Influence Of Carburizing and Carbonitriding in 16mncr5 to Enhance Mechanical Properties

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Abstract- 16MnCr5 low alloy steel carburized at 925^0C and carbonitrided at 860^0C. The tensile strength is improved in carburizing compared with carbonitriding 387.077N/mm^2 and 369 N/mm^2. Likewise hardness is increased in the surface of carburized specimen. Carbon enriched up to 0.6% with effective case depth of 0.47 -0.50 mm in carburizing. Carbonitriding enriches carbon up to 0.494% with 0.45-0.50mm effective case depth. SEM analysis and fractography are showing ductile fracture in the core and brittle fracture in the case. Surface of carburized specimen has 720 HV higher than carbonitrided specimen 702.6 HV.

Keywords – Carbonitriding, carburizing, fractography, low alloy steels

I. INTRODUCTION

Steel is a Fe-C alloy. It is designated by carbon and other alloying elements present in it. Structural applications, offshore requirements, machine elements, defence sectors, power transmissions, air craft are found to be the major applications. Mechanical, thermal and chemical properties play a vital role in choice of steels. Properties of the steel are improved by the heat treatment and surface treatments.

Number of investigations is studied on surface treatment of low alloy steels. Behavior of different types of steels under different surface treatment is studied as follows. Steel with 0.20-0.25% C is surface treated by carbonitriding may improve the hardness range from 720-940 HV. During carbonitriding precipitation of Fe4N is decomposed to austenite phase in a discontinuous manner. Fe4N compound is precipitated in grain boundary [1]. AISI 1020 and 5115 steel are surface treated under carburizing and carbonitriding. Increase in hardness value is found in carbonitriding in both steels is 743 HV and 820 HV respectively [1].

AISI 5140 (41Cr4 steel) is borocarburized to form two zones. First iron boride zone (FeB and Fe2B) that exhibiting low case depth of 100 μm in first method and have reached 125 μm in second method. The second zone is a carburized zone formed by the influence of chromium in 41Cr4 steel [19]. Carburizing may embrittle the steel by the influence of carburizing defects. Mo, Ni alloying elements in the steel may control the carburizing defects [3].

Austenite grain boundaries embrittle with increase in phosphorus and carbon concentration. This may results in intergranular brittle fracture and embrittlement occurs due to hydrogen present in the carburizing atmosphere [4]. Alloying elements such as Cr, Mn and Si having a rich affinity to oxygen results in intergranular oxidation and leads to premature failure in steels [5].

20MnCr5 carburized shaft is failed in premature ductile intergranular mechanism [6]. 18CrNi8 steel is pack carburized at 925^0C of 3 to 12 hrs. The total case depth is found 1.06 times the effective case depth [7].

AISI 4140 steel is surface treated by different techniques [8-15]. Surface wear and hardness are improved by boronizing [16]. Modified 20MnCr5 steel is pack carburized. It leads to form inhomogeneous carbon and residual stress distribution [17].

AISI 316 and AISI 304 compared with the effect of molybdenum on low temperature plasma carburizing. It shows the hardness and degree of lattice expansion in AISI 316 is higher than of AISI 304. Degree of lattice expansion improves the octahedral sites and influences the carbon super saturation in carburizing [18]

Aim of the paper is to compare mechanical properties in 16MnCr5 performed under carburizing and carbonitriding.

II. EXPERIMENTAL WORK

Chemical Analysis –

Chemical test is performed by using OES-foundry MASTER, GERMANY in As-received 16MnCr5 steel, carburized, carbonitrided specimens. Table.1 shows the chemical composition of the As-received 16MnCr5 steel specimen.

Table 1. Chemical composition of As-conditioned 16mncr5 steel

Element	**C**	**Si**	**Mn**	**P**	**S**	**Cr**
% weight	0.159	0.211	1.20	0.0140	0.0260	1.10

Carburizing Process –

16MnCr5 steel is received in rod form with dia Ø22 mm and 300 mm length. Carburizing experiment carried out in SQF batch furnace. Specimens are loaded into container using suitable fixture. Furnace sealed and allowed to reach 9000C. Flame curtains are opened to allow additives to burn out. Heating is continued until it reaches 9250C. Propane 1%, Natural gas 4% is introduced and maintained for 2hrs 10 minutes to progress. Case get deeper due to high carbon content potential 0.95 wt% set in furnace is known as boosting. For diffusion the enriching gas supply is stopped and till temperature maintained at 9250C and held for 50mins. Temperature is dropped to 9000C and equalized for 1 hr. Tempering is achieved at 1200C for 2hrs. [2]

Carbonitriding Process –

16MnCr5 steel with same dimension (Ø20mm and 300mm length) is placed inside the SQF furnace. Carrier gases used are propane and ammonia. Specimens are heated at the temp of 8600C for 2hrs 35mins called boosting. Diffusion is followed by holding at 8600C for 1hr 10mins. Temperature is dropped to 8400C and equalized for 15 minutes. After quenching, tempering is carried at 1200 C for 2hrs.

