

Long-Term Cost Savings by Using High Alloyed Stainless Steel in Seawater Coolers

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ABSTRACT

A refinery has for decades been using tubes in CuNi 70/30 for several seawater cooled heat exchangers. Over the years the refinery has been facing a lot of corrosion issues with these heat exchangers, leading to frequent leakages, plugging of tubes and ultimately complete retubing of the tube bundles. Apart from high maintenance costs, this also leads to production losses with associated lost earnings. This paper will show the long-term cost of the CuNi 70/30 heat exchanger solution, and compare this to an initially more expensive stainless steel solution but which has a lower long-term maintenance cost. The cost calculations are based on data supplied from fabricators, material suppliers and end-users.

Key words: Corrosion resistant alloys, Maintenance, Seawater Corrosion

INTRODUCTION

Copper alloys such as copper nickel (CuNi) and Admiralty Brass (CuZn) are often successful material selections for seawater coolers. The copper alloys successes in these highly corrosive environments can be attributed to the ability of copper to form a protective scale, thus stopping corrosion of the material. On copper alloys in seawater, the protective scale formed comprises a mix of cuprous oxide (Cu₂O), copper oxide (CuO) and copper hydroxy chlorides [1]. This protective scale is quite soft though and can be eroded by solid particles in the seawater or sheer stresses from high flow velocities. While the flow rates can be adequately calculated and kept below certain alloy dependent limits, turbulence in the tube entrance in heat exchangers can be very difficult to control and failures are common in these areas. Another drawback with copper alloys is that the protective scales is sensitive to sulphide species in the process water. Sulphide species will promote the formation of copper sulphide (CuS) which makes the scale soft and non-adherent to the tube surface. Therefore, formation of CuS will lead to very rapid corrosion of the tubes.

By contrast, stainless steel alloys are not sensible neither erosion-corrosion in seawater, nor are they affected by sulphide species in the seawater. This can be attributed to the nature of the passive layer of stainless steel, being constituted of relatively hard chromium oxyhydroxides which rapidly reforms when damaged. Therefore, when erosion-corrosion or sulphide species cause rapid failures of copper alloys, stainless steels can be attractive alternative solutions.

Super duplex stainless steel UNS S32750 has a good track record in seawater cooled heat exchangers, but it is limited in its use in chlorinated seawater due to the risk of crevice corrosion if the temperature goes above approximately 50°C. An alternative stainless steel solution to S32750 is the hyper duplex grade UNS S32707 which has shown to have excellent corrosion resistance properties in chlorinated seawater [2]. For a case where a copper alloy is failing, a stainless steel solution using S32750 or S32707 could be considered as viable options.

Looking at the initial investment cost of a seawater cooler using stainless steel it is more expensive than a copper solution. It can therefore be difficult to see the advantage of changing the metallurgy as any cost saving due to less maintenance and retubing will not occur until several years ahead. In this paper, the long-term cost when changing an existing CuNi 70/30 solution to a solution using S32707 will be presented.

BACKGROUND AND METHODOLOGY

The example and cost calculations discussed in this paper are based on the service of seawater cooled shell and tube heat exchangers in a refinery. The originally installed heat exchangers have tubes of CuNi 70/30 (UNS C70600) and have been in service since the early 2000's. In total, there are more than twenty ten exchangers in parallel trains and their service life and maintenance requirements are by now well documented by the refinery personnel.

To be able to perform meaningful life-cycle cost calculations and compare between different material solutions it is important to have accurate data. This includes the investment in the initial equipment, the maintenance cost over the expected lifetime of the equipment and finally the cost of retubing, replacement of the tube bundle or replacement of the whole heat exchanger. In the here discussed case, the average service life of a tube bundle with CuNi 70/30 tubes is four (4) years with at least one unscheduled maintenance stop being performed during that period to plug leaking tubes. There are no other known issues with the heat exchangers and the calculations will thus focus on maintenance and retubing of the tube bundle.

During operations of a refinery there are regularly scheduled maintenance stops performed. These planned stops were not included in the analysis as they would induce the same cost regardless of material solution. Thus, only unscheduled maintenance stops directly connected to leakage and plugging of the heat exchanger tubes were considered in the analysis. The cost for maintenance includes labour and material cost and are based on an average value supplied by the refinery.

Production and revenue losses due to unplanned shutdowns should preferably also be included in these kinds of calculations as they can easily overshadow any other costs related to an unplanned stop. Production and revenue losses have not been included in the present case though and is discussed in more detail below.

Changes in heat exchanger design

As hyper duplex stainless steel S32707 has a lower heat transfer coefficient than CuNi 70/30, changing the tube bundle to a like-to-like configuration would lead to decreased efficiency of the heat exchanger. Calculations were therefore performed to investigate how different tube dimensions and a change in the number of tubes affect the operations of the heat exchanger. The calculations showed that due to a 10% overcapacity of the original CuNi 70/30 design, a decrease in tube wall thickness of the S32707 tubes, compared to the CuNi tubes, would still give sufficient efficiency of the heat exchanger. Thinner walls of the tubes in S32707 will result in a lower tube side flow rate, which also needs to be addressed for the energy balance of the plant. In this case the change in the tube side flow rate was deemed acceptable though.

Additional checks when changing from CuNi 70/30 to S32707 tubes, such as vibrations, mechanical integrity, etc. were also performed without remarks.

COST BREAKDOWN

Period for evaluation and tube bundle life expectancy

To perform a long-term cost comparison of the different material solutions, the time frame for the analysis needed to be defined. It was decided that twenty (20) years was a reasonable time for the evaluation. For the existing CuNi solution it was determined by the end-user that the average lifetime of a tube bundle before retubing was four (4) years.

For the alternative material solution using S32707, neither the shell side hydrocarbons nor the seawater was expected to cause corrosion of the tubes. Even so, two different case scenarios were used. For the first case it was considered that corrosion or some other degradation mechanism of the tube bundle would occur, which would lead to replacement of the tube bundle after ten (10) years. For the second case the expected lifetime was set to twenty (20) years.

A summary of the basic data for the long-term cost analysis is shown in Table 1.

Table 1
Basic data for analysis

Life-cycle analysis	20 years
Average lifetime CuNi 70/30	4 years
Expected lifetime UNS S32707	10 or 20 years

Initial equipment cost and cost of tube bundle replacement

The initial purchasing cost of the equipment includes design, materials, and fabrication. It was assumed that installation at site, shipping, etc. is the same regardless of material solution used. To assess the cost of newly fabricated heat exchangers, a well-established fabricator with long experience of designing and building heat exchangers was contacted. The fabricator was supplied with the drawings of the heat exchangers and based on these could make an estimate of the total cost for one unit if they would source the material and build it. The results of the analysis are showed in Table 2.