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# INVESTIGATION OF MICROSTRUCTURE OF CYCLICALLY CRYOGENICALLY TREATED SPECIMENS OF SS316L AND COMPARISON OF ITS MECHANICAL PROPERTIES WITH CYCLICALLY HEAT TREATED SPECIMENS USING IN AN AUTOMOBILES.

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## ABSTRACT

Subject to a continuing debate, cryogenic treatments of alloy steels have been claimed to significantly increase wear resistance and toughness through the interplay of three effects: completing martensitic transformation, promoting uniform precipitation of fine carbides and imparting residual stresses. This study reexamines effects of various heat-treatment schedules including cyclic heat treatment at (690 C) and cyclic cryogenic(Shallow) treatment at (-85 C) on microstructure and selected properties of Stainless steel 316L.Examination methods include SEM,, micro hardness, Charpy impact, wear resistance measured using the standard pin-on-disk technique adopted from the field of thin-film technologies. Results confirm the cryo-treatment enhanced precipitation in the subsequent tempering step of what turns out to be 100-250 nm alloy-depleted carbides, and moderate improvements in wear resistance and hardness, both scaling with the cryogenic treatment time and at the cost of reduced impact resistance and also corrosion resistance. Reported results and correlations shows that it is mainly suitable for automobile industries.

***Keywords: Cryogenic Treatment, Hardness, SEM analysis***

## 1. INTRODUCTION

Steel is widely used in the various engineering application such as automotive, agricultural, constructional purposes etc. Steel generally contains 0.02–2.1% carbon content and depending upon the need of industry steel is selected for different processes. After that there are different types of heat treatment processes which used for improving its various mechanical properties by altering the microstructure of steel. Properties of heat treated specifically depend on three different phases such as heating temperature, soaking period and cooling rate. Over the past few decades, extensive interest has been shown in the effect of low-temperature treatment on the performance of stainless steels [1, 2, 3]. Low-temperature treatment is generally classified as either “Shallow Cryogenic treatment” at temperatures down to about −85 C or “Deep Cryogenic treatment” at liquid nitrogen temperature of −196 C [5].Cryogenic treatment is not a substitute for heat treatment, as often mistaken for, but it is a supplementary process to conventional heat treatment before tempering [2, 5].Cryogenic treatment is an optimal method for reducing percent of retained austenite. Cryogenic treatment consists of heating steel up to austenite temperature, cooling it in quench environment and then immediately putting it in sub- zero centigrade degree and then tempering heat treatment. Increasing resistance to wear, reduction of internal stresses, consistency of dimensions and deposition of micro carbides in the field can be regarded as the most important privileges of using cryogenic heat treatment. The less the temperature of cryogenic environment, improvement in properties is performed with more rapidity. [4] With cryogenic treatment applied immediately after quenching, residual austenite is reduced, and spots for the nucleation of -carbides created during tempering are created in martensite.

Cryogenic treatments can produce not only transformation of retained austenite to martensite, but also can produce metallurgical changes within the martensite. This offers many benefits where ductility and wear resistance are desirable in hardened steels [6] Previous research studies mainly focuses on the enhancement of the properties of high speed steel, tungsten carbide, aluminum, die steel and its micro structural changes. The objective of this work was to investigate the effects of cyclic cryogenic treatment in conjunction with the inter critical heat treatment on the wear behavior, hardness and microstructure changes in stainless steel 316L.

## 2.SUMMARY OF LITERATURE REVEIW

Recent studies have indicated that cryogenic treatment is an essential supplementary treatment, which is performed on products after conventional heat-treatment in order to increase their wear resistance in some materials and to produce dimensional stability in others. The cryogenic treatment is conducted on stainless steels, tool steels, maraging steel, cast iron, carburized steel, tungsten carbide, polymers and composites. In all of the materials mentioned, the cryogenic treatment increases the wear resistance and subsequently increases the product life. The cryogenic treatment has been used as a finishing process in the past few decades. This process is also being used in aircraft and automobile industries as well as many other areas.Over the last decade, several researchers have reported that the Cryogenic Treatment (CT) considerably improves the wear resistance (WR) of steels than those obtained either by Cold Treatment (CT) or by Conventional Heat Treatment (CHT). In addition, it has also been reported that Cryogenic Treatment and multiple tempering after cryogenic treatment enhances the dimensional stability and reduces the residual stresses. These positive effects increase the service life of the components made of AISI 316L stainless steels. Literature of past work does not adequately clarify the selection of tempering, cryogenic temperature and soaking time. There is a need to standardize the process for cryogenic treatment in particular stainless steels and understand the underlying metallurgical mechanism responsible for improvement of wear and changes in microstructure during cyclic cryogenic treatment. In general, cyclic cryogenic treatment and multiple tempering are still in the dormant level as far as microstructure level study is concerned. This is the main focus of the present work on Stainless steel 316L.

