ISSN (e): 2250 – 3005 || Volume, 06 || Issue, 08|| August – 2016 ||
International Journal of Computational Engineering Research (IJCER)

Studying the Fatigue Properties of Hardened for Carbon Steel

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ABSTRACT
In this investigation, Medium carbon steel is a standout amongst the most critical materials utilized as a part of mechanical applications especially it is used in applications exposed to fatigue stresses such as airplanes, automotive components and electrical engines industries. Medium carbon steels were prepared and the effect of hardening on hardening strength of medium carbon steel was studied, the flame hardening method was used at different speeds then fatigue test was done. The following results were obtained, first sample (none), second sample (3.5 mm/s), and third sample (1.75 mm /s) and forth sample (1.165 mm/s). It has been found that as the flaming speed increases, the fatigue strength of the material decreases. The fatigue test result at stress (407.44 N/mm^2) was as follow: for the first sample the no. of cycles to failure was at (67511 rpm), for the second sample (95832 rpm), for the third sample (122565rpm) and for the fourth sample it was (134585 rpm).

Keywords: *Medium carbon steel, flame hardening, fatigue test.*

I. INTRODUCTION

The medium carbon steels have a typical sumbstance of carbon (0.45-0.8) that implies that they are not as hard as high carbon steel nor are as solid as the Mild carbon steel. The mechanical properties of medium carbon steel were examined in two diverse extinguishing media (water and palm oil). The properties are hardness, effect and quality of the material. Result demonstrated that water extinguished steel deliver best properties in quality and hardness; while palm oil extinguished steel has its best properties in affect quality [1-3]. Some mechanical properties of medium carbon steel [4]: (1) Machinability is 60%-70%; along these lines cut marginally superior to anything low carbon steels. It is less machinable than high carbon steel since that is hard steel. (2) Good toughness and ductility. Enough carbon to be extinguished to shape martensite and bainite (if the area estimate is little). (3) Responds to warm treatment yet is frequently utilized as a part of the regular condition. (4) The hardenability is low. (5) The loss of strength and embrittlement are diminished by both low and high temperature. (6) Subject to corrosion in many conditions. All heat treating operators consist of subjecting a metal or steel to a definite time-temperature cycle which may be divided into three parts: (1) Heating the metal or alloy. (2) Holding at certain temperature (soaking). (3) Cooling [5-6]. Medium carbon steel is steel where the main interstitial alloying composition is carbon. It is usually patronize by utilize high temperatures so as to reinforce ductility and strength. A 0.8% carbon steel (medium carbon steel) will begin to solidify at approximately 1470 ^{0}C. And when solidification is complete, the structure will consist of crystals of austenite of composition 0.8% carbon. As the steel cools slowly, the structure becomes uniform and no further structural change will take place. The upper and lower critical temperatures coincide and the austenitic structure transform at this temperature to pearlite. The treatment of medium carbon steel with warm altogether changes the mechanical properties, for example, ductility, hardness and strength. Heat treatment of steel somewhat influences different properties, for example, its capacity to direct heat and power also. An assortment of techniques exists for treating steel with heat [7].

The utilizes for medium-carbon steel are characterized by the prerequisite for a tensile strength and ductility that, regardless of its brittleness when contrasted with different types of steel, settle on it the favored decision. Medium carbon steels is utilized for making auto parts, for example, crankshafts, gears, axles, device shanks and heat treated machine components. It is additionally used to make lead screws brilliant drawn bar, railroad wheels, tracks, turbine circles, interfacing poles, cable car axles, firearm parts shells rifle barrels, producing kicks the bucket and axles. Medium-carbon steels have great wear protection, so they are frequently utilized for vehicle parts and comparative applications. They are additionally utilized as a part of producing and for extensive parts [8]. Surface hardening is a procedure which is utilized to enhance the wear protection of parts without influencing the milder, intense inside of the part. This blend of hard surface and protection and breakage upon affect is helpful in parts, for example, a cam or ring apparatus, bearing or shafts, turbine applications. Most surface medications result in compressive remaining stresses at the surface that decrease the likelihood of crack initiation. Further, the surface hardening of steels has leverage over through hardening in light of the fact that more affordable low-carbon and medium-carbon steels can be surface hardened without the issues of contortion and splitting related with the through hardening of thick segments [9]. Plain-carbon and low combination steels are utilized for surface hardening. Manganese might be available in sums up to 1.4% since it balances out cementite and builds the profundity of hardening .tragically it expands the propensity of steel to crack amid quenching [10].

