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Research paper



Relation between Fatigue Limit and Tensile Strength at Different Tempering Temperature and Time of Ck55 Steel

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Abstract

Fatigue properties of tempered Ck55 (.55%C) has been investigated by using Moore rotating beam testing machine at a load ratio of R = -1 and cycling frequency of 100 Hz with specific consideration regarding micro structural points of interest. Ck55 steels demonstrate a distinct variation of fatigue limit and life at different tempering temperature and time length. No specimen failed below fatigue limit for high number of cycles. The actual fatigue test results for given materials, relates the tempering temperature and time which is because of the formation and changes in the microstructure. An attempt has been made to imperative connections between tensile strength and endurance life by varying tempering temperature and time.

Keywords:*Ck55;FatigueLimit;FatigueLife;Tempering;TensileStrength.*

1. Introduction

There is essentially no vulnerability about how steel is an imperative building material and broad assortment with several properties by heat-treatment processes. This process consists of heating, followed by quenching in water and then reheating some temperature below lower critical temperature. Here this process includes any desired rate of cooling to get high hardness incentive to resist shock and fatigue. Our main objective is to focus on the reliance of fatigue strength of differently heat-treated steels with tensile strength with the changing tempering temperature and time. As most of the materials fail due to fatigue, that's why, our main aim is to relate the micro structural changes due to tempering treatment on the fatigue strength. The material selected for the study is Ck55 as it is still gaining emphasis in the automotive industries. In this paper, efforts have been made to analyze the fractography of specimens which are failed due to dynamic loading in Moore bending test and tensile test.

2. Literature Review

From the accessible study materials, it is truly denoted that numerous endeavors were made to comprehend and expect the practices of steel that incorporates the investigation of microstructures, its properties and its advancement. A brief survey of a few literary works is introduced under here. Metal generally fails due to repetitive and fluctuating stress by the application of single application of load. This stress is much lower than that required to cause failures. Failures under dynamic loading are called as fatigue failures, in the fact that it is generally occurred only after noticeable period of service as explained by Dieter[1].So, it is very importance in design point while selecting a material, the effect of strength on fatigue properties like fatigue limit and fatigue life.

This present work is not only giving a detail perspective of the fatigue, this also helps to analyze to the fatigue mechanism, and factors influencing fatigue properties. This also involves study on fatigue failure since its revelation in 1830. Here, a brief discussion on the basic factors, its consequences due to variation in mechanical and physical properties according to the types of the heat treatments and the most well-known techniques utilized have been discussed as a part of the investigation of fatigue.

Some of the researchers like Bannatine1, Murakami, Naito and Asami [2,3,4,5,6] have found that due to crack initiation at inclusions, high strength steels fail at very high numbers of cycles. The question arises here that; fatigue limit does exist for steel in general? And which are preferred heat treatments to reach the optimum strength and better life?

Sakai[7] and Durmus[8] reveals that all the specimens are under high cycle fatigue (HCF) region and the fatigue strength enhanced with the variation in tensile strength. Somer[9] describes the change in strength and fatigue limit, and ductility is because of soft coarse ferrite grains. To increase the strength and fatigue limit by compromising ductility only can possible by doing tempering after quenching. This results in the formation of hard martensitic structure. Atanu[10] et. al. comments that because of finer micro constituents like ferrite and pearlite, the strength property enhances. From that point, it diminishes insignificantly with the appearance of cementite spheroids by substituting lamellar pearlite. He also notes that ductility exhibits marginal changes with the number of heat treatment cycles. The fractured surface at first displays lamellar pearlite along ferrite which looks like dimples in tensile test images. The dimples region steadily devours the whole fractured surface and with increasing number of heat treatment cycles, the lamellar fracture region gradually dispensed. From this,

