International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 12 (2015) pp. 30901-30910

http://www.ripublication.com

Effect Of Shallow Cryogenic Treatment On Mechanical Properties Of AISI 1018 Steel

T.S.V.Dheemanth[1], K.Rahul[1], N.Suman[1], R.Devanathan[1], Sanjivi Arul[2]

[1]Students, [2]Associate Professor,
Department of Mechanical Engineering, Amrita School of Engineering,
Amrita Vishwa Vidyapeetham, Coimbatore –641112, Tamilnadu – India
[2]s_arul@cb.amrita.edu

ABSTRACT

In this work the effect of shallow cryogenic treatment (SCT) on mechanical properties of AISI 1018 steel were studied. Experimental studies were conducted on the carburized, shallow cryogenic treated and untreated AISI 1018 steel specimens. Carburizing is done at 920^{0}C, kept at that temperature for 10 hours. Shallow cryogenic treatment (-77^{0}C) is performed on carburized specimen in order to improve mechanical properties. Mechanical properties like tensile, hardness, wear test were performed, it shows improved results on shallow cryogenic treated and case carburized steel material compared to untreated material and non-carburized material. This is due to transformation of some amount of retained austenite (in carburized specimen near case alone) to martensite.

Keywords: AISI 1018 steel, carburizing treatment, Shallow cryogenic treatment (SCT), Hardness, Tensile, Wear, Microstructure

INTRODUCTION

Surface hardened AISI 1018 steel is used in the manufacturing of parts such as dowels, worms, pins, gears, etc. Carburizing one of the effective technique used in surface hardening of steel [1].

Bulk modification and surface modification techniques are widely employed to improve mechanical properties of a material. In bulk modification technique, the properties of material change throughout the material. This can be accomplished by changing chemical composition, heat treatment or cryogenic treatment [2-5]. Surface modification techniques include coatings, diffusion treatment, surface alloying, surface hardening, etc. surface modification is used to improve properties at surface without changing properties at core [6, 7].

In recent decade cryogenic treatment is applied for many steels to improve wear and other material properties. But there is no single phenomenon which explains how cryogenic treatment improves the performance of steel. R.Mohandoss et al. [1] studied the influence of cryogenic cooling on case carburized EN-19 reports that there is increase in tensile strength, hardness in case carburized and cryo-treated compared to case carburized and un-treated steel material resulting in case carburized condition there are traces of retained austenite in the case region for about 3-4%. In cryo treated condition these retained austenite has been converted to finely distributed martensite in a ferrite matrix. Devanathan et al reported that increase in the hardness is due to the shallow cryogenic treatment (SCT) after GTAW welding process [8].

Baldissera and Delprete et al. [9] said that the improvement in mechanical properties of cryo-treated steel can be ascribed to different phenomena such as;

(i) Precipitation of small secondary carbides
(ii) Complete change from the retained austenite into martensite;
(iii) Significant reduction of residual stresses.

It is reported that martensite transformation starts at martensite start temperature (M_s) and continues till martensite finish temperature (M_f) [1] which is well below room temperature for AISI 1018 steel. Low temperatures are generated either by shallow cryogenic treatment (SCT) using dry ice (-77^{0}C) or deep cryogenic treatment (DCT) using Liquid Nitrogen (-196˚C). Normally, shallow cryogenic treatment is widely used for high precision parts in order to have high dimensional stability [10].

Concerning the carburized steels, it has been observed that both retained austenite elimination and precipitation of fine carbides with the help of an optical microscope are effective in deep cryogenic treatment mechanisms [11].

M. Preciado et al states that the no decrease of retained austenite fraction has been detected but the precipitation of Fine secondary carbides been observed in a carburized steel in [12].Barron and Mulhern et al. [13] reported that significant improvement on the sliding wear performance of cryo-treated cast iron and it is observed as 43.5% in the case of C1045 steel. In order to improve properties at core as well as surface, carburizing and shallow cryogenic treatment is employed.

The aim of this work is to study the effect of shallow cryogenic treatment on mechanical properties of case carburized AISI 1018. Shallow cryogenic treatment shows its effect only when the carbon percentage of steel is above 0.6% [1]. So, carburizing is required to change carbon percentage of AISI 1018 from 0.156% to above 0.6%. Carburizing has been performed in order to increase the carbon percentage from 0.156%C to 0.711%C near the surface, followed by shallow cryogenic treatment (SCT) which has been done at -77^0 C for different soaking periods. Carburizing is done at a temperature of 920^{0}C and kept at that temperature for 10 hours. Tensile, hardness, surface roughness and wear tests were conducted on commercial, carburized, carburized and shallow cryo-treated specimens. Soaking time, which is being one of major factors in shallow cryogenic treatment, is studied in this work.

