New system for the diagnosis of fouling and corrosion in heat exchangers using the Digital Twin

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1 Introduction

Reducing energy consumption is one of the fundamental objectives in all industrial processes. One way to achieve this is to use heat exchangers to heat or cool fluids in a given time interval. These systems are used in different industries to transfer thermal energy between two or more fluid streams through contact surfaces, and therefore play a key role in saving resources and energy, as well as contributing to the reduction of the environmental impact of industrial processes.

One of the main causes that undermine the capacity and efficiency of these systems is the accumulation of unwanted deposits on the transfer surfaces. This phenomenon is known as fouling and occurs regardless of the type of heat exchanger used. In general, more than 90% of heat exchangers experience fouling problems [1], which has a direct and negative impact on maintenance time and costs, as well as energy consumption. The total pollution costs related to fouling in exchangers are around 4 billion euros per year in industrialised countries [2].

Another aspect that, together with fouling problems, reduces the efficiency of the system is corrosion, which causes deterioration of the transfer surface with the consequent loss of material. This can lead to cracks or leaks, the latter causing mixing of the working fluids in the heat exchanger and, therefore, contamination of the process.

Corrosion is considered one of the most serious problems as it is responsible for the repair and replacement of equipment and installations in most industries, with annual losses due to corrosion problems amounting to hundreds of billions of euros. In particular, in petrochemical refineries, corrosion in exchangers is one of the most common reasons for system downtime [3].

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In view of the above, there has been a clear trend in recent years to develop systems that allow the behaviour of heat exchangers to be modelled and both pathologies to be controlled. For the most part, the control of these pathologies has been carried out off-line or with the help of inspection methods carried out manually, giving rise to events that were not identified in time and led to substantial damage or failure of the system.

The aim of this work is to develop an innovative integral system for diagnosing and proposing treatment for the most frequent pathologies (fouling and corrosion) that occur in heat exchangers, based on the creation of a Digital Twin of the system. This system will be able to:

- monitor in real time the dynamic behaviour of the system.
- detect the presence or formation of a pathology.
- develop a personalised predictive maintenance plan.

2 Methods

The new system will be an automated predictive system that aims to mitigate the risk of fouling and control corrosion on the heat exchanger transfer surface through continuous, real-time monitoring. The system will predict the appearance of both pathologies and plan their maintenance by means of a Digital Twin and the use of artificial intelligence techniques, increasing the efficiency and profitability of the production process, and reducing the costs associated with maintenance tasks.

The purpose of the development of the new system is to optimise downtime, increase the efficiency of the system and extend its useful life. The system is characterised by the following two innovations:

- designing a network of sensors to determine the parameters of interest at low cost for any type of heat exchanger.
- implementing, calibrating and validating the Digital Twin of the heat exchanger, which will predict the evolution of the fouling factor, know the state of corrosion of the exchanger, and design a maintenance plan based on both factors.

The new system for the diagnosis of fouling and corrosion in heat exchangers using the Digital Twin will be composed of the following subsystems:

- Hardware subsystem: it will be formed by different wireless sensors in charge of registering the parameters of interest to carry out the diagnosis and treatment of pathologies in heat exchangers. A priori, temperature, pressure, flow and ultrasonic sensors will be used. Likewise, the communication system shall allow the data recorded by the sensors to be sent to an access point, in real time, by means of short-range wireless technology. At this access point, the recorded data shall be organised in data packets by time and sensor type. Additionally, if any simple pre-filtering of data is deemed necessary, this will also be carried out at the access point. Once the recorded information is correctly organised, it will be sent via the long-distance communication system, again using wireless technology, to the cloud, where it will be analysed and processed.

- Software subsystem: in charge of processing all the information previously collected by the hardware. It will contain all the developed algorithms necessary to process the data collected by the measurement unit. It will include the mathematical modelling necessary to represent the dynamic behaviour of the heat exchanger, the neural network for the prediction of the fouling factor, as well as the determination of the cleanliness indicator.
- Digital platform: the design of this management tool will be carried out in an intuitive and manageable way that will allow the results to be represented in the form of graphs, tables and diagrams, thus visualising the information in a quick and easy way. In addition, it will be implemented in such a way that it can be supported by different devices, facilitating access to the results at any time and from any device (computer, Smartphone, etc.) with an internet connection.

