International Journal of Engineering & Technology, 7 (4.39) (2018) 238-241

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Impact of Tempering Factors on Mechanical Properties of Ck55 Steel (0.55wt%C - 0.75wt%Mn)

S.R. Biswal[1*], S.T. Nayak[2]

[1] *Assitant professor, Department of Mechanical Engineering, Institute of Technical Education and Research, Shiksha 'O' Anushandhan Deemed to be University, Odisha, India*

[2] *Student, Department of Mechanical Engineering, Institute of Technical Education and Research, Shiksha 'O' Anushandhan Deemed to be University, Odisha, India*

**corresponding author email: sweta.iter@gmail.com*

Abstract

In the composite era, steel have been still gaining emphasis for automobile machine parts. In this regard Ck55 steel is taken due to its optimum balance between ductility and strength in tempered conditions. In present study, Ck55 grade steel is tempered at three temperature conditions i.e. at 600^0C, 400^0C and 200^0C for different time length. The properties of all the specimens are evaluated and we found the maximum hardness and tensile strength for tempering at 200^0C for 1 hour with minimum ductility because of the presence of less no. of softer carbide and ferrite. We get the maximum ductility at tempering at 600^0C for 2 hours with minimum tensile strength because softer carbide and ferrite dominants whole of the microstructure. It is found that tempering time and temperature greatly influences the strength as well as hardness value without much compromise in the ductility.

Keywords: *tempering, hardness, tensilestrength,ck55*

1. Introduction

As we know, steel plays a vital role in everybody's day today life. Steel with favourable properties are the best among the goods and acceptable for many applications. In this study, medium carbon steel i.e. Ck55 grade which contains 0.55% carbon is preferred for its optimum balance between ductility and strength (which can be achieved by tempering treatment process). Steel with higher strength and ductility can substitutes the current automotive steels, which can also be recognized and can provide stimulation for their rapid development and acceptance in this role. As per the designer point of view, selecting a material with varying mechanical properties are the most important requirements. The variation of mechanical properties can be controlled by the method of heat treatment. Tempering gives the balance result among all the heat treatment processes in terms of strength with ductility. As per the researchers, there is significant changes in microstructure while taking different tempering temperature and time. So, in this paper, we try to investigate the effect of the micro structural changes due to tempering temperature and time on mechanical properties.

2. Literature Review

The process of timed heating and cooling subjected to a material in the solid state in such a way that it produces different microstructure and desired mechanical properties which is known as Heat treatment. The properties which are influenced by heat treatments i.e. percentage elongation, hardness, yield strength, Young's modulus and ultimate tensile strength etc. Among all the heat treatment processes, tempering is the most important heat treatment process due to its balance characteristics