High Temperature Corrosion and Descaling

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High temperature corrosion is a phenomenon that occurs when a metal is exposed to an oxygen-rich environment, such as air, and subsequently develops an oxide layer, comparable to rust, as a result of this exposure. In this report, high temperature is defined as any temperature between 600°C and 950°C. The accumulation of oxide material on the surface creates challenges, as it is difficult to predict material loss over time. This unpredictability complicates the design process, especially when the component is expected to last for several years. Moreover, to reuse the material, it must be cleaned. The cleaning process is known as descaling. This thesis investigates the oxidation behavior and descaling process of a specific group of alloys: austenitic stainless steels, which represent one of the most widely used groups of stainless steels on the market.

The project was developed in two parts. The first part concentrated on developing an efficient descaling method for the selected group of austenitic stainless steels after oxidation at four different temperatures for the same duration. The second part examined the material loss of four of these austenitic stainless steels: 304, 310S, 316L, and 347, at two different oxidizing temperature: 600°C and 800°C, over a period of almost 2000 hours.

To remove the oxide scale, it is necessary to immerse the sample in an acid solution to dissolve the oxide layer. Two different aqueous acid solutions were tested: one was a mixture of rock salt and nitric acid, while the other combined nitric acid and hydrofluoric acid. The second solution was found to be more efficient, both in terms of time and surface cleanliness. After descaling, the sample surfaces were photographed at low magnification. The samples were then cut to obtain cross sections, a perpendicular cut to the surface, which allowed observation of both the surface and internal regions using an optical microscope. The descaled samples showed a tendency to exhibit minor intergranular corrosion, small cracks extending from the surface to the internal region, or surface erosion, especially after treatment with the rock salt solution. Moreover, it was observed that the lower the oxidizing temperature, the easier it was to descale the samples.

In the second part of the project, the previously established descaling method was used to descale a larger number of samples with the descaling solution containing hydrofluoric acid. This process allowed the development of a model for thickness loss over time at the two different service temperatures 600°C and 800°C. The models were based on oxidation kinetics, which predict that materials can oxidize following linear, parabolic, or logarithmic trends.

After analyzing the data, 310S was found to be the best-performing material at both oxidizing temperatures, exhibiting the lowest material loss over time and showing a logarithmic trend of thickness loss in both scenarios. The logarithmic trend is considered optimal, as it results in less thickness loss over time. 347 also demonstrated good performance at 800°. On the other hand, 304 showed the fastest material loss at 800°C, though it had a good performance at a lower temperature of 600°C with a logarithmic trend. 316L was the material that performed worst overall.

In conclusion, the solution containing hydrofluoric acid provided the best results in terms of surface cleanliness. Among the materials tested, 310S proved to be the most resistant to thickness loss over time.