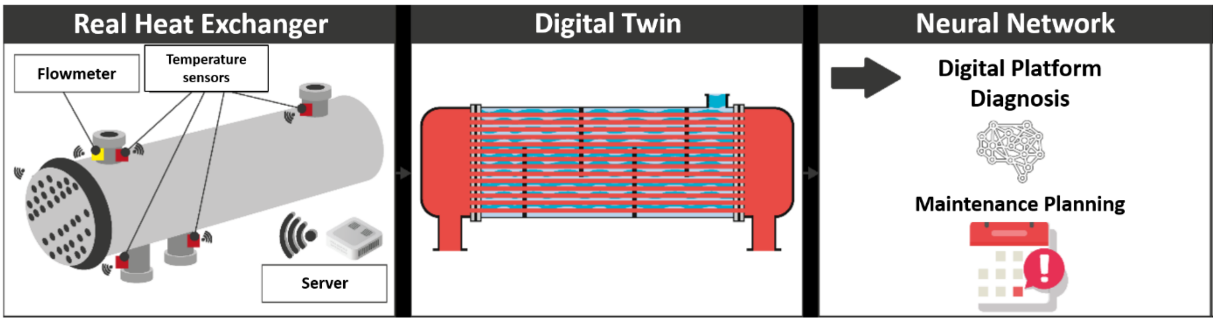

Figure 1. New system for the diagnosis of fouling and corrosion solution schematic.

3 Results

The new system for fouling and corrosion diagnostics will therefore allow optimal automation of maintenance work on the heat exchanger. Traditional heat exchanger inspection techniques will be eliminated, which will be associated with a reduction in the cost and time required for inspection. In addition, thanks to the integration of the system with a Neural Network for decision making, it will be possible to optimise the distribution of economic resources associated with maintenance.

The most significant differential aspects of the solution are linked to the sophisticated data processing and the advanced algorithm, which allow the application of the Digital Twin concept in the field of heat exchangers. The newly developed system offers the following advantages:

- It allows the monitoring of their dynamic behaviour accurately, continuously and in real time.
- It allows the development of predictive estimates and simulations that allow the establishment of action scenarios where the pathological response of the system to different combinations of parameters can be anticipated.

- Low-cost system that allows optimisation of cleaning cycles, considering optimal maintenance schedules to reduce the economic costs associated with equipment downtime.
- System valid for all heat exchangers, regardless of the type and type of working fluid.
- The system has a digital platform for the management and display of results in real time.

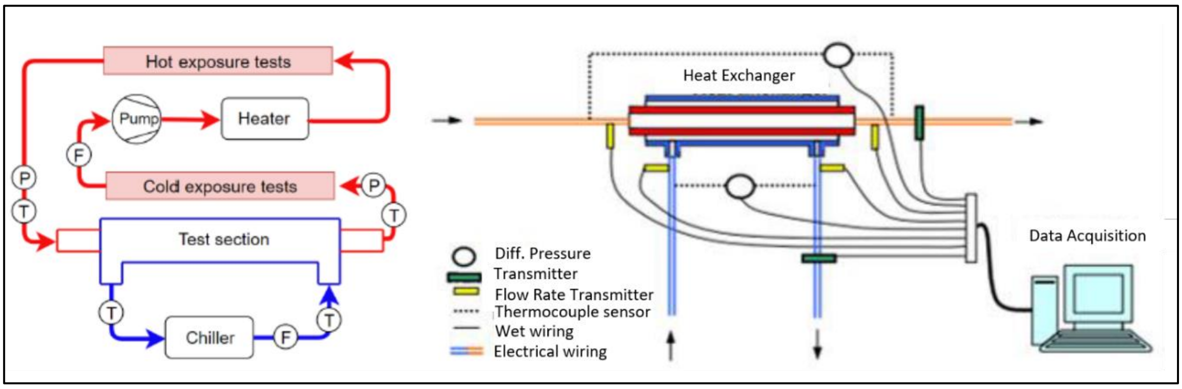

Figure 2. Different instrumentation in heat exchangers.

4 Conclusions

The novelty of the proposed system is the prediction of the state of health of a heat exchanger through continuous monitoring in real time, which provides accurate information to carry out a control of the main pathologies and an optimised maintenance of the heat exchanger.

In order to achieve this solution, several challenges had to be overcome to obtain the innovative system. Some of them are listed below:

- programming of a numerical model capable of representing the dynamic behaviour of any heat exchanger.
- prediction of the evolution of the surface fouling factor.
- design a maintenance plan based on the results of the predictive model of the fouling factor and the state of corrosion of the heat exchanger.

References

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