Experimental Procedure

Chemical composition of commercial AISI 1018 steel and case carburized steel is confirmed using the spectroscopic analysis as reported in the Table 1. Case Carburizing is performed on commercial AISI 1018 steel of size 300 mm width × 200 mm length × 5 mm thickness and composition of material after carburizing is shown in Table 1. The specimen were cut as per the test requirements. The experimental samples of commercial, Case Carburized AISI 1018 steel with and without shallow cryogenic treatment process are numbered as reported in the Table 2.

Table 1: Chemical Composition of Commercial and Case Carburized AISI 1018 steel.

Composition	Commercial	Case Carburized
%C	0.156	0.711
%Si	0.238	0.209
%Mn	0.835	0.810
%P	0.012	0.012
%S	0.016	0.004

Table 2: Experimental Sample Details

Samples	Commercial Steel	Case Carburized	Case Carburized and Shallow Cryogenic Treated(SCT)		
			7hrs	14hrs	21hrs
A	✓	-	-	-	-
B	✓	✓	-	-	-
C	✓	✓	✓	-	-
D	✓	✓	-	✓	-
E	✓	✓	-	-	✓

Hardness:

Experimental specimens were tested with the help of the Rockwell hardness tester with diamond cone intender of cone angle 120^0 and the applied load of 150 Kgf.

Wear:
Wear specimen were prepared using cylindrical steel tube of length 40 mm, outer diameter of 10 mm and inner diameter 8 mm is taken. Material with the cross sectional area of 5*5*6 mm^3 is inserted in the steel tube. To hold this material, a cold setting resign is prepared and poured into steel tube. This test specimen is left for 2 hours to allow cold setting resin solidify. After the solidification of cold setting compound, grinding is performed on specimen in such a way that material which is to be wear tested is exposed out partially and remaining part of material is held by cold setting resin. Ducom (India) make Pin-on-Disc wear tester is used for wear testing. The parameters of wear testing machine is as shown in Table 3.

Table 3: Parameter for Pin on Disc Machine.

S.no	Wear parameters	Units	Value
1	Load	Kgf	1
2	Track diameter	Mm	90
3	Velocity of disc	m/s	2

We have calculated N (r.p.m) from below equation
N = (V*60*1000)/ (2*π*r)
= **425 r.p.m**

Wear rate calculation:
Volume loss = weight loss/density;
Wear rate = Volume loss/ (velocity*time).

Tensile test:
Tensile testing has been done on all experimental samples which are prepared by following ASTM E8 standards. Tensile test was conducted on computerized Tinius universal testing machine (UTM).

Microstructure:
The experimental specimens were prepared by standard metallographic procedures such as belt grinding, surface polishing and etching with nital solution. A Zeiss Axiovert 25 CA inverted metallurgical microscope was used to observe the microstructure of the specimen.

Results and Discussion:
Effect of Carburizing and Shallow Cryogenic Treatment on Hardness:
The average hardness values of all the experimental samples of AISI 1018 steel are shown in the Table 4 and fig.2.

Table 4: Hardness Values after SCT

Samples	"B" SCALE	"C" SCALE
A	62	-
B	90	11
C	92	14
D	95	17.5
E	96	18.6

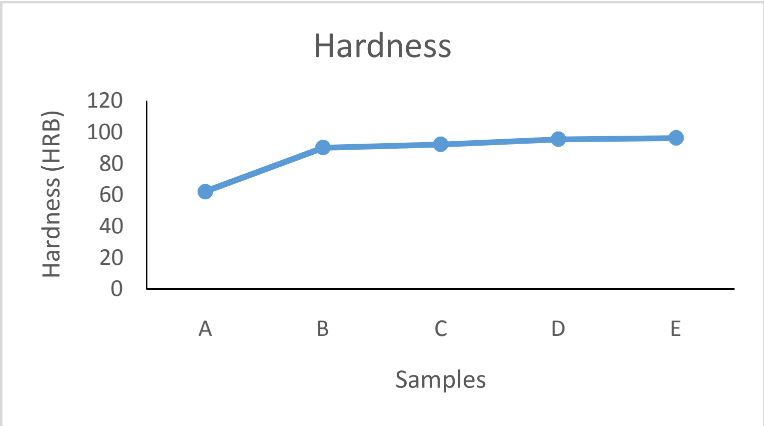

Figure 2: Specimen conditions Vs Hardness

From the fig.2, It can be noted that the hardness values has increased in samples B, C, D, E compared to A. Hardness (HRB) of B is 45.16% more compared to A. The increase in hardness of sample B is due to increase in carbon percentage from 0.156% to 0.711% (in surface alone) due to case carburization results in the free carbides.