### 2.1 Problem Definition

Effects of cyclic cryogenic treatment on microstructure and physical properties of stainless steel 316L and comparing its physical properties after each cycle of the cryogenic treatment with that of each cycle of conventional heat treatment.

### 2.2 Objectives

Therefore the present investigation is based on the effect of cyclic cryogenic and heat treatment and study of its various properties after each cycle on stainless steel 316L and has following objectives,

1)To make a comparative study on the hardness of cyclically cryogenic treated SS316L samples with that of cyclically heat treated austenitic stainless steel of grade SS316L.

2)To study the effect of cyclic cryogenic treatment on the microstructure of cyclically cryogenic treated specimen and compare with cyclic heat treated specimen.

3) To study the micro structural changes using optical microscope and SEM.

4)To study the corrosion behavior after cyclic cryogenic treatment using intergranular corrosion test(IGC) using practice E

5)It is intended that, this research will be useful in promoting the applications of cryogenic treatment on stainless steel 316L.

## 3. EXPERIMENTAL PROCEDURE

The investigations were made by using the specimen made from the sheet having dimensions 300mm wide & 10 mm thick. After that the specimen were divided into two groups A & B. First of all the group A specimen were heat treated in a muffle furnace at a temperature of 690o C for about 60 minutes followed by cooling it down in the furnace then this is continued for three different cycles. The Group B specimen were shallow cryogenically treated at a temperature of -85 0C having soaking period 12 hours under controlled conditions followed by tempering at a temperature of 240 0C for about 1 hour and this is repeated for 3 consecutive cycles. Treatment process of the specimen are shown in Fig.1.The samples of the group A & B were then subjected to microhardness test to study the effect of shallow cryogenic treatment over cyclic heat treatment. Then we study the microstructure of the group B specimens after each cycle of shallow cryogenic treatment

### 3.1 Intergranular Corrosion Test

The specimen was prepared according to ASTM standards (60 x30x4mm) the specimen was kept in acidified copper sulfate solution by dissolving 100 gm of copper sulphate, 700ml of distilled water and 100ml of sulphuric acid solution and diluted to 1000 ml with reagent water. The specimen was put in the solution for 2 days and the bend test was conducted on shallow cryogenically treated specimen for three cycles and no fissures or intergranular cracks were formed on the surface of the specimen after the test.

### 3.2 SEM Analysis

SEM was carried for both cryogenically treated samples to study the microstructural changes. Results of the SEM analysis are shown in fig. 3.3.1 and fig. 3.3.2 for cryogenically treated corroded and uncorroded SS316L samples respectively. The results showed the presence of the fine precipitated carbide particles in case of cryogenically treated samples which verify that the refinement of carbides takes place after the cryogenic treatment.