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we can get a conclusion that microstructure extraordinarily impacts as far as possible.
The decrease in hardness is because of the vanishing of Martensite stage but at a Lower tempering time yields fine martensite and contains small amount of soft cementite. Higher hardness was obtained as result of this at lower tempering time. Coarse carbide and ferrite matrix formation induces ductility by sacrificing strength as the tempering time expanded further, which incredibly influence the ductile and fatigue properties [11, 12].
From the literature survey[13], we get the inferences that micro structural changes influence mechanical properties which are the main factors to cause fatigue failure in steel. Heat treatment assumes to be expected to play a principal part in creating distinctive microstructure, it is important to relate fatigue behaviour of steels with mechanical properties. The result of this may enhance the application of steel in engineering fields. Depending upon the researches completed previously in 19th and 20th century, we find that tempering is the best way to induce proper properties in materials with varying tempering temperature. But the impact of tempering time on the mechanical properties is still not discussed by any researchers, which is the main motivation behind this study. Whereas tempering temperature effect properly mentioned in many of the literature mentioned above but we are also giving efforts to highlight this more. So, depending upon the earlier work, our investigation is mainly focused upon the study of fatigue behavior of Ck55 steel in heat- treated conditions at different tempering time and temperature.

3. Methodology

The chemical composition of the selected Ck55 medium carbon steel taken for this paper before heat treatment is shown in Table 1. The mechanical properties of as received samples is been tabulated in Table 2. These Specimens were properly machined and polished before the testing. Afterwards, the specimens were heated at 800°C and soaked for 1 hour, quenched in water and finally were tempered at 600°C, 400°C and 200°C at three different tempering time 1 hour, 1½ hour and 2 hours respectively. Mechanical properties of all these specimens were analyzed after the heat treatment. Then these specimens are polished for micro structural analysis. Specification of the specimens for tensile and fatigue test is given in the Fig. 1.

Table 1: Chemical Composition in wt.%

C	S	P	Mo	Mn	Si	Fe
0.55	0.35	0.020	0.05	0.75	0.2	Balance

Table 2: The mechanical properties of the as received samples

Specimen Specification	Yield Stress in (MPa)	Ultimate Tensile Stress (MPa)	% of Elongation	Maximum Load (KN)
Specimen as received	397.61	583.16	21.60	45.795

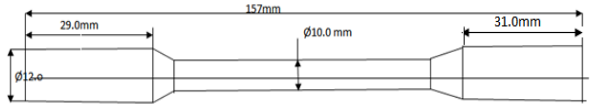

Fig. 1: Tensile Test and Fatigue test Specimen specification

These following testing methods are done for evaluating the mechanical properties and fatigue properties of differently heat-treated specimens.

3.1. Tensile Strength Test

INSTRON 8502 servo hydraulic testing machine is used for tensile test of the specimens which has cross head speed 1mm/min. Maximum load capacity of INSTRON is 150 KN. All The mechanical properties are measured by this tensile test.

3.2. Fatigue Life Estimation Test

A Rotating Bending Machine (RBM) gives the fatigue properties like fatigue limit and fatigue life at zero mean stress. In our research, we want to relate the fatigue properties to mechanical properties, so this test is the vital among all. Here specimen having specification mentioned in Fig. 1 are subjected to the Rotating beam machine is also known as Moore testing machine at frequency of 100Hz (stress ratio, R= -1).

3.3. Microstructural and Fractographical Analysis Test

After the failures under fatigue test and tensile test, specimens are subjected to fractography analysis, which are done by Scanning Electron Microscopy (SEM). For these studies, specimen was cut by 10 mm near the failed area to analyze the type of failure and its causes.

4. Results

4.1. Impact of Heat Treatment on Fatigue limit

The properties are obtained from tensile test and fatigue test of Ck55. That data is illustrated in Table III. Endeavors have likewise made to set up structure-property relationship.

