heat Transfer
Stationsweg 22
3862 CG Nijkerk
The Netherlands
E-Mail: info@bronswerk.com
http://www.bronswerk.com/de/

Bronswerk Heat Transfer supplies a self-cleaning heat exchanger with circulating metal particles.

AKK Industrieservice & Handels GmbH
An der Schachtebeeke 8
31863 Coppenbrügge
Germany
E-Mail: info@akk-service.de
http://www.akk-service.de/

AKK Industrieservice & Handels GmbH is an independent company which offers repair and maintenance services for heat exchangers from different producers such as Laval, Sondex or Ecoflex.

SONDEX Deutschland GmbH
Robert-Koch-Straße 3
21423 Winsen
Germany
E-Mail: info@sondex.de
http://www.sondex.de/

Sondex provides efficient and energy-saving components for the pulp and paper industry. Their plate heat exchangers, pumps and spiral heat exchangers are suited for:

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Alfa Laval Mid Europe GmbH
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21509 Glinde
Germany
E-Mail: info.mideurope@alfalaval.com
http://www.alfalaval.com/Pages/default.aspx

Alfa Laval Mid Europe GmbH offers solutions for energy savings and maintenance for technical components in pulp and paper industry like:

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- Drum thickeners
- Centrifuges
- Membranes and more