Operation and Maintenance of Industrial Heat Exchangers to Minimize Fouling and Corrosion

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ABSTRACT: Heating equipment is used to transfer heat from one fluid to another through the use of heat exchangers (HE). Domestic and industrial uses are many. However, it is dispersed among industrial bulletins, rules and standards for industrial design as well as technical publications. In industrial applications, heat exchangers are crucial. It is utilized for the heating and cooling of large-scale industrial process fluids. In general, wire and tube heat exchangers utilize an inline wire configuration between the two sides, but this study used a staggered wire design, which minimizes convective heat transfer limitation. In this book work, the author aims to condense into a fundamental foundation and ideas design of heat exchangers as well as operation, cleaning, and green technology maintenance on heat exchangers directly connected to industrial practices. This paper elaborates the applicability of the operation and maintenance infrastructure of industrial heat exchanger and its applicability in various sectors to solve the existing problems.

KEYWORDS: Cleaning of Heat Exchanger, Fouling Mitigation, Green Technology, Heat Exchanger

INTRODUCTION

In industrial applications, heat exchangers are crucial. It's used for heating and cooling large-scale industrial process fluids. Heat exchangers are dynamic designs that may be tailored to any industrial process based on temperature, pressure, fluid type, phase flow, density, chemical composition, viscosity, and a variety of other thermodynamic characteristics. The effective heat recovery or dissipation of heat has become a critical problem for scientists and engineers as a result of the worldwide energy crisis [1]. Heat exchangers are intended to improve efficiency by optimizing the surface area of the wall between two fluids while decreasing resistance to fluid flow via the exchangers while staying within material cost constraints. Corrugations or fins in the heat exchanger might improve the performance of heat exchanging surfaces by increasing surface area and channeling fluid flow or inducing turbulence. As a result of fouling, the total heat transfer coefficient of industrial heat exchangers may be measured online. If processed water is not properly handled, it can cause significant damage to equipment. When it comes to treating water, chemicals are widely employed in the business. Chemical’s worth 7.3 billion dollars are discharged into the air, dumped in waterways, and buried in landfills every year in the United States. Industry buys 40% of these chemicals to prevent scale buildup in cooling towers, boilers, and other heat transmission devices[2]. More than 2 billion dollars of hazardous waste are disposed of each year into the ground, which belongs to us all; this equals more than 1 trillion gallons of polluted water. It is possible to clean clogged tubular heat exchangers by using a variety of procedures such as sandblasting, high-pressure water jet, or bullet cleaning. Large-scale cooling water systems for heat exchangers employ a variety of water treatment methods to prevent fouling of the heat exchanging equipment, such as filtration, chemical addition, catalytic approach, and others. As part of the steam system for power plants, various water treatment procedures are employed to reduce fouling and corrosion of the heat exchanger and other equipment. In order to prevent corrosion, most of the chemicals and additions are harmful to the environment [3]. As a result, the time has arrived to use environmentally friendly chemicals. It's a piece of heat transfer equipment that uses a thermal energy exchange procedure between two or more mediums that have different temperatures to transfer heat from one to the other. Many different sectors use industrial heat exchangers such as electricity generation and oil and gas processing. Other industries that use industrial heat exchangers include alternate fuels production, cryogenics and air conditioning and refrigeration, heat recovery, and more. As a result of this, heat exchangers are ubiquitous in our everyday lives, including evaporators, air preheaters, vehicle radiators as well as condensers, oil coolers, etc. To accomplish desired performance in diverse applications, a wide range of variable flow configuration is used to separate the fluid on the heat transfer surface. It is possible to classify heat exchangers in a variety of ways. In general, industrial heat exchangers are categorized according to their structure, heat transfer processes, degrees of surface compactness, flow arrangements, pass arrangements, phase of the process fluids, and heat transfer mechanisms, among other characteristics [4]. In order for a heat exchanger to function normally, it must be designed to withstand a variety of service situations, including uncorded, corroded, and fouled states. An important consideration in the design of a heat exchanger is that it must be easy to maintain, which generally entails cleaning or replacing worn-out or corroded tubing, fittings and other elements over time. It is therefore important to keep the design as basic as possible, especially if significant fouling is to be expected. This can be done by minimizing temperature in combination with fluid velocity and lowering pre-foulant concentrations. There should also be allowance for the greatest flowing velocity, subject to pressure drop and erosion from the flow. Material selection within budgetary constraints also slows down the buildup of deposits and allows for a shorter stay. Not only should the heat exchanger be suitable in terms of pH, but it should also be compatible in terms of the heat equipment and transfer lines. The development and buildup of undesirable materials deposit onto the processing equipment surfaces is always described as fouling. These materials, which have a low thermal conductivity, form an insulator on the surface, reducing the surface's ability to transmit heat under the temperature difference for which it was developed. Furthermore, fouling increases fluid flow resistance, resulting in a greater pressure drop across the heat exchanger [5]. Crystallization fouling, particle fouling, corrosion fouling, chemical reaction fouling, biological fouling, and solidification fouling are all forms of fouling that may occur on heat transfer surfaces. Initiation of fouling, transit to the surface, attachment to the surface, removal from the surface, and ageing at the surface are the five steps of fouling formation. pH, velocity, bulk temperature of fluid, temperature of the heat transfer surface, surface structure, and roughness are all elements that influence fouling factors. The overall fouling process is typically seen to be the product of two concurrent sub processes: a deposition and a removal process. The heat transmission performance of the heat exchanger degrades over time as these deposits develop. Soil, atmosphere, water, and aqueous solutions are all frequent enemies of ordinary metals and alloys. Corrosion is the term for the degradation of these metals. It is understandable that corrosion occurs as a result of electrochemical mechanisms. Corrosion causes premature equipment failures in most commercial processes and engineering activities, resulting in unwelcome consequences. This involves costly breakdowns, unplanned shutdowns, and higher maintenance costs. Chemical industries, oil refining, sea and land electric power plants, paper production, air conditioning, refrigerator, food and liquor manufacturing all have increased downtime. As a result, general information and corrosion mechanisms will pique the public's and industry's attention. Several factors influence the rusting process[6]. As a result, these criteria should take into account the fundamentals of heat exchanger design. Figure 1, Illustrates the process of heat transfer resulting in erosion, spalling, dissolution and sedimentation in the heat transfer surface.

