Self-cleaning evaporator driven by MVR – the way to go!

SANDEEP JADHAV
Marketing Manager,
Shachi Engineering Pvt. Ltd.
Email:sandeep.jadhav@shachiengg.com

INTRODUCTION

Self-cleaning evaporators have been applied for decades and have proven to solve cases where fouling of the tubes caused severe problems. For the past three years, Shachi Engineering and Klaren International are actively collaborating to supply Multi-Effect Evaporator (MEE) plants to treat difficult effluent from manufacturers of dyestuffs. In these plants one of the effects is equipped with the self-cleaning configuration, while the other effects are of the conventional forced circulation type. The reason to equip only one of the effects with the self-cleaning configuration is purely economic. The self-cleaning technology will require additional CAPEX, but will give a higher availability and productivity of the plant and avoid cleaning costs. So, selecting the effect most prone to fouling can already make a huge step to increase the time between cleanings, but it means that the other effects still can show fouling.

This is one of the important reasons why a concept using Mechanical Vapour Recompression (MVR) is very interesting, because there will only be one effect. So, the question about which effect to equip with the self-cleaning technology becomes obsolete.

In an evaporator driven by an MVR (also known as Mechanical Vapour Compression, MVC), the vapour coming from the evaporation is compressed by a compressor to a higher pressure and temperature. This higher temperature allows the vapour to be used in the shell side of the heat exchanger in the evaporator, where it condenses. In other words, all the energy used to evaporate or the latent heat is recovered. In a MEE this, by definition, is only done partially. Of course, the MVR requires energy to drive the compressor, but overall, the use of primary energy is significantly less.

This paper discusses the MVR with the self-cleaning system from different perspectives: its energy consumption; the experiences with self-cleaning; the design of it; and the operational aspect of applying a compressor. Before discussing the MVR, first the self-cleaning system is briefly described.

Self-cleaning evaporators by applying a fluidized bed

The operating principle of the self-cleaning fluidized bed evaporator is based on the circulation of solid cleaning particles through the tubes of a vertical shell and tube heat exchanger. The fouling liquid flows upward through the tube bundle of the heat exchanger that incorporates specially designed inlet and outlet channels. In the inlet channel the solid particles are fed to the fluid using a proprietary distribution system to ensure a uniform division of particles over all the tubes.

The particles (mostly stainless steel or ceramic particles with a size between 1 and 4 mm) are fluidised by the upward flow of liquid, where they create the mild scouring effect on the wall of the heat exchanger tubes, thereby removing any deposit at an early stage of fouling formation. After the tube bundle, the particles disengage from the liquid in the separator,

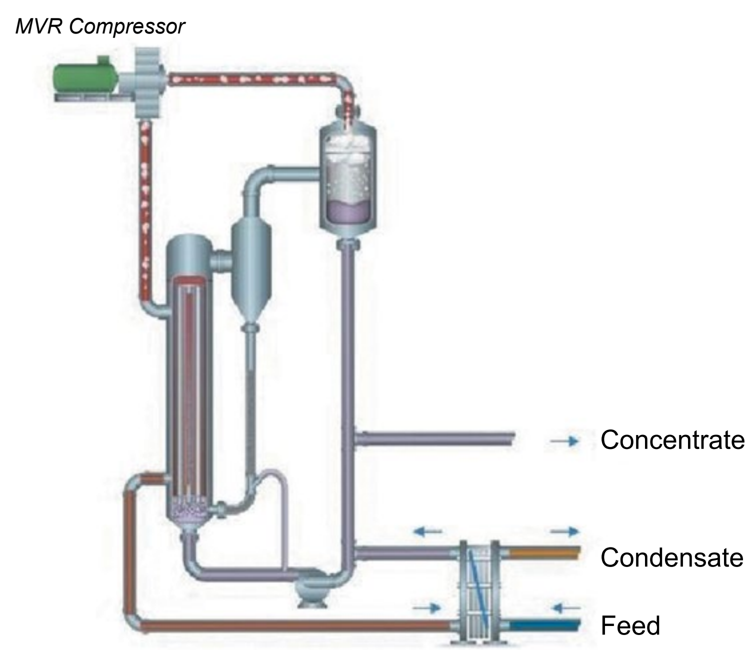

Fig. 1: Schematic of self-cleaning evaporator driven by MVR

Content Index to Advertisers Index to Products Advertised

and are returned to the inlet channel through an external down-comer, and the cycle is repeated.

