Analyze the effect of Molybdenum on Heat Resistance Stainless Steel Casting SCH 22

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Abstract. There was SCH 22 component named hanger that is produced by casting, where it is one of the components applied at 1100°C work temperature. Problems on the product is the occurrence of scaling, causing the function failure and shortening its lifetime. Generally, this scaling occurs when the material is exposed to high temperature, then kinds of iron oxide layers are arisen such as FeO, Fe₃O₄, and others. Based on the literature, Molybdenum can be added to the SCH 22 with maximum limit of 0.5%. The purpose of this study is to know the influence of Molybdenum to the mechanical properties and analyze the phenomenon of scaling on Heat Resistant Stainless steel Casting (SCH 22). It is expected that molybdenum could increase the scaling resistance in the high temperature. The method is making specimens through metal casting process where the molybdenum content are made to 0.3%, 0.7%, 1.1%. Each specimen should be heated at 1150°C and held for 4 hours. Then the mechanical strength and micro structure are observed to see the effect such molybdenum addition. The result is obtained that the 0.7% addition of molybdenum element can reduce the degradation due to scaling on Heat Resistance Stainless Steel Casting SCH 22.

Keywords: scaling, molybden, stainless steel casting, heat resistance.

1. Introduction

The SCH 22 is a Heat Resistant Steel Casting, that is generally applied to working temperature between 650°C and 1315°C. The material is selected because of its resistance to corrosion, it is stable at high temperatures, and its resistant to creeps or heat-breaking/ cracking. The material is applied to heat-resistant components in the cement processing industry, fertilizer industry, oil/ gas industry and in the oven industry heating. It is expected to use local content of the component in product supply, and promotes the development of this material in terms of quality and quantity.

Hanger is one of the components applied at 1100°C. Problems that occur on the product is the occurrence of scaling, that is causing the function failure and shortening its lifetime. Generally scaling occurs because the material is exposed to high temperatures, then kinds of iron oxide layers are arisen such as FeO, Fe₃O₄, and others. There are various ways to increase oxidation resistance at high temperatures, such as adding 25-30% Cr, <2% Si, <4% Al, Yttrium and Cerium as well as by addition of Ni [1][2]. Based on the literature can also be given Molybdenum to the limit of 0.5%.[1]. On other hand, Ferro-Molybdenum addition has influence on impact toughness values of the sintered low alloy steel [3]. The influence of the addition of Molybdenum element to the Heat Resistant Steel of SCH 22, so far has not been studied by practitioners and scientists on a national scale.

The purpose of this study is exploring the influence of Molybdenum to the mechanical properties and analysing the phenomenon of scaling on Heat Resistant Stainless Steel Casting SCH 22. Figure-1 shows the hanger components that have been heated at high temperatures. The component is damaged by degradation.
2. Method

The casting process is designed to obtain the test sample through the manufacture of mold, melting and followed by modification by varying the amount of molybdenum from 0.3% to 1.1%. The specimen pouring scheme can be seen in following figure 2.

![Figure 2. Schemes of molybdenum modification](image)

Specimen test preparation by metal casting process had the following stages; making 4 pieces of mold that is containing of each 3 test specimens in the form of Y-block, following with mold casting with varying amount of Molybdenum. The process of alloying and pouring can be seen in Figure-3. When the Y blocks test sample are already frozen and cold, then it should be removed from the mold. The next process is to clean the Y block test sample from the attached sand. Figure-4 shows a sample of Y blocks that have been cleared.

Preparation of the test sample for tensile test specimen by cutting Y block test sample, then grinding with cylindrical shape. The cylindrical form is then obtained by lathe machine in accordance with the standard size of the tensile test. Figure 5 Shows the sample preparation process for tensile test specimens.
Hard test specimens by cutting the Y block test sample then grinding process with a cylindrical shape. The cylindrical form is by lathe in accordance with the standard size of the hard test. Figure 7 shows the sample preparation process for hardness test specimen.
The next step is heating process on each specimen with the temperature of 1150°C and 4 hours holding time, using a heating stove.

![Figure 9. Heating of specimen with heating stove](image)

![Figure 10. The cycle of heat treatment](image)

Preparation for micro structure test specimen is cutting Y block test sample, then grinding process with cylindrical shape. The cylindrical form is then processed in the lathe according to the different diameter. The cross section to be observed, sanded gradually from 240 to 1000 mesh. Then, it is polished by using alumina powder and etching process afterwards, by etching *vilella* for 18 minutes.