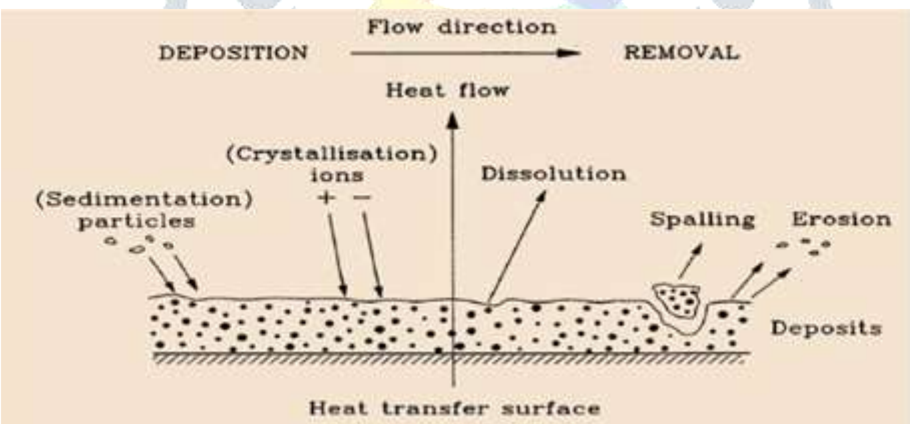

Figure 1: Illustrates the process of heat transfer resulting in erosion, spalling, dissolution and sedimentation in the heat transfer surface[6]**.**

Apart from the significant expense of heat exchanger fouling, there has been very little research done to accurately assess the economic costs of fouling [7]. As a result, these costs are attributed to differences in heat exchanger design and operation. However, in order to assess the cost effectiveness of various mitigation measures, it is necessary to have a solid understanding of fouling economics.