For samples C, D, E, It can be observed that there is an increase in hardness (HRB) of 48.38%, 53.22%, 54.83% respectively compared to A. The increase in hardness of samples C, D, E is due to the shallow cryogenic treatment which results in the transformation of some amount of retained austenite in carburized specimen near surface alone to martensite [1]. Shallow cryo-treated specimens have also shown increase in hardness because of the precipitation of secondary carbides [13]. Hardness value of sample E has a little increase of 1.05% over sample D. From this we can say that an optimal hardness can be achieved when AISI 1018 is shallow cryo-treated for 14 hours.

Effect of Carburizing and Shallow Cryogenic Treatment on Wear rate:
The wear rate values of all the experimental samples of AISI 1018 steel are shown in the Table 5 and fig.3.

Table 5: Wear results after SCT

Samples	Weight before the test(g)	Weight after the test(g)	Difference(g)	Wear rate(mm^3/m)
A	7.801	7.793	0.008	0.0008470983
B	6.790	6.785	0.005	0.0005294367
C	6.885	6.881	0.004	0.0004235494
D	7.017	7.013	0.004	0.0004235494
E	7.544	7.542	0.002	0.0002117747

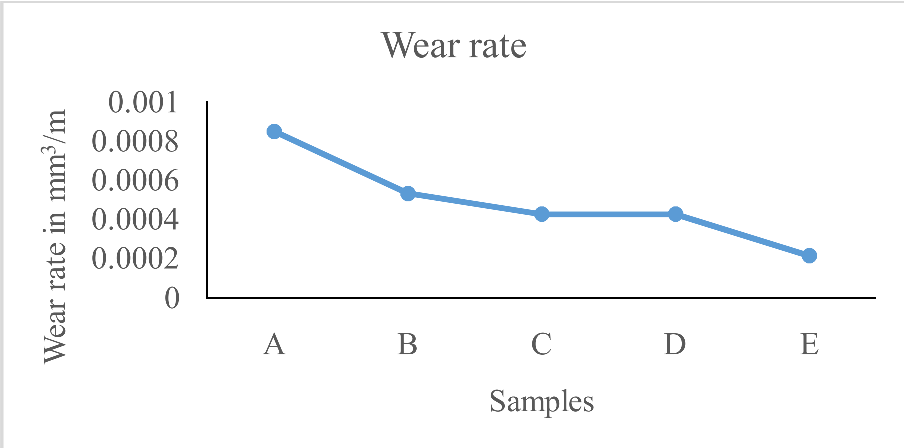

Figure 3: Wear rate in mm^3/m Vs Experimental samples

From the fig.3, it can be observed that the wear rate for the samples E(-75%), D(-50%), C(-50%), B(-37.5%) decreasing respectively compared to sample A. Significant improvement in the wear resistance is due to fine dispersion of carbide precipitation during shallow cryogenic treatment [9]. This implies there is a great increase in wear resistance of a steel when it is shallow cryo-treated. Wear resistance is highest for shallow cryogenic treated AISI 1018 with soaking time of 21 hours.

Effect of Carburizing and Shallow Cryogenic Treatment on Tensile strength:
The tensile strength values for all experimental samples of AISI 1018 steel are shown in Table 6 and fig.4

Table 6: Tensile results after SCT

Samples	Yield Strength(MPa)	Ultimate Tensile Strength(MPa)
A	361.1	455.6
B	480	604
C	485	606
D	514	614
E	529	661