To control the quantity of particles fed to the inlet, a part of the inlet flow to the heat exchanger is used to push the particles from the down-comer into the inlet channel.

With the self-cleaning evaporator many types of fouling deposits can be effectively handled, whether hard or soft, originating from biological, crystallization, chemical or particulate fouling mechanism, or a combination of these.

MVR versus MEE from the perspective of energy efficiency

As already stated in the introduction, the MVR requires significantly less energy than a MEE. For the latter, the energy consumption in the form of fresh steam is highly dependent on: whether or not a thermo-compressor (TVR) is used; the selection of the entrainment ratio in the situation when applying a TVR; the number of effects in the MEE; and the configuration of the pre-heater train.

For a four-effect MEE with TVR and an entrainment ratio of 1, a steam consumption of 0.28 kg steam per kg of water evaporation is quite a representative number. Besides the consumption of steam, the MEE-plant with condenser will also use electricity. The electricity consumption is about 0.03 kWh per kg of water evaporation. When using a boiler plant efficiency of 75% and an efficiency for a conventional power plant of 33%, it can be calculated that it takes 73-kg of coal to evaporate 1-m^3 of water when using a MEE.

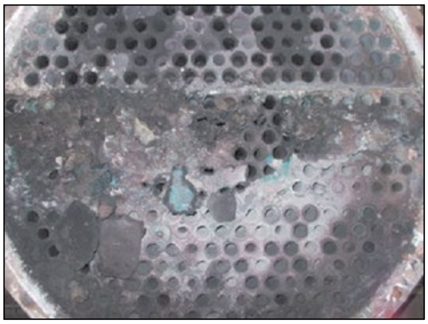

Fig. 2: Fouling as experienced in evaporator of effluent from dyestuff producer

A typical MVR with a double stage compressor takes 0.06-kWh of electricity to evaporate 1 kg of water. When we assume the same power plant efficiency of 33% to produce electricity, we can calculate that it takes only 43-kg of coal to evaporate 1-m^3 of water when using a MVR.

So, ultimately, one can save 41% in the use of primary energy when using an MVR to treat wastewater by concentrating it through evaporation.

Table 1: Comparison energy use – MVR versus MEE

Energy use	MEE	MVR
Steam use (per kg water evaporated)	0.28-kg	–
Electricity use (per m^3 of water evaporated)	0.03-kWh	0.06-kWh
Prime energy, coal, requirement (per m^3 of water evaporated)	73-kg	43-kg

Experience with self-cleaning evaporator in dyestuff effluent treatment

The effluent from a dyestuff manufacturer is characterised by a combination of well-known salts and organic components. When concentrating this effluent, the liquid develops a thick and hard deposit, especially on the hottest tube wall (being that of the first effect). Experience has shown that within 250 to 300 hours the evaporation capacity of a four-effect evaporator reduces by 50%.

After retrofitting the first effect with the self-cleaning fluidized bed technology, the evaporation capacity remained constant over time. In this typical case, the fouling in effects two, three and four had always been less significant than that in effect one, but it had reduced after the retrofit as well.

Knowing the strong dependency on the exact liquid composition, the performance for a second evaporator plant of the same client, but at a different site with a different effluent composition showed that introducing the self-cleaning technology solved the fouling in the first effect, but the other effects still had fouling. Therefore, the evaporation capacity still reduced over time, but at a much smaller rate, increasing the average capacity and the time between cleanings.

Design of an MVR – effect of liquid composition and fouling

The thermal design of an MVR requires careful attention with respect to the compressor performance, the composition of the liquid and the required heat transfer area.

