Thermal stability of Titanium and Niobium stabilized stainless steel

Stainless steel has many applications and is one of the most common materials used in everyday life. In this master thesis, four different types of stainless steels were compared with respect to their temperature tolerance. This was done through observing the microstructure, and therefore being able to conclude the most tolerant material after heat exposure. More specifically the size of the steel grains was investigated after several types of heat treatments at different temperatures. This will allow Alfa Laval to ensure high quality in their heat exchangers manufactured from stainless steel.

Steel is an alloy where primarily, but not only, carbon has been added to iron to make it harder and generally more mechanically durable. Further, by adding chromium the steel can be made stainless. This allows for resistance to rust.

Figure 1: *Stainless steel.*

In stainless steels, there are several different qualities which may be customized. One of them is the size of the grains. These grains are the constituents that makes up the material.

The grain size is correlated to thermal and mechanical properties, most essentially lower grain size creates a stronger material.

Alfa Laval makes several different heat exchangers (see figure 2 for an example) using stainless steel for the material's high stiffness and functionality at high temperature. To be able to make better heat exchangers, higher temperature resistance is needed.

Figure 2: *An example of Alfa Laval's heat exchanger.*

A heat exchanger is a device which puts two mediums in proximity to each other, hence transferring the heat from the hotter to the cooler medium. Due to this usage case, the application is limited to mediums with temperatures that the heat exchanger can handle. The medium flows through small channels under high pressure within the material, hence the stress tolerance (hardness) of the material at high temperatures is important.

Because of the correlation between grain size and hardness, the grain size of the different stainless steels was studied. Two conventional stainless steels (304 and 316) were compared with two high temperature types (321H and 347H). This was done through heating the stainless steels at different temperatures and then measuring the grain size. The conclusion was that the high temperature steels indeed deserve their name. The grain size was significantly lower below (and including) heating to 1020℃. Above that point the high temperature stainless steels do not have a significant difference in grain size in comparison to the conventional temperature steels (304 and 316). See figure 3 for an example of a stainless-steel microstructure.

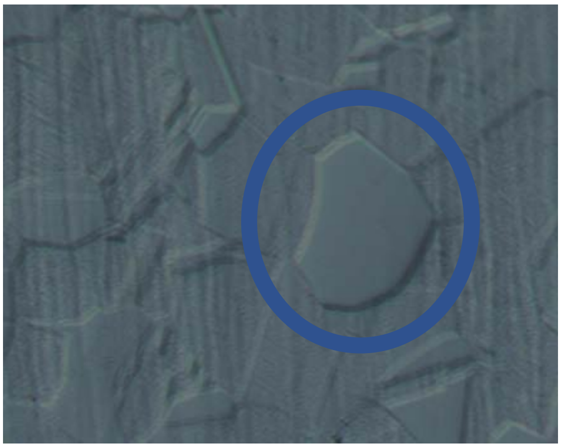

Figure 3: *The microstructure of a stainless steel, where the blue circle marks a particularly clear example of a grain.*

The channels in which the mediums flow, are deformed from a solid piece of stainless steel. Hence, it is very relevant to know how deformed stainless-steel changes grain size after heating it.

The materials were deformed and then investigated for their grain growth. One of the new stabilized stainless steel (347H) exhibited lower grain growth in comparison to non-deformed. No other of the stainless steels did. This is very positive for 347H since this might mean that one of the weaknesses of heat exchanger manufacturing (larger grains in the channels), could be completely removed.

What makes a stainless steel stainless is the thin oxide layer protecting it. In this thesis, a study of whether this could be detected through X-ray diffraction was performed. Direct detection of the oxide layer is useful since that allows detection of corrosion. This is because the oxide layer is present when no corrosion occurs. Corrosion is one of the leading causes in the failure of heat exchangers, generating cracks in the stainless steel.

The experiments were performed by using the state of the art X-ray diffractor at the Division of Synchrotron Radiation Research, Lund's University.

The result did not show a signal for the oxide layer, although it did generate a signal for the stainless steel. The signal was contaminated by artifacts in the beam path. This is positive for future studies, since removing obstructions in the beam path might make the oxide signal sufficiently high. Further studies in this master thesis has been obstructed by covid-19.