Kinds of surface hardening (warm medications) are Flame hardening, Induction hardening, Electron shaft hardening. Flame hardening is a technique for hardening of surfaces of segments, as a rule in chose zones by a brief span use of warming took after by quenching. Flame hardening depends on the nearness of satisfactory carbon content in the material to accomplish the hardness level required. Flame hardening is the procedure of particular hardening with an ignitable gas fire as the wellspring of heat. The warming media might be oxygen-acetylene, propane or some other mix of fuel gases that will permit sensible warming rates .the hardening temperatures are the same as those required for heater hardening [11, 12]. Flame hardening is a heat treating process in which a thin surface shell of a steel part is warmed quickly to a temp., over the basic purpose of the steel. After the grain structure has turned out to be austenitic the part is immediately quenched, changing the austenite to martensite. Flame hardening is basically used to grow abnormal amounts of hardness for wear protection. The process likewise enhances bending and torsional strength and life of fatigue [13, 14]. The accomplishment of numerous flame hardening applications depends to a great extent on the ability of the administrator. This is particularly obvious when the volume of work is so little. The guideline working factors are remove from internal center of oxy-fuel gas flame to work surface, flame speeds and oxygen to fuel proportions, rate of movement of flame head or work and sort of quenching [15]. Flame hardenings have the accompanying advantages: (1) Flame hardening gives a hard, wear protection surface to the segment enhancing its strength of fatigue, (2) Flame hardening offer choices for the treatment of extraordinarily huge parts, where just confined surface hardening is required, (3) Flame hardening can be mechanized for reproducible outcomes once the procedure parameters have been set [4].

S.K. Akay et al. (2008) introduced the impact of heat treatment on the life of fatigue for low carbon steel sheet with double stage microstructure. The steel sheets were heat treated with two distinct methods; middle of the road quenching, moderate quenching then tempering. The properties of life of fatigue, tensile, hardness, micro hardness and microstructure were assessed by the mechanical check and metallographic investigation, separately. The comes about demonstrated that double stage steel (DPS) microstructures, formed by ferrite and martensite had higher completely turned around plane bowing strength of fatigue when contrasted and as-got steel and tempered martensite (TM) steel. The exploratory outcomes demonstrated that life of fatigue for the heat treated steel sheets upgraded with expanding measure of martensite in the microstructure. The most astounding strength of fatigue was seen on the transitionally strengthened steel sheets at 870 °C. inwar d microstructures, initiation of fatigue crack and engendering of the heat treated steel were broke down by microscopy of scanning electron (SEM) [16]. *Vytautas et al.* (2010) researched the impact of different sorts of surface medications (hardening with high recurrence electric flow, moving by rollers, treating) on strength of fatigue for carbon steel examples. Investigated innovation of surface hardening extraordinarily expands the strength of fatigue and toughness of examples. They assessed that hardening impact relies upon the lingering stresses presented applying twisting and warm treatment administrations. The ideal treatment of the dissected carbon steel is misshapening up to 1 mm profundity, hardening with high-recurrence electric present and hardening for 2 hours at 200 ºC. Conditions of machine components amid misuse, likewise strength and security of all development depends a considerable measure on the condition of metals surface layer. Hardening of metals surface enables changing costly metals to shoddy ones. Change of surface quality permits expanding the solidness of all development [17]. *Sweta Rani Biswal* (2013) examined fatigue of medium carbon steel (EN9 grade) and researched the impact of different heat treatment operations (normalizing, tempering, annealing) on life of fatigue since the mechanical properties are incredibly affected by heat treatment strategies. Additionally examined the adjustment in the estimation of perseverance farthest point of the material worried because of different heat treatment operations and found that the specimens tempered at low temperature (2000C) shows the best outcomes to the extent fatigue strength is concerned [18].

II. EXPERIMENTAL WORK

The basis material utilized in this paper was medium carbon steel (1039), which contains (0.39) C %. The first work in this paper is examining the chemical composition of the metal used in the test conclusion in State Company for Inspection and Engineering Rehabilitation (SIER). Chemical structure illustrates in table (1).