Table 3: The mechanical properties of heat-treated samples

Specimen Specification	Tempering Time (hours)	Yield Stress (MPa)	Ultimate Tensile Stress (MPa)	ductility	Maximum Load (KN)	Fatigue limit (MPa)	Fatigue life (No. of cycles)
Quenched from 800^0C and Tempered at 200^0C	1	819	978	11	55.57	655	5.01×10^6
	1½	812	969.789	12	76.157	649	7.9×10^6
	2	728	951.69	18	74.736	582	1.2×10^7
Quenched from 800^0C and Tempered at 400^0C	1	619	934	22.5	73.347	495	1.58×10^7
	1½	507	894	23	70.205	405	1.5×10^7
	2	465	762	24	59.839	372	2.51×10^7
Quenched from 800^0C and Tempered at 600^0C	1	741.12	891	24	69.970	592	7.9×10^6
	1½	623.43	783	25	61.488	498	1.25×10^7
	2	618.51	783	26	60.625	494	3.1×10^7

We may relate the variation in fatigue limit and fatigue life with reference to tensile strength as fatigue test solely depend upon the tensile strength. As per the Table III, we have found that increment in the tensile strength results in increment of fatigue limit. The highest 655 MPa value we have found for low temperature (200^0C) tempering with lowest fatigue life 5.01×10^6 at tempering time 1 hour. But at a specific tempering temperature if there is increment in tempering time then tensile strength decreases so as the fatigue limit. However, fatigue life increases because of in-

crease in ductility; we can compare the values from Table IV. It has been observed that fatigue limit highest for 200^0C at 1 hour i.e. 655 MPa with 5.01×10^6fatigue life and lowest for 200^0C at 2 hours i.e. 582 MPa with 1.2×10^7, which indicates that at a specific temperature with the increase tempering time, the fatigue limit decreases and fatigue life increases. At tempering temperature 400^0C and 600^0C, fatigue limit variation is same as that of 200^0C. At the low tempering temperature 200^0C, the impact of time winds up noticeable and but at high temperature (600^0C), the impact is more articulated with time. It is found that after 1½ hours, the impact of time turns out to be for all intents and purposes inconsequential (as far as possible stays steady). There is only one insignificant result we get at the intermediate temperature 400^0Cfrom 1½ hours to 2 hours, sharp fall in fatigue limit is found. Here the impact of time is more critical. From above explanations, it can be reasoned that the tensile strength greatly affects fatigue properties that might be expected to the micro structural changes. From the tensile test fractography dimple like structure appeared as shown in Fig. 2; this depicts the material's ductility tendency. There is increment in the shape and size of dimples as the temperature fluctuated from 200^0C to 600^0C might be a result of carbide arrangement which prompts both strength and ductility, which adjusts the fatigue limit and life. Fatigue properties greatly influenced by both treating time and temperature. At low temperature tempering, Best outcomes are obtained i.e. for the examples at 200^0C. Low tempering temperature for least treatment time indicates preferred outcomes over tempering for longer time.