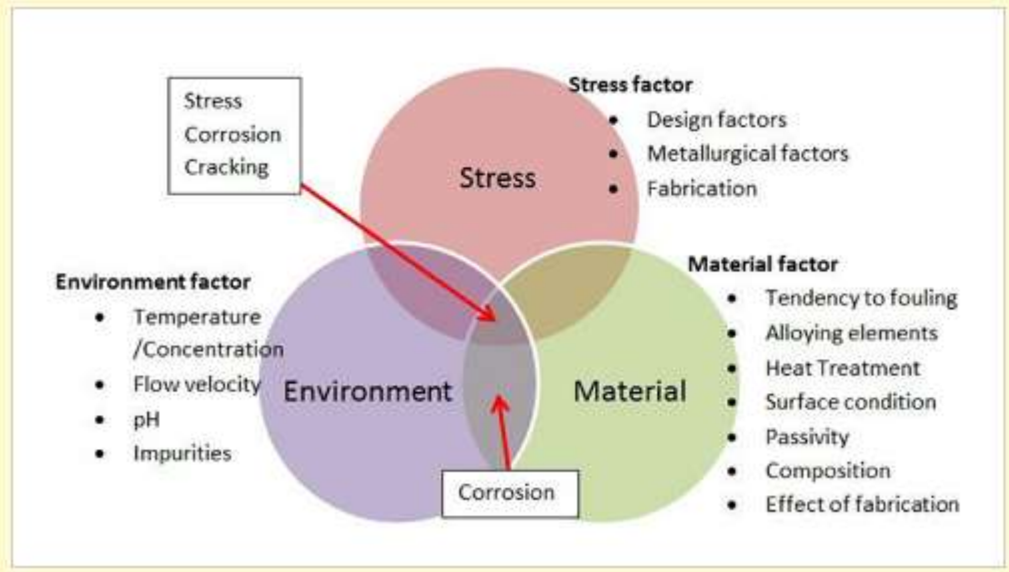

Figure 2: Illustrates the factors affecting the heat exchanger corrosion, which include environmental, material and stress loss[6]**.**

Figure 2, Illustrates the factors affecting the heat exchanger corrosion, which include environmental, material and stress loss. Costs of additional fuel required if fouling causes additional fuel to be burned in heat-exchanging equipment to counteract the fouling effect [8]. Costs of removing fouling deposits, chemicals, and other anti-fouling device running costs. Plant shutdowns, whether scheduled or unexpected, caused by fouling in heat exchangers can result in significant production losses. These losses are frequently regarded as the primary cost of fouling and are notoriously difficult to assess. The cost of disposing of a considerable quantity of chemical/additives used in fouling mitigation. A lot of work has gone into reducing fouling and controlling corrosion. Several techniques for controlling fouling and corrosion have been developed in recent years. Chemical inhibitors, mechanical inhibitors, altering the phases of the solution, electromagnetic fields, electrostatic fields, acoustic fields, ultraviolet light, radiation or catalytic treatment, surface treatment, green additives, fibre as a suspension, and so on are all examples of these techniques. Until it was outlawed, chromate was an effective chemical agent for corrosion prevention and crystal growth control. To replace chromate-based additives, polyphosphate corrosion inhibitors were used.

Figure 3: Illustrates the deposition of fouling material over cross section of the tubular heat exchanger[6]**.**

Figure3, Illustrates the deposition of fouling material over cross section of the tubular heat exchanger [9]. In water with a high calcium hardness, this inhibitor has a propensity to breakdown the foulant. Fouling of high calcium water with phosphate corrosion inhibitor was examined. To combat fouling and corrosion, a catalyst material made of zinc and tourmaline was investigated. Most of the techniques for fouling and corrosion mitigation that have been utilised in the past, such as chemical/additives, have been dangerous to the environment. So, the time has come to use green technology and chemical techniques that are not harmful to the environment [10].

DISCUSSION

Cleaning heat exchangers is frequently required in order to maintain or restore heat exchanger efficiency. Cleaning methods may be divided into two categories: online and offline cleaning. Cleaning can be done online in some apps to maintain acceptable performance without interrupting operations. Offline cleaning must be utilized in other instances. Online cleaning often employs a mechanical technique that simply cleans the tube side and does not necessitate disassembly. The benefits of online cleaning include the heat exchanger's continued service and the anticipation that no cleaning-related downtime will occur. However, it increases the expense of a new heat exchanger or the high cost of retrofits, and there is no guarantee that all of the tubes will be adequately cleaned.

