Material Characterization of 316L Stainless Steel After Being Subjected To Cryogenic Treatment

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Abstract - Post processing of materials is necessary to suit them for the intended requirements. The properties of stainless steel of grade 316L cannot be influenced with further processing such as hot working [1]. Thus the current study aims at investigating the properties of stainless steel of grade 316L after being subjected to deep cryogenic treatment. The specimens from both cryogenically treated and untreated conditions were subjected to Tensile Test, Charpy Impact Test, Rockwell Hardness Test, Microstructure and Percentage Shear Area Analysis and the results thus obtained are discussed in this paper. The results have shown that cryogenic treatment has improved the hardness and strength.

Keywords - *Cryogenic Treatment, 316L stainless steel, Tensile toughness, Hardness, Impact strength, Microstructure, Percentage Shear Area.*

I. INTRODUCTION

Cryogenic Treatment is the process of subjecting the material to a very low temperature such as -186 °C. This can be done by treating the material in a liquid nitrogen gas chamber. The cooling is done gradually and then allowing it to come back to room temperature naturally after a long soaking. Previously done studies suggest that after being subjected to cryogenic treatment various types of steels like tool steel have shown an increase in hardness[2], carburized steel shows an increase in Hardness and Tensile strength [3],4340 steel shows a increase in fatigue life, slight decrease in impact strength, increase in hardness[4], austenitic stainless steel of grade 304 showed an improvement in fatigue limit and fatigue life and without any significant changes in hardness and Ultimate Tensile Strength[5,6], Also a bibliographic review of various metals subjected to cryogenic treatment have laid the emphasis on the changes which undergoes in mechanical properties of various materials [7]. But very less investigation has been done to study the material characteristic of austenitic stainless steel of grade 316L. The current study aims at investigating and comparing the material characteristics of 316L stainless steel before and after being subjected to Cryogenic Treatment.

II. MATERIAL AND METHODOLOGY

For this investigation stainless steel of grade 316L (S31603) a molybdenum-bearing austenitic stainless steels which is more resistant to general corrosion and pitting/crevice corrosion than the conventional chromium-nickel austenitic stainless steels such as Type 304. These alloys also offer higher creep, stress-to-rupture and tensile strength at elevated temperature. In addition to excellent corrosion resistance and strength properties, the Type 316L also provide the excellent fabricability and formability which are typical of the austenitic stainless steels. The chemical composition of which is given below in table 1.

Table 1: Material chemical composition

Material		**C**	**Mn**	**Si**	**S**	**P**	**Cr**
Weight %		0.019	1.693	0.503	0.011	0.020	16.448
Ni	**Mo**	**V**	**Cu**	**Sn**	**B**	**Co**	**Nb**
10.094	2.094	0.187	0.410	0.007	0.0003	0.240	0.036

2.1 Cryogenic Treatment

In this process liquid nitrogen is passed over a chamber containing the specimens for a period of 1 hour so as to decrease the temperature from room temperature to -186 °C. After attaining the required temperature it is to be maintained for the next 16 hours. Finally it is allowed to get back to room temperature naturally from -186 °C as shown in fig.2.

Fig.1. The Cryogenic Treatment Chamber

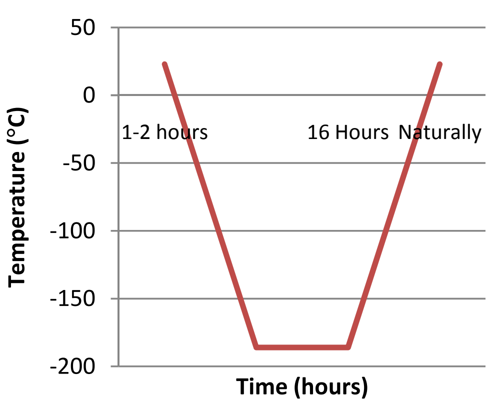


Fig.2. Cryogenic Process steps involved.

2.2 Tensile Test

The ASTM standard A370-77 [10] specimens are prepared for the tensile test as shown in Fig.3.

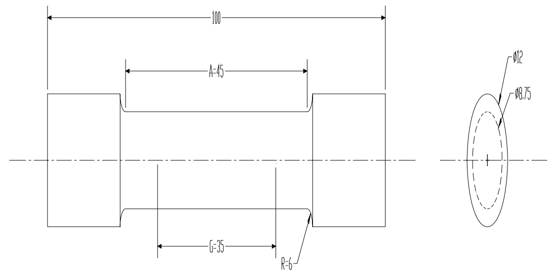
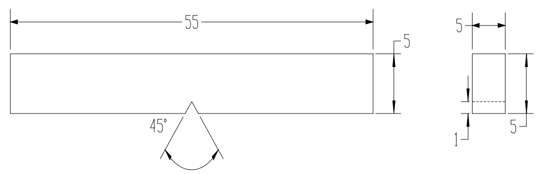


Fig.3. Tensile Test Specimen Geometry.

The test was carried out on a Universal testing machine at room temperature with the load being applied gradually for both the cryogenic treated and untreated specimens and the results thus obtained were recorded.

2.3 Charpy Impact Test

The specimens for the Charpy Impact Test are prepared as per the ASTM standard E23-72 [11] and the specimen geometry is shown in Fig.4



All dimensions are in mm

Fig.4. Impact Test Specimen Geometry.

The Impact test is carried out on Impact Testing Machine at room temperature for both the Cryogenic treated and untreated specimen and the results thus obtained are recorded.

2.4 Rockwell Hardness Test

The Rockwell Hardness Test was carried out on Rockwell Hardness Tester at room temperature for the Cryogenic treated and untreated specimen and the results obtained were recorded. The major load applied is 150 Kg. The scale used is HRC.