The compressor design and selection will determine the temperature increase given to the vapour and yields the driving force for heat transfer between the condensing vapour and the liquid at the tube side. The higher the temperature difference, the lower the required heat transfer area (HTA). On the other hand, the higher the temperature increase the more power the compressor will consume.

The required temperature increase will also depend on the liquid composition, as salts increase the boiling point. This boiling point elevation (BPE) lowers the temperature difference between

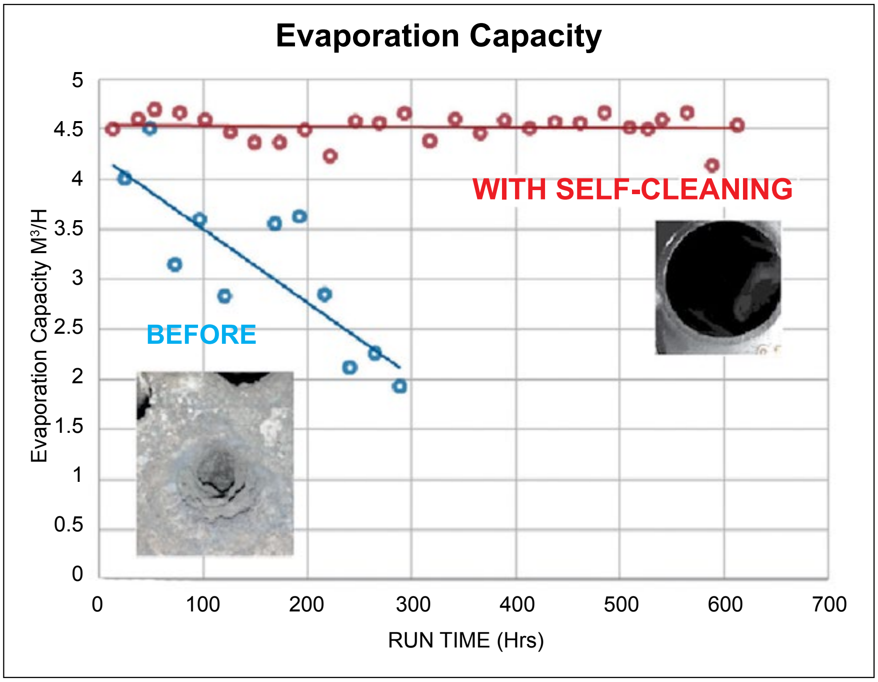

Fig. 3: Evaporation rate of MEE plant before and after the revamp of the first effect to self-cleaning

vapour and shell. For example, if the vapour from an atmospheric evaporating system is 100°C, the liquid will boil at 108°C, assuming a BPE of 8°C. When the two-stage compressor gives a temperature increase of 16°C, the vapour will condense at 116°C. The driving force for heat transfer then roughly becomes 8°C. In case of a single-stage compressor, with temperature increase of only 8°C, no driving force would be left. The required heat transfer will linearly depend on the temperature difference after correction for BPE. When under-predicting the BPE, the chosen HTA could become too small, affecting the capacity by tens of per cent.

Since fouling can easily reduce the coefficient of transfer by 20-50% or even more, the formation of scales can just as well have a detrimental effect on the evaporation capacity. This makes the self-cleaning system very attrac-

tive. It prevents overdesign and keeps the plant capacity constant.

Operational aspect using compressors

Operating compressors requires the attention of plant operation. When using root blowers, the equipment is more robust and the required attention is less than with turbofans. Turbofans have fast running impellers with high tip speed that are susceptible to vibration issues when the impellers get dirty.

Monitoring the vibration and stopping the fan in time will prevent larger damages. When taking care of the compressor, experience has shown that MVR units have a good reliability.

CONCLUSION

The self-cleaning evaporator using a MVR is the way to go – to save on primary energy when treating effluent, and maximizing the potential of the self-cleaning heat exchanger technology.