Tensile Test –

Gauge length prepared as per the ASTM standard A356 /A356M. Gauge length is 200mm and overall length is 300mm and fillet radius is 5mm.Tensile test is conducted on the specimen of 16MnCr5 As received form and carburized, carbonitrided specimen. The test is conducted in UTM machine FIE. Model;UTM 40.SR.No;11/98-2450. Tensile specimen shown in fig.1

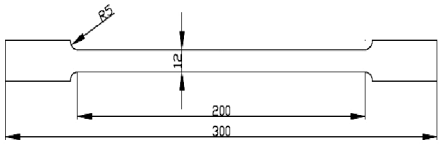

Fig. 1. Tensile test specimen

Hardness Test –

To check the indentation behavior and scratch resistance of the surface of the 16MnCr5 steel are tested using Rockwell's hardness testing machine in As received condition and thermo chemically treated specimens. (Carburized and Carbonitrided)

Micro Structure

Microstructure of 16MnCr5 steel in as received and surface treated are seen in optical microscope by having different magnification, specimen prepared by polishing in different grades of emery paper, disk polishing and followed by etching with 4% nital.

Micro Hardness

Micro hardness is evaluated by using micro hardness tester for As-condition, carburized and carbonitrided specimens.

Fractography

The oxide formation and method of failure in 16mnCr5 is checked using Fractography in scanning electron microscopy for as received and surface treated specimens.

III. RESULTS AND DISCUSSIONS

Chemical Test

Chemical analysis values are compared between as received specimen, carburized and carbonitrided specimen. Table 2 and 3 shows the chemical composition of carburized and carbonitrided specimens.

Table -2 chemical composition of Carburized 16MnCr5 steel

Element	**C**	**Si**	**Mn**	**P**	**S**	**Cr**
% weight	0.600	0.203	1.19	0.0130	0.0240	1.11

Table -3 chemical composition of carbonitrided 16MnCr5 steel

Element	**C**	**Si**	**Mn**	**P**	**S**	**Cr**
% weight	0.494	0.216	0.77	0.023	0.043	0.0015

Carbon content is measured by OES technique. Received steel contains 0.159 %, carburized and carbonitrided contains 0.6% and 0.494% respectively.

Tensile Test

Tensile strength of 163N/mm2 is observed from as received condition of 16MnCr5. Carburized specimen shows 387.077 N/mm2 and carbonitriding specimen shows 369 N/mm2. From these values carburized specimen are having maximum tensile strength of 387.077 N/mm2. % of elongation is very low in carbonitrided specimen 5% and carburized 6%, as received specimen show 20.5%. Percentage of reduction of area is found to same in carbonitriding and carburized specimen is 8.884% and 17.355%.in as received condition

Hardness Test

Rockwell hardness values are found for As-received steel is 20 HRC. For carburized specimen core hardness is 38 HRC and case hardening found to be 59 HRC. In carbonitriding specimen for core 34 HRC and surface shows 54 HRC. From the result carburized specimen shows most surface hardness.

Micro Structure

Microstructure of As received 16MnCr5 steels shows ferrite and pearlite at magnification of 200X. Percentage of ferrite is 82.71% and pearlite 17.29% found by lever rule method shown in fig.2.

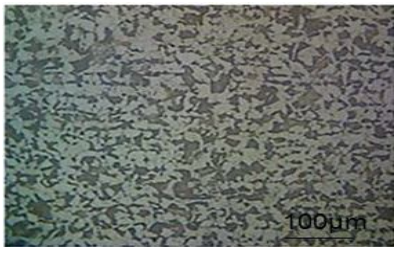

Fig. 2. Microstructure of 16MnCr5 steels shows ferrite and pearlite at magnification of 200 X

In carburized specimen surface shows fine martensite and core having low carbon martensite at 200X. Microstructure shown in fig.3 (a,b). In carbonitriding specimen surface shows martensite with retained austenite and core shows low carbon martensite at 200X. Microstructure shown in fig.4 (a,b)

(a) (b)

Figure 3 microstructure of carburized specimen having both core and case

(a) (b)

Figure 4. microstructure of carbonitrided specimen having both core and case

Micro Hardness

Micro hardness value for As-received is 230HV. After carburizing core has 370HV, surface has 720HV and by carbonitriding core has 330, surface has 705.6HV.The case depth is shown in fig 5

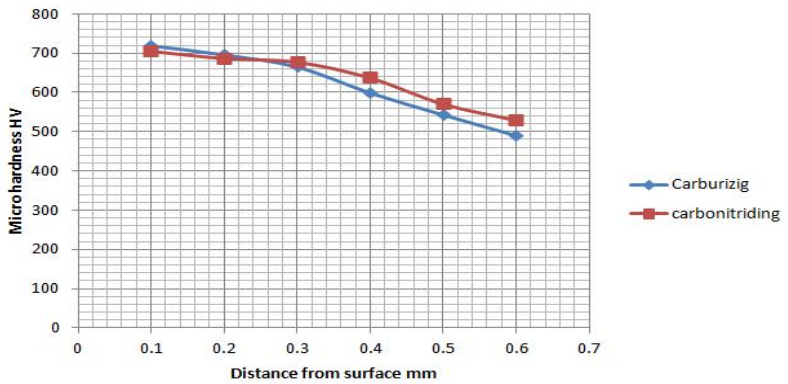

Figure 5. Case depth achieved from carburizing and carbonitriding.