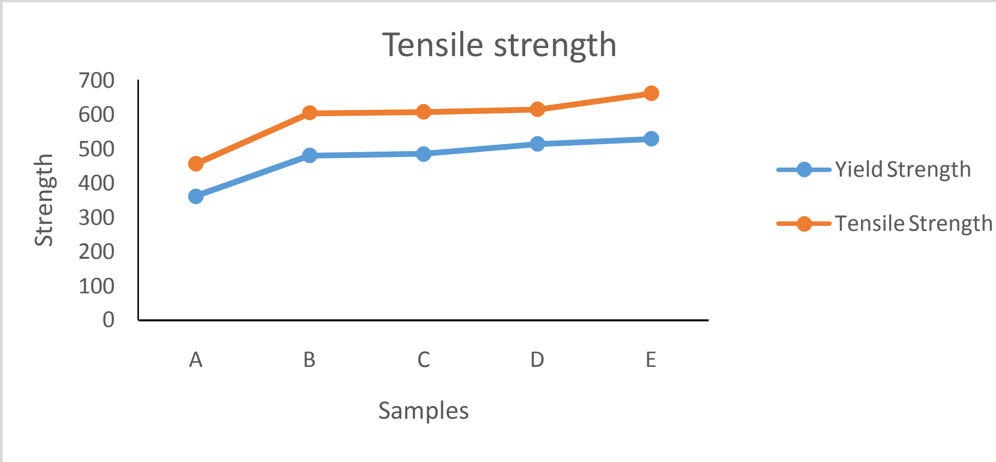

Figure 4: Tensile and Yield strength Vs Conditions

From fig.4, it can be noted that the tensile strength has improved by 32.5% respectively for sample B compared to sample A due to the carburizing and annealing. It is clear that tensile properties have improved for the sample E (45.08%), D (34.76%), C (33.01%) compared to sample A. This trend is followed due to the very fine carbides precipitation which occupies void spaces and results in the increase in density [10].

Effect of carburizing and shallow cryogenic treatment on Microstructure:
The surface of A, B, C, D and E specimens were prepared and following microstructures were observed. The microstructure is observed on the cross section.

Sample A: Commercial Steel

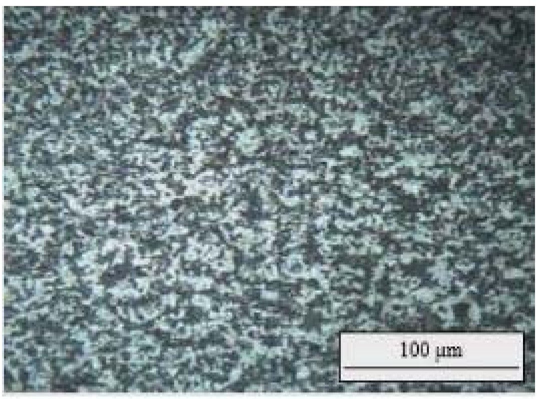

Figure 5: Optical Microstructure of commercial AISI 1018 Steel

Sample B: Carburized specimen:

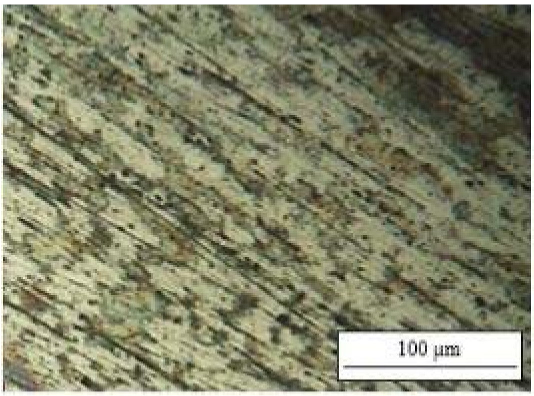

Figure 6: Optical Microstructure of Carburized AISI 1018 Steel

From the fig 5, we can observe fine pearlite in sample A. In carburized specimen, we can observe coarse pearlite and more amount of retained austenite. After carbon is induced at 920^0C (during carburizing) annealing is done for 10 hours.

Sample E: Shallow Cryo-Treated for 21 Hours on carburized steel:

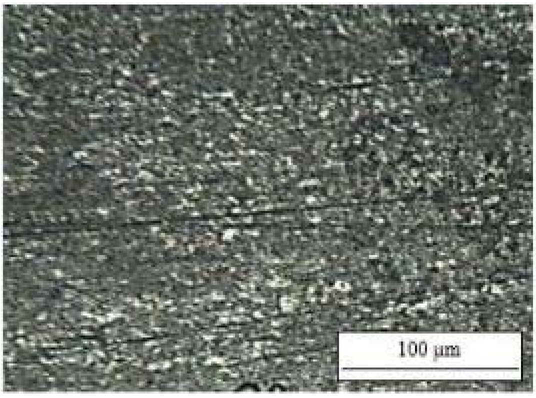

Figure 7: Optical Microstructure of Shallow Cryo-Treated for 21 Hours on carburized steel

From fig.7 we can observe that retained austenite present in carburized specimen is transformed to martensite and grain size of sample E is finer than sample B. We observed that for the shallow cryo-treated specimen, microstructure contains more amount of martensite along with retained austenite. It can be observed that large alloy carbides were fragmented into secondary dispersed carbides. From these micro structure changes, we can infer that both toughness at core and hardness at surface are increasing.