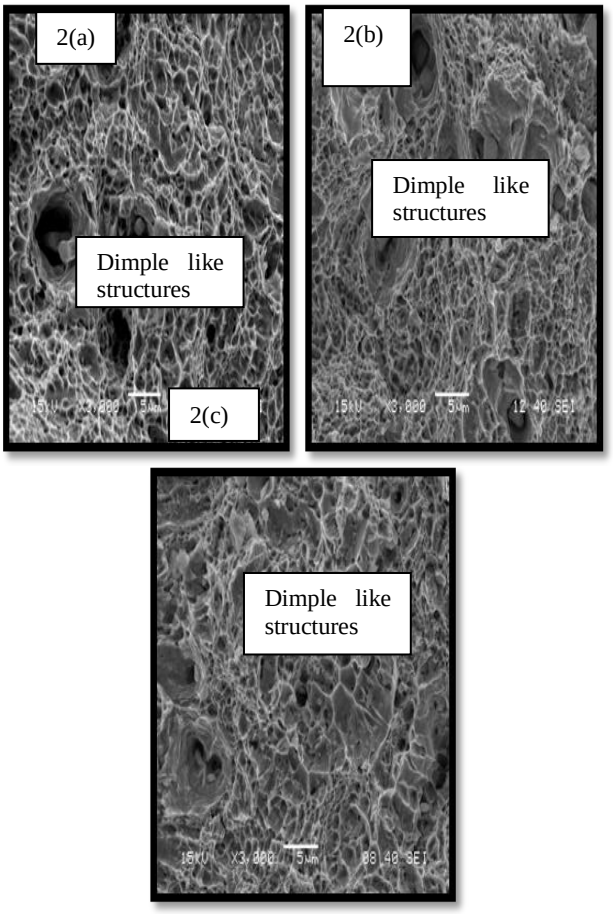

Fig.2: (a) Tempered at 200^0C, 2(b) Tempered at 400^0C& 2(c) Tempered at 600^0CTensile Test Fractography at 3000X,

The comparison graph is shown in Fig. 3 describes the variation of fatigue limit at different temperature and time.

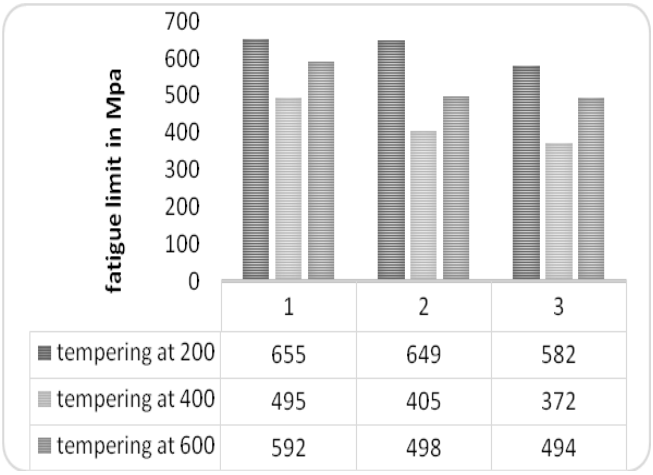

Fig. 3: Comparison graph for Fatigue Limit

4.2. Impact of Heat Treatment on Fracture Surface

Surfaces of several specimens have been explored precisely to study the conceivable non-propagating cracks as in the Fig. 4. Investigations of fracture surfaces validated that the fatigue limit is correlated to crack propagation. Additionally, the tensile test images, as given in Fig. 2 describes that materials induce ductility as tempering temperature increases which validates by the presence of dimple like structures. Crack surfaces of the failures of Ck55 are clearly visible in Fig.4. Striation marks are the indication of ductile failure. Saw-tooth-like striation marks are clear indication of surface failure. This is better noticeable in Fig. 4 (a) fractography. In stage I, Crack initiate as seen in Fig. 4(a), whereas stage II describes the crack growth where fracture surface is perpendicular to the principal stress as shown in Fig. 4(b). Fig. 4(c). It gives the clear view of crack propagation. The underlying crack (~10 µm) is slanted by 45^0 to the principal stress as seen in the figures shape the fracture surface.