Fractography

Fractography conducted on tensile tested specimens in As-received, carburized and carbonitrided. In as received 16MnCr5 the fracture is said to be ductile with neck formation around the fractured region. In carburized and

carbonitrided specimens inter granular fracture is identified. The macro fractured images are shown in fig 6. The micro images are shown in fig 7.

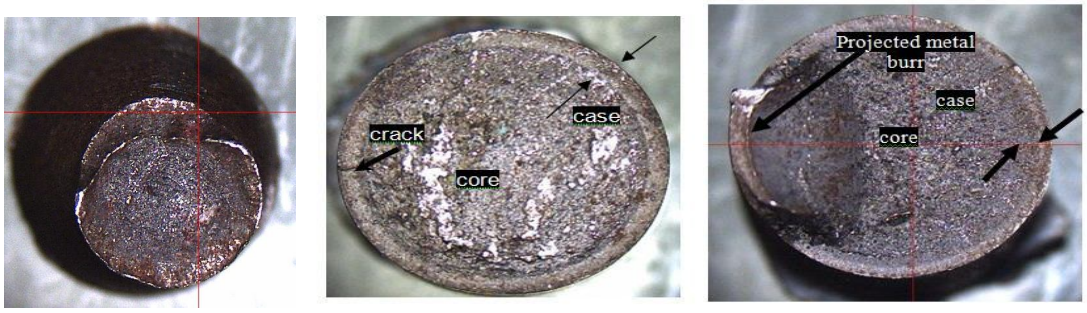

Figure 6. Macro images of As received, Carburized and carbonitrided tensile fractured specimen

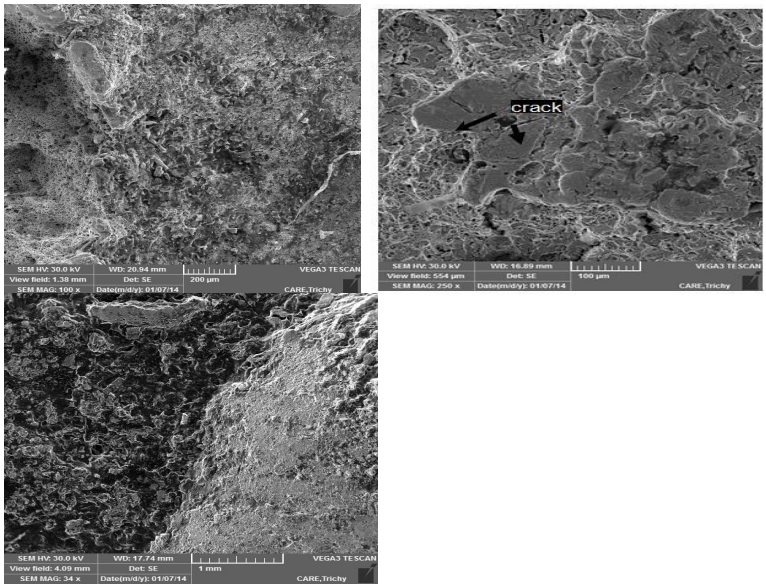

Figure 7. Fractography images of As received, Carburized and carbonitrided tensile fractured specimen

Fractography image shows micro voids and dimples in ductile fractured As-received specimen, where in Carburized specimen inter granular fracture with dimples are observed, while in carbonitrided specimen the case and core with the cleavage and dimples are observed

IV.CONCLUSION

16Mncr5 steel was successfully surface treated by carburizing and carbonitriding. Fine martensite is observed in the surface. Micro hardness of 720HV is improved in carburizing. Fine martensite and carbide precipitation observed in the surface. Micro hardness observed 705.6 HV in carbonitriding .Tensile strength of 387.077 N/mm2 improved in carburized specimen compared with carbonitriding. In carburizing carbon enriches up to 0.6% with case thickness of 0.45 to 0.50 mm. In carbonitriding N-precipitates and carbon enriches up to 0.494 %. Case depth measured 0.45 to 0.52 mm. Enriched diffused carbon increases the surface hardness. From the above experimental result shows improved hardness found in carburizing 59HRC. Fractography has done for tensile failed specimens. In as-received specimen micro voids are observed which initiates the crack propagation and crack regions shown with dimples and vein formations. Carburized specimen shows thin line formation of crack in macro image. Intergranular crack formations found with dimples in fractography image. Projected metal burr observed in macro image of carbonitrided specimen. Cleavage found in fractography image with dimples .Investigated specimens failed as ductile fracture with cup and cone found in as-received specimen. Carburized specimen failed with influence of intergranular crack shows ductile in core and brittle in surface. Cleavages are found in carbonitrided specimen. It results both surface treated specimen failed under intergranular mechanisms

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