Experiment of adding molybdenum to AISI 310 to increase tensile strength

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Abstract. Supercritical coal power plants began in 1983 with 24.1 MPa moisture parameters and 538°C / 538°C temperature (superheated and reheated steam). Ultra supercritical technology began in 1993 with 24.1 MPa and 538°C / 593°C. Starting in 2000, an ultra-high temperature supercritical power plant was built at 25MPa and 600°C / 620°C in Tachibana and Isogo Powerplants. From this phenomenon, together coal at the power plant, there is often damage to the turbine blade because the material from the turbine blade is not able to withstand temperatures > 760°C. So the words between these can be analyzed by adding molybdenum on AISI 310 raw material in order to find a new material that is resistant to temperature > 760°C. Stainless steel is a steel that has an important role in the industry. One type of stainless steel is austenitic stainless steel. In general, stainless steels containing Ni, Cr and no other blends. The strength and tenacity of the austenitic stainless steel can be increased by alloying and thermo mechanical treatment (TMT). In the integration process, a structure can be carried out which can be improved by the mechanical properties of the material. To find out the austenitic stainless steel needs to be developed to increase resistance to the corrosive environment, and also its mechanical properties. This development can be done by combining AISI 310 with Molybdenum

Keywords: power plant, stainless stell, AISI 310, molybdenenum

1. Introduction
The world’s energy needs are increasing with the increasing population of the world population. This was explained in APEC Energy Demand and Supply Outlook - 5th Ed [1]. It can be seen in Figure 1, an increase in energy demand continues to occured from year to year, especially in industry and transportation. In addition to increasing energy needs, technology to get energy from year to year has increased from one of the super critical steam power plant to ultra critic. Powerplant is now increasingly being used as the main source of electrical energy. Utilization of
steam power in this steam power plant uses the principle of utilizing turbine turns connected to generators [2].

![Figure 1. World’s energy need 1990-2035 [1]](image)

At the super critical steam power plant the critical temperature and pressure that must be achieved is more than 600°C at 28 MPa at efficiency of 40% - 45% and its not fulfilling the desire of the purpose of the existing steam power generation system. As for the use of ultra-critical technology, it is expected to reach temperatures of 760°C - 800°C with a steam condition of 35 MPa. The high temperature and pressure that must be achieved in a super critical Powerplant has an impact on the high temperature that must be resisted by the turbine blade, especially the turbine blade material which has a stainless steel base. One type of stainless steel is austenitic stainless steel. In general, these stainless steels contain Ni, Cr and other combined elements. Where almost all turbine blade material in the power plant is a mixture of steel with a content of 9% - 12% Cr [3]. Meanwhile, in the ultra critical power plant, the turbine blade material with alloy steel with a content of 9-12% Cr has not been able to withstand high temperatures up to 800°C. For material grades with Cr contents above of 12%, the eutectic carbides typically are (FeCr)\(_7\)C\(_3\) which are much harder that a common of FeCr [4].

Generally, by adding other alloying element, the bulk of hardness and abrasion wear resistance of these alloys is increasing also [5-8]. For example, the addition of molybdenum is to improves the corrosion resistance of the passive layer in the presence of chloride ions (chemicals, road salt, sea water, etc.), so steels with this addition element have a higher resistance to pitting and crevice corrosion than conventional nickel-chromium steels [9].

While the results of the study [10-12] show that the addition of molybdenum could increases corrosion resistance of forged austenitic stainless steels and it lowers a critical passivation, shift positive value, raise the temperature of the critical pitting and also reduces the number and size of pitting. It is expected that the addition of Molybdenum elements can increase the resistance of high temperature resistant materials to reach temperature more than 760°C.

The material will later be used in high temperature boiler and turbine components to ensure sufficient creep strength. In this research, smelting is conducted on AISI 310 and adding some Molybdenum around 0.054% and knowing how much value of tensile strength and hardness will get.

2. Experimental method
304 stainless steel scrap was chosen as the raw material for this study. The first process is smelting AISI 304 Stainless steel scrap with the addition of a determined chemical element to become AISI 310 Stainless steel. After the process, AISI 310 Stainless steel is added with another alloy element,
Molybdenum (Mo), to obtain a higher temperature resistance than AISI 310 Stainless Steel, only 500°C. The next process is the homogenization process, to get the homogenization of the chemical composition of a metal alloy from the casting process. Then the chemical composition is have an examination and tested for the mechanical properties of materials with two research results, strength testing (tensile test) and hardness testing using brinell (HB), then the results of the study were analyzed with the value of the test results using the standard used.

3. Results and discussion

3.1 Chemical composition examination

With qualitative observations, the chemical elements contained in the casting experience have an imperfect mixture of materials than expected results, because they contained alloying elements that are not in accordance with AISI 310 standards on the market. These results have been tested by optical emission spectrometers, with the ARL 3460 testing machine. Optical Spectrometer and refers to the standard Manual Book ARL 3460. Chemical composition can be seen in Table 1.

| No | Element   | (%)  |
|----|-----------|------|
| 1  | Carbon (C) | 0.080|
| 2  | Silicon (Si)| 0.529|
| 3  | Sulfur (S) | 0.010|
| 4  | Posfor (P) | 0.028|
| 5  | Manganese (Mn) | 0.740|
| 6  | Nickel (Ni) | 19.659|
| 7  | Chromium (Cr) | 22.25|
| 8  | Molybdenum (Mo) | 0.054|
| 9  | Ferro (Fe) | 56.125|
| 10 | Aluminium (Al) | 0.008|

3.2 Results comparison

Figure 3 is a comparison graph of fracture between AISI 310 material and AISI + Molybdenum, from both graphs it can be seen that AISI 310 + Mo material has a fracture resistance value of ±21000 N at 23 mm, the value is higher than that of AISI material 310 with a fracture value of ±20000 N at 22.5 mm. This proves that the addition of molybdenum material to the AISI base material can increase the fracture strength value.

Figure 4 shows stress and strain on AISI 310 and AISI 310 + Molybdenum materials. It can be seen in both graphs that AISI 310 Material has a stress vs. strain value of ±400 MPa vs ±48%, this value is lower than the test results obtained by AISI 310 + Molybdenum material with a value of ±500 MPa vs ±63%. It states that the addition of molybdenum material to AISI 310 can increase the tensile strength of the material by ±100 Mpa.
Brinell hardness testing is done by three times testing at different points, with relatively different values and then obtained an average value. It can be seen from table 2 that the AISI 310 material hardness value has a hardness value of 56 HRB compared to the AISI 310 + molybdenum material magnitude value with a value of only 46.6 HRB.

| Material          | Brinell Test with Steel Ball Ø1/16inch |
|-------------------|---------------------------------------|
|                   | 1st    | 2nd    | 3rd    | Average |
| AISI 310          | 48 HRB | 60 HRB | 60 HRB | 56 HRB   |
| AISI 310 + Mo     | 42 HRB | 59.5 HRB | 38 HRB | 46.5 HRB |

The comparison of the hardness values shows the addition of molybdenum material that have an impact of decreasing in the hardness value of AISI 310 material. It is also experienced by wang.al [13] where after increasing the Molybdenum content it can reduce the hardness value around 288 HV (Hardness Vicker) the value result is only half of the material hardness value without the addition of molybdenum.

4. Conclusions
From the results of tests and discussions that have been carried out, it can be concluded that, the tensile strength test results of AISI + molybdenum material are higher than the tensile strength values of AISI material without molybdenum with values of ± 500 MPa vs ± 63% and ± 400 MPa respectively vs ± 48%. Whereas the AISI 310 + molybdenum material hardness test value is still
lower than the AISI 310 material without the addition of molybdenum with the respective values of 46.6 HRB and 56 HRB.

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