Flame hardenings processes were used in this paper which consists of the following steps: Step (1): five samples of medium carbon steel (1039) are prepared according to standard specifications for fatigue testing ASTM G99 using turning machine as shown in figure (1). This step was done in Public Company for Electrical Industry. Step (2): The first sample was not exposed to any surface treatment. Sample No. (2) was hardened by oxy acetylene torch. This process is called flame hardening; the sample is first subjected to heat of the torch for certain time and then is cooled directly by water after hardening. The heat used was at temperature (750^0C) and hardening time was (5 sec.) this means that the hardening speed depend on length of specimen was (3.5 mm/sec). Sample number (2) after being hardened by oxy acetylene torch is shown in figure (2).

Table (1) Chemical composition of specimens

Element wt %	C	Si	S	P	Mn	Fe
Standard: 1039 ASTM value	0.36-0.44	0.4	≤ 0.05	≤ 0.04	0.7-1	0.057
Measured value	0.39	0.173	0.022	0.009	0.796	remain

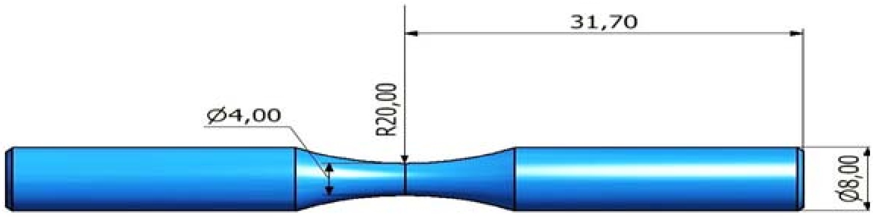

Fig. (1) Fatigue sample with dimensions ASTM G99

Fig. (2): Sample number (2) after hardening

Step (3): sample No. (3) is hardened by oxy acetylene torch for hardening the sample by flame hardening method, then direct cooling by water. The heat of the torch was at (750 C^0) and hardening time (10 sec). The hardening speed was at (1.75 mm/s). Step (4): sample No. (4) is hardened by oxy acetylene torch in the Mechanical workshop for hardening the sample by flame hardening method, then direct cooling by water. The heat of the torch was at (750 C^0) and hardening time (15 sec.). So the hardening speed was at (1.165 mm/s). Step (5): A sample No. (5) was tested by tensile, in this test; the ultimate strength was at (1010 Mp). Step (6): fatigue test is achieved in material testing laboratory, Sample No. (1) was not hardened by flame hardening method. All the five samples were fatigue tested. In this test, the applied stress was constant at (407.44 N/mm^2), where it was benefiting from the ultimate strength. The applied load was at (20 N) and the number of cycles at which the samples failed was calculated.

III. RESULTS AND DISCUSSION

Table (2) explains the relationship between the flame hardening speed and the number of samples.

Table (2) Relationship between hardening speed and number of samples.

No. of Sample	Time of Flame Hardening (sec)	Hardening Speed (mm/s)
1	non	non
2	5	3.5
3	10	1.75
4	15	1.165

Figure (3) shows stress and strain of a tensile test for sample No. (5).

Fig. (3) stress-strain curve of a tensile test sample

Table (3) explains the relation between the flame hardening speed and number of cycles to failure that results from fatigue test.

Table (3) Relation between flame hardening speed and number of cycles.

No. of Samples	Applied load (N)	Applied bending stress (N/mm^2)	Flame hardening speed (mm/s)	Number of life cycles (rpm)
1	20	407.44	non	67511
2	20	407.44	3.5	95832
3	20	407.44	1.75	122565
4	20	407.44	1.165	134585

Figure (4) shows the relation between No. of samples and flame hardening speed.