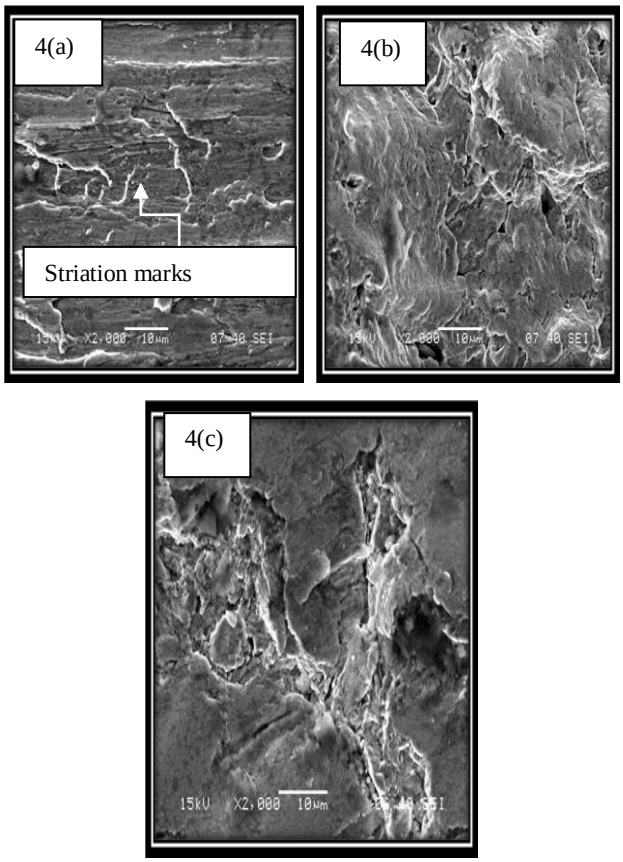

Fig. 4: (a), 4(b) &4(c) Images of fatigue test specimen

5. Conclusion

Important inferences we found are as follows: specimens of Ck55 failed in high cycle region. Tempering treatment has an exceptionally critical impact on fatigue life since its alter both the tensile strength and microstructure of the material (Ck55). This is maybe because of the way that these specimens possess varying high strength with significant ductility. At lower tempering temperature for 2 hours tempering time, demonstrates preferred outcomes. It can likewise be inferred that higher fatigue limits with low fatigue life is obtained at higher UTS. Tempering treatment influences both mechanical properties and fatigue properties. It might be presumed that fatigue strength is specifically corresponding to change in tensile strength. As per fatigue strength is concerned, tempering treatment at low temperature might be viewed as the most ideal heat treatment. Now, we may conclude that both tempering time and temperature greatly relates the fatigue properties which can be generalized after TEM analysis.

References

[1] Deiter GE (1988), Mechanical metallurgy, Mc graw hill ltd, UK, PP 375,378,379.
[2] Bannantine JA, Comer JJ & Handrock JL (1990), Fundamentals of metal fatigue analysis. New Jersey: Prentice-Hall.
[3] Murakami Y & Endo M (1994), 'Effects of defects, inclusions and in homogeneities on fatigue-strength', Int J Fatigue, Vol.16, No. 3, pp.163–82.
[4] Naito T, Ueda H and Kikuchui M (1984) 'Fatigue behavior of carburized steel with internal oxides and nonmartensitic microstructure near the surface. Metal Trans, Vol.15A, pp.1431–1436.
[5] Asami K & Sugiyama Y (1985), 'Fatigue strength of various surface hardened steels', J Heat Treatment Technol Assoc, Vol.25, pp.147–50.
[6] Murakami Y, Takada M & Toriyama T (1998), 'Super-longlife tension compression fatigue properties of quenched and tempered 0.46% carbon steel', Int J Fatigue, Vol. 16, No. 9, pp.661–667.
[7] Sakai T, Takeda M, Shiozawa K, Ochi Y, Nakajima M & Nakamura T (1999), 'Experimental evidence of duplex S–N characteristics in wide life region for high strength steels', Proceedings of the seventh international fatigue conference, Beijing, China,Higher Education Press, vol. 1, pp.573–578.
[8] Durmus A & Bayram A (2004),'An investigation on the tensile and abrasive wear properties of plain carbon dual-phase steels', pp.571-576.
[9] Somer & Nacy M (2007), 'Effect of Heat Treatment on Fatigue Behavior of (A193-51T-B7) Alloy Steel', Proceedings of the World Congress on Engineering, London, U.K.,Vol. II.
[10] Sahaa A, Mondal DK & Maity J (2010), 'Effect of cyclic heat treatment on microstructure and mechanical properties of 0.6wt% carbon steel', Materials Science and Engineering, Vol. A 527, pp.4001–4007.
[11] Olivera E & Jovanovic M (2006), 'The austempering study of alloyed ductile iron, Materials and Design', Volume 27, pp.617–622.
[12] Putatunda SK & Kesani S (2006) 'Development of austenite free ADI (austempered ductile cast iron)', Materials Science and Engineering A, pp. 112–122.
[13] Biswal SR (2013) 'Fatigue Behaviour Analysis of Differently Heat treated Medium Carbon Steel'