Figure 4: Illustrates the process of automatic cleaning used to clean heat exchanger with the help of water jets.

Figure 4, Illustrates the process of automatic cleaning used to clean heat exchanger with the help of water jets. Because of the precision required for successful heat exchanger tube cleaning, an automated hydro blasting method is suitable. For years, Thompson Industrial Services has been developing automated techniques with the goal of benefiting our clients by reducing cleaning time, increasing productivity, and significantly enhancing all aspects of safety. A recent heat exchanger cleaning job exemplifies how effective our automated solutions are at achieving these objectives. The paper mill's initial benefit from this strategy was the significant decrease in labour required for the task. In fact, the crew that completed the work was only half the size of the team that would have been required to clean a typical heat exchanger. With fewer technicians on the job, the facility's operations as a whole were less disrupted, and there was a decreased risk of harm because there were fewer individuals engaged. The risk of injury was further reduced by removing the technician from the close area of our strong hydro blasting instruments, as is always the case with automated equipment. This hydro blasting procedure was not only safer, but also faster than a typical heat exchanger cleaning. A non-automated cleaning is expected to take 16-20 hours, but our crew completed the Florida paper mill cleaning in 9.5 hours, less than half the time! The mill benefits the most from the shorter work since it saves money. Not only is the ultimate cleaning bill cheaper, but the heat exchanger spends less time offline for maintenance, allowing production to restart faster. Heat exchanger cleaning equipment may now be operated without the involvement of a human operator, resulting in greater precision and efficiency. Water pressure can be increased, less safety precautions are required, and cleaning time can be increased by 100 percent with full-pressure usage on both the inlet and exit strokes, supplemented by more accurate targeting when robotic positioners are controlled from a distance, according to the study. The method can avoid the buildup of particulate matter, biofilm development, and the deposition of scale and corrosion products. It can only be used to flow via tubes on the inside. Fouling issues on heat exchangers are alleviated by high and low frequency sound emitters horns. In the sticky and tenacious deposits that are commonly associated with slagging, sound is significantly less effective. The initial application of the protective layer is the first phase. The second phase entails maintaining the film, which would otherwise be removed by flow shear forces. Stopping the machine and cleaning the heat exchanger is an alternative to cleaning it online. Offline cleaning may be divided into two types: chemical cleaning and mechanical cleaning. The recommended cleaning technique does not include dismantling the heat exchangers, however access to the interior surfaces is typically required. It would be smart to consider installing a "standby" heat exchanger, which would allow for the cleaning of the clogged heat exchanger while still maintaining output. Drills, cutting and polishing tools, and brushes made of various materials, such as steels or nylon, brasses, may be applied to the spinning shaft, depending on the tube material and the type of the deposit. The energy to remove the deposits is transmitted by a shock wave in the air near to the surface to be cleaned, or by the general vibration of tubes that caused the explosion. In the field of boiler plant cleaning, it is a relatively new idea. It is possible to start cleaning the building while it is still hot. Temperature fluctuations, especially fast temperature changes, cause the foulant layer to fracture and flake. This method is comparable to steam soaking. The dislodged debris is carried away by the water flushing, which is continued until clean surfaces are produced. For removing iron oxides, calcium/magnesium scales foul ant, and other contaminants, use a hydrofluoric, hydrochloric, citric, or sulphuric acid inhibitor or a chemical cleaning agent. Heavy organic deposits, such as tars and polymeric foulest, can be cleaned using chlorinated or aromatic solvents followed by washing.

CONCLUSION

Fouling and corrosion are the two biggest problems in heat exchanger operation that have yet to be overcome. There is still a dearth of knowledge about the fouling deposition concerns and their economic consequences. Aside from that, corrosion has a wide range of consequences that can have a far greater impact on the efficiency, reliability, and safety of equipment or buildings than the mere loss of metal. As a result, the current study will raise awareness about the importance of this situation and the implementation of viable mitigation strategies in different nations. An industry's production expenses can be reduced by using the right cleaning methods and controls. As a result of chemical use and maintenance labor, as well as lost production time and water waste, the cost of production increases considerably. Corrosion control and fouling cleaning are therefore crucial, and the relevant authorities must understand the relevance of both and impose a certain standard cleaning process in the industries.

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