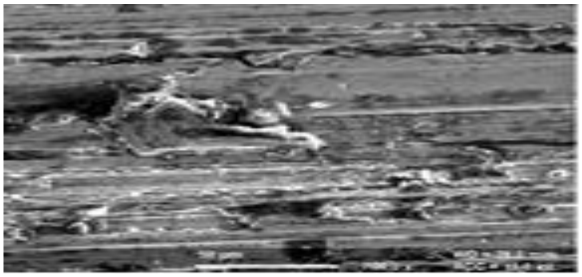

***Fig.1 SEM image of stainless steel 316l after corrosion test***

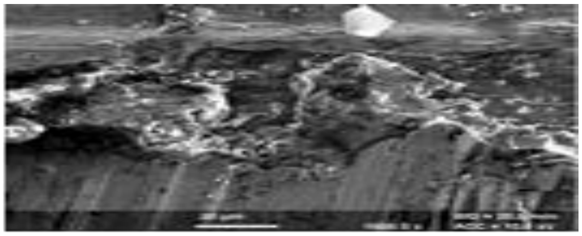

***Fig.2 SEM image of uncorroded SS 316l after corrosion test after a single cycle of shallow cryogenic treatment***

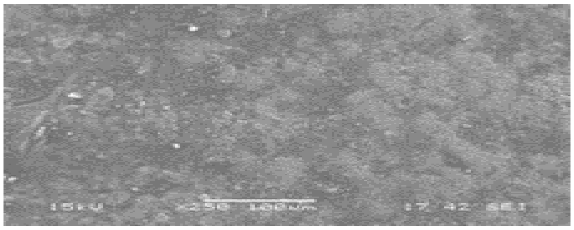

***Fig.3 SEM image of uncorroded SS 316l after corrosion test after a second cycle of shallow cryogenic treatment***

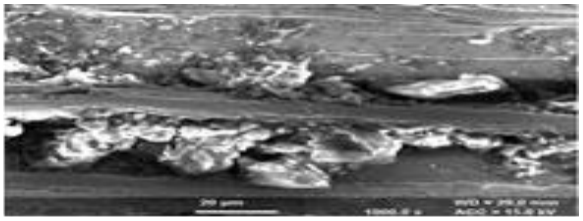

***Fig.4 SEM image of uncorroded SS 316l after corrosion test after third cycle of shallow cryogenic treatment***

## 4. RESULTS AND DISCUSSION

Table 4.1 shows the hardness of both cyclically cryogenic treated and cyclically heat treated SS316L (Stainless Steel316L) samples. They are having somewhat similar result where there is no much variation in the hardness values of cyclically heat treated samples and cyclically shallow cryogenic treated samples.

***Table 4.1 Results of Rockwell Hardness test of cyclic cryogenic treated specimens and cyclic heat treated specimens***

| Cycle | Hardness (HRb) Cyclic cryogenic treated |
|---|---|
| After cycle 1 | 83.8 |
| After cycle 2 | 79.3 |
| After cycle 3 | 76.6 |
|  | Hardness (HRb) Cyclic heat treated specimens |
| After cycle 1 | 84.3 |
| After cycle 2 | 81.3 |
| After cycle 3 | 78.1 |

The results obtained in the present study are in accordance with the above two tables. Even the micro hardness results also are not showing conspicuous variation between the cyclic shallow cryogenic treated and cyclic heat treated specimen. The precipitation of fine carbides during the cryogenic treatment cycle may affect the wear resistance and the toughness but only a small, if any in specimen hardness. It was seen that the hardness falls uniformly after each cycle in both cases i.e. the cyclic shallow cryogenic cycle and cyclic heat treated specimens.

## 4. CONCLUSION

1. The shallow cryogenic treatment makes the carbides present small in size which was observed from microstructure comparison of cyclic heat treated specimen and cryogenically treated specimen and more the cycles the more the affinity for number of carbides to be small and they will be lying uniformly with large carbides which may be helping to increase wear resistance .
2. In the corrosion test, the weight loss of cryogenically treated specimen is more as compared to that of untreated specimen. This can be attributed to the fact that tspecimen becomes brittle after cryogenic treatment.
3. As of SEM analysis, it is obvious that refinement of carbides is extra in case of cryogenically treated stainless steel 316L in comparison to that of cyclically heat treated specimen.
4. There is not much difference in hardness between cryogenically treated and cyclically heat treated SS 316L specimens. But hardness decreases with each cycle of shallow cryogenic treatment
5. It was also observed that post-cryogenic treatment fine machining (grinding) is easier in case of cryogenically treated specimen rather than cyclically heat treated specimen.
6. Homogenized annealing will increase the average grain size of both pro eutectiod ferrite and austenite. The cyclic heat treatment will diminish the grain size of both pro eutectoid ferrite and austenite in case of cyclic heat treatment.
7. As a result of repeated cryogenic treatment the presence of retained austenite is decreased.
8. After each cycle of cryogenic treatment more the number of retained austenite is changed to martensite in case of cyclic cryogenic treatment.
9. The grain structure microstructure get more and more refined with each cycle of cryogenic treatment.
10. Carbon clustering decreases due to lesser the carbon density with each cycle of shallow cryogenic treatment which causes decrease in hardness with each cycle.
11. After cryogenic treatment the microstructure is heated up uniformly inside the chamber which makes the molecules coarsen in nature hence after each cycle the molecules become coarser in nature which is the reason why specimen gets less hard in nature after each cycle in case of cyclic heat treatment.
12. From this result we have concluded that, this material is most suitable for automobile fields.

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