Conclusion:

Based on the experimental results, the following conclusions are given.

- Tensile strength and hardness have increased by 45% and 54.8% respectively for carburized and shallow cryo-treated sample for 21 hours compared to commercial AISI 1018 steel. Wear rate has decreased by 75% for shallow cryo-treated sample for 21 hours compared to sample commercial AISI 1018 steel.
- In case of hardness, significant increase in hardness is observed in between shallow cryo-treated sample for 7 hours (48.38%) and 14 hours (53.22%). But, change in hardness values for shallow cryo-treated sample for 14hrs and 21hrs (54.83%) almost remains the same. So, we consider 14 hours soaking time to be the optimal time for hardness applications.
- Microstructure of carburized sample shows grains of larger size which is due to carburizing and annealing.
- It is found that microstructures of shallow cryo-treated sample for 21 hours are finer with homogeneously distributed carbides. It is also found that fine carbides are more concentrated near the surface.

Due to carburizing and shallow cryogenic treatment, AISI 1018 has improved tensile strength as well as hardness at surface. Soaking time can be chosen depending on the material property desired for required application.

REFERENCES

1. Doss, R.mohan., 2008, “Mechanical Behaviour of Cryogenically Treated En19”. International journal of power control signal and computation, Vol.4 (1), pp.49-51.
2. Karjagi Kiran Suresh., S. Ilangovan., Sanjivi Arul., A. Shanmugasundaram., 2015, “Effect of Zn/Cu Content on Microstructure and Mechanical Properties of Al-Zn-Cu Cast Alloys”, International Journal of Applied Engineering Research ISSN 0973-4562 Vol.10 (4), pp.9325-9333.
3. S.R. Kasthuri Raj., S. Ilangovan, Sanjivi Arul., A. Shanmugasundaram., 2015, “Effect of Variation in Al/Si Content on Mechanical Properties of Zn-Al-Si Alloys”, International Journal of Applied Engineering Research, Vol.10(2), pp.2723-2731.
4. A. Ramasundaram., S. Ilangovan., Sanjivi Arul., A. Shanmugasundaram., 2015, “Influence of Specimen Temperature on Wear Characteristics of Al-Zn-Mg Castings”, International Journal of Applied Engineering Research, Vol.10 (6) pp.15417-15428.

5. Shanmugam Murugappan and Sanjivi Arul., 2015, "A Study on Effect of Sub Zero Temperature Cooling on Surface Roughness of Turned EN8 Steel Rod", International Journal of Applied Engineering Research, Vol.10(8), pp.21549-21563
6. R.J. Kiran., Sanjivi Arul., S.Ilangovan., A.Shanmugasundaram., 2015, "Study on Effect of Various Cutting Fluids During Turning Operations of AISI 1016 Steel", International Journal of Applied Engineering Research, Vol.10 (7), pp.16825-16832.
7. G. Harish Reddy., Sanjivi Arul., R. Sellamuthu., 2014, "Improving Surface Hardness of Mild Steel Plates by Addition of Silicon Carbide Using Gas Tungsten Arc as Heat Source", Applied Mechanics and Materials, Vol.592-594, pp.879-882.
8. R.Devanathan., Sanjivi Arul., S. Ilangovan., A. Shanmugasundaram 2015" Study on The Effect of Shallow Cryogenic Treatment on Hardness and Microstructure of GTAW welded AA6061 Specimens", International Journal of Applied Engineering Research, Vol. 10 (8), pp. 21091-21099.
9. P. Baldissera and C. Delprete., 2008, "Deep Cryogenic Treatment: A Bibliographic Review Politecnico di Torino", The Open Mechanical Engineering Journal, Vol.2, pp.1-11.
10. A.Bensley et al., 2007, "Effect of Cryogenic Treatment on tensile behaviour of case carburised steel – 815M17", Material Characterisation Vol.58 (5), pp.485-491.
11. A. Bensely., A. Prabhakaran., D. Mohan Lal and G. Nagarajan., 2005"Enhancing the wear resistance of case carburized steel (En 353) by cryogenic treatment", Cryogenics, Vol. 45, pp.747-754.
12. M. Preciado., P. M. Bravo and J. M. Alegre., 2006, "Effect of low temperature tempering prior cryogenic treatment on carburized steels", Journal of Materials Processing Technology, Vol. 176, pp. 41-44.
13. R. F. Barron., C. R. Mulhern., 1980, "Cryogenic Treatment of AISI-T8 and CI045 steels", Advances in Cryogenic Engineering Materials, Vol.26, pp.171-179.