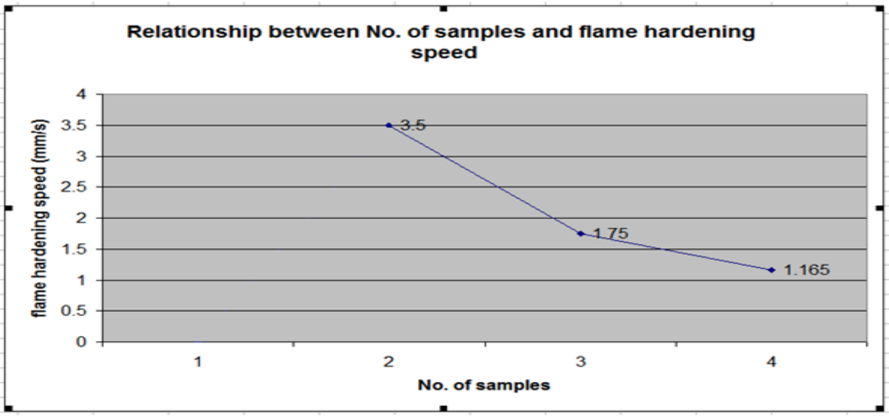

Fig. (4): the relation between No. of samples and flame hardening speed.

Figure (5) shows the relation between the No. of samples and number of life cycles:

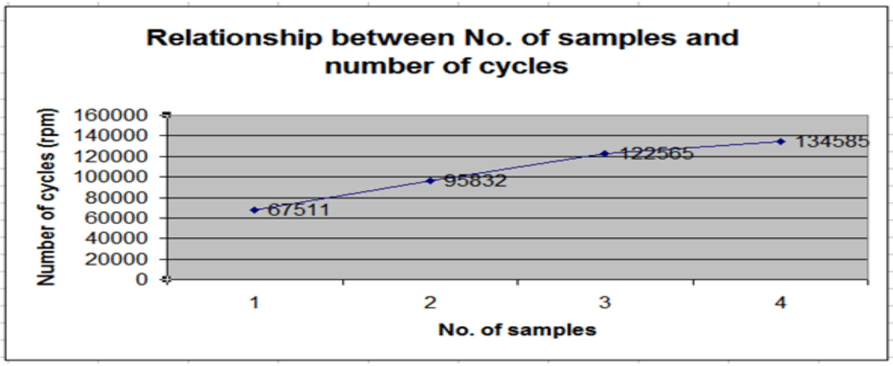

Fig. (5) Relation between the No. of samples and number of life cycles

Flame hardening process didn't do on sample No. (1), the reason is to compare it with other samples that have been hardened by oxy acetylene torch for understand the influence of flame hardening speed on strength of fatigue for the material. From table (2) it is clear that sample No. (2) was subjected to oxy acetylene torch for (5 sec.) at flame hardening speed of (3.5mm/s), sample No. (3) subjected to oxy acetylene torch for (10 sec.) at speed of (1.75 mm/s) and sample No. (4) was subjected to oxy acetylene torch for (15 sec.) at speed of (1.165 mm/s), so in this case flame hardening speed decreases as the No. of samples increases.

Table (3) shows the relationship between flame hardening speed and No. of life cycles for fatigue test. Sample No. (1) failed at No. of cycles (67511 rpm), sample No. (2) failed at (95832 rpm) at flame hardening speed of (3.5 mm/s), sample No. (3) failed at (122565 rpm) at flame speed of (1.75 mm/s) and finally sample No. (4) failed at (134585rpm) at flame speed of 1.165 mm/s).

From information above notice that there is a reverse relationship between flame hardening speed and No. of life cycles. With the flame hardening speed decreases, No. of cycle's increases So the fatigue strength of the material increases. The fatigue strength of sample No. (4) is more than sample No. (3) and strength of fatigue for sample No. (3) is more than sample No. (2) and fatigue strength of sample No. (2) is more than sample No. (1) because the No. of cycles to failure is more and flame hardening speed is less.

IV. CONCLUSIONS

Regarding the effect of hardening speed by oxy acetylene torch on medium carbon steel can conclude the following points:

1. The flame hardening speed increases, the fatigue strength of the material decreases.
2. The flame hardening speed effect on No. of cycles to failure on fatigue strength.
3. The No. of cycle's increases when hardening speed decreases flame so the fatigue strength of the material is increase.
4. There is a straight relationship between the No. of cycles to failure and fatigue strength and there is a reverse relationship between flame hardening speed and fatigue strength.

In order to enhance the capability of medium carbon steel to withstand the fatigue crack the following recommendations can be suggested:

1. Increasing the number of the samples in order to get more precise result.
2. Changing the value of the stress greater or less than the stress used.
3. Apply other methods of surface hardening such as carburizing, coating and nitriding in order to know which method is the best.
4. It is possible to use flat samples instead of circular samples which were used in this project so that to know the difference between them.

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