![Figure 11. Preparation for tensile test specimens](image)

![Figure 12. Specimen test for tensile strength](image)

Figure 11. shows a specimen that has been heated at a temperature of 1050°C, and has been held for 4 hours. Figure 12 mentions the observation with an optical microscope for viewing and determined the *scaling* mechanism on Heat Resistant Steel. Microscopic observations are performed by optical microscope with magnification of 100x and 500x, performed at the center and edge of the specimen. Such testing is performed to determine the phase configuration that occurs.
3. Results and Discussion

3.1. Results of Chemical Composition Characterization

The carbon content exceeds the target where the target at JIS standard is max 0.45 % and actual 0.50 % but it can still be tolerated because it is still close to the DIN standard which has a maximum carbon content of 0.5 %. For the composition of chemical elements such as Si, Mn, Ni and Cr are according to the standard.

Table 1. Chemical composition

| Standard          | Chemical composition ( % ) |
|-------------------|----------------------------|
|                   | C  | Si  | Mn  | P  | S  | Ni | Cr  |
| JIS               | 0,35-0,45 | ≤ 1.75 | ≤ 1,5 | ≤ 0,04 | ≤ 0,04 | 19-22 | 23-27 |
| Foundry results   | 0,50 | 1,1  | 1,2  | 0,03 | 0,00 | 19,8 | 25,4 |

All specimens have the same composition as those listed in Table 1. While the difference is its molybdenum due to the modification. The results of the composition of the molybdenum modification are shown in Table 2.

Table 2. The results of the composition of the molybdenum modification

| Specimens       | I  | II | III | IV |
|-----------------|----|----|-----|----|
| Target % Molybdenum | 0  | 0,3| 0,7 | 1,1|
| % Molybdenum actual | 0  | 0,15| 0,5 | 0,7|

It is noticed that the target did not match with actual result. This was analyzed in addition to improper ladle volume calculation and incomplete fluid stirring process in the ladle, which caused the liquid became to the non homogeneous. But the data can still be used anyway because the Mo content tends to increase.

3.2. Results of Mechanical Testing Characterization

The tensile testing process is based on the JIS Z 2201 standard.[8] Figure 11 shows the curve of tensile test results.
Tensile strength values of about 400 to 500 N/mm$^2$ are obtained. The value of the tensile strength standard value for SCH 22 material is 440 up to 640 N/mm$^2$. The highest tensile strength is in the amount of molybdenum of 0.5 %. The above curve shows that the influence of molybdenum increases its tensile strength but not in the very significant value.

3.3. Results of Microstructure Characterization

Observation of microstructure on all specimens that have been heated at 1150°C with 4 hours holding time, is done with 100x magnification, on the side or edges of objects, with following results.

Figure 14. microstructure SCH 22 after heated 1150°C with held for 4 hours, without modification Mo.

Figure 15. Microstructure SCH 22 after heated 1150°C, held for 4 hours with modification 0.15% Mo

Figure-14 shows the micro structure of stainless steel SCH22 without molybdenum modification. There is degradation at the grain boundary up to 2 mm deep from the surface. Scalling begins from the grain boundary of the carbide that surrounds the austenite phase. Further, Figure-15 shows the micro structure with 0.15 %, in which the degradation at the grain boundary is approximately 400 mm deep from the surface.

Figure 16. Microstructure SCH 22 after heated 1150°C, held for 4 hours with modification 0.5% Mo

Figure 17. Microstructure SCH 22 after heated 1150°C, held for 4 hours with modification 0.7% Mo

Meanwhile, Figure-16 shows the micro structure with 0.5 % molybdenum modification, with the same heating at 1150°C in 4 hours holding time where the degradation at the grain boundary is approximately 200 µm depth. For these additions of molybdenum element, the degraded areas of samples are dwindling. In Figure-17, modification of 0.7% molybdenum shows the degradation at the grain boundary with the depth of approximately 50µm, and, the degraded areas are more dwindling.
Figure 18. Microstructure SCH 22 after heated 1150°C, held for 4 hours without modification Mo, 500x magnification.

Figure 19. Microstructure SCH 22 after heated 1150°C, held for 4 hours with modification 0.7% Mo, 500x magnification.

Figure-18 and Figure-19 compare the SCH 22 microstructure between 0% molybdenum with a 0.7% molybdenum. With 500x magnification it appears more clearly morphologically of the grain boundaries that are affected by degradation or scaling. From such observation of microstructure, with the higher percentage of molybdenum up to 0.7% it is shown that the degradation due to oxidation or scaling on carbide grain boundaries is getting thinner. It indicates that the molybdenum element can strengthen the bond at the carbide grain boundary, thereby it is increasing the heat resistance in the area as well.

4. Conclusion

After the number of processes, the addition of molybdenum element up to 0.5% into Heat Resistant Stainless Steel Casting /SCH 22 material can increase its tensile strength, although not so significantly. However, the addition of such element up to to 0.7% has no effect on the value of hardness. Moreover, this 0.7% addition of molybdenum element can reduce the degradation due to scaling on SCH22 stainless steel as well.

5. References

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