2.5 Microstructure Analysis

The microstructure of the stainless steel was prepared as per ASTM standard with the prescribed etchant. These specimens were observed under the optical microscope and the microstructures before and after cryogenic treatment were obtained.

2.6 Percentage Shear Area

The Percentage shear areas were obtained by comparing the actual fractured surface with the comparator chart given in ASTM E23.

III. RESULTS AND DISCUSSIONS

The results obtained during the Tensile test, Charpy Impact test, Rockwell Hardness test, Microstructure and Percentage Shear Area of 316L stainless steel before and after cryogenic test are illustrated and discussed below :

3.1 Tensile Strength

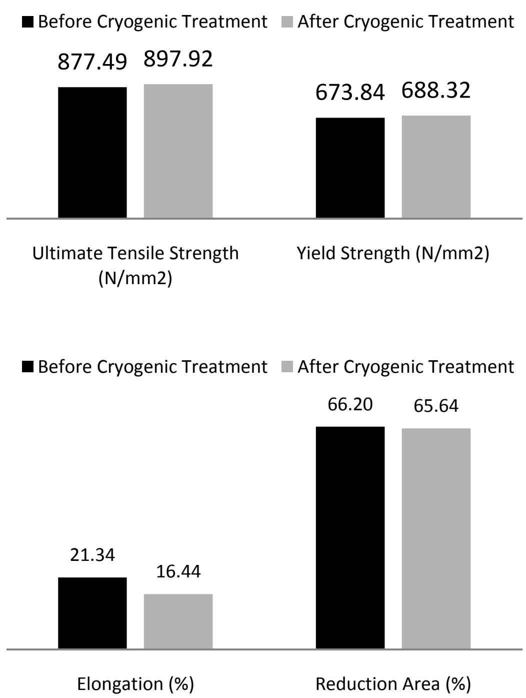


Fig.5. Tensile Test Results.

The Ultimate Tensile Strength and Yield strength have shown a slight improvement along with slight decrease in Percentage elongation and percentage reduction area as seen in fig.5. This illustrates that thereis an increase in strength and decrease in ductility.This shows that there is a chance for increase in the hardness.

The plot shown in fig.6. shows that there is time for necking is more in the cryogenically treated sample when compared to untreated sample and this may be due to hardening effect.

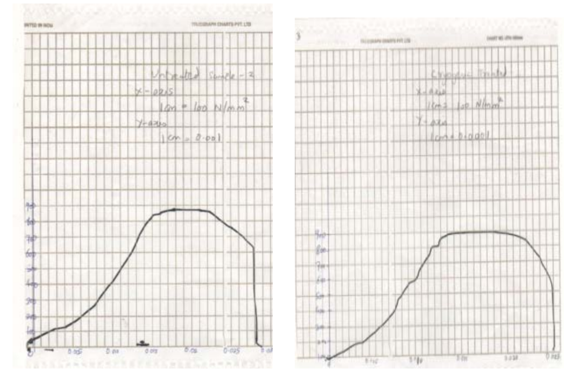


Fig.6. Stress – strain curve (a)before Treatment and (b) after Treatment.

3.2 Charpy Impact Toughness

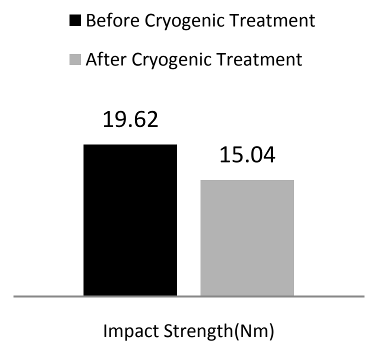


Fig.7. Impact Toughness.

The Impact toughness shows a decrease in value as seen in fig.7.which also leads to an indication that hardness value can increase

3.3 Rockwell Hardness Number

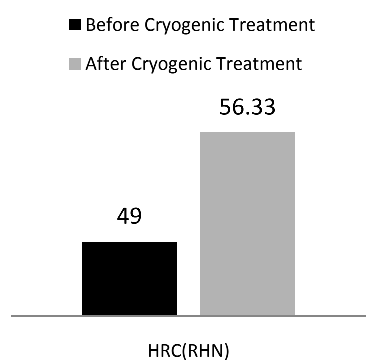


Fig.8. Hardness Survey

As discussed in the above tests, there is an increase in hardness value for the cryogenically treated material as seen in fig.8.

3.4vMicrostructure

Fig.9. Micro structure at 100X (a) Before Treatment and (b) After Treatment

The microstructure shows precipitation of carbides along the grain boundaries as seen in fig.9. This may lead to an increase in hardness.

3.5 Percentage Shear Area

(a) (b) (c)

Fig.10. (a) Before Treatment (60%) (b) After Treatment (63.33%). and (c) Comparator for 60%.

The above values obtained in fig.10.on comparison with percentage shear fracture comparator shows a slight increase in the value which is negligible.

IV. CONCLUSION

The investigation on the material characteristics of stainless steel of type 316L after being subjected to Cryogenic Treatment leads to the following results:

1. The Tensile Strength and Yield strength of the material are found to have increased along with a decrease in percentage elongation and reduction in percentage area. This actually shows the increase in strength and decrease in ductility. Also more time to neck is seen in cryogenically treated samples due to increase in hardness.
2. The Impact toughness of the treated sample is less than untreated samples this indicates there might be an increase in Hardness as the toughness and hardness are generally inversely proportional.
3. The Hardness of the treated sample shows a significant increase than untreated samples.
4. The Microstructure shows precipitation of carbides along grain boundaries which may lead to hardening effect.

Thus from the above tests we can see an improvement in hardness of cryogenic treated samples which indicates there is scope for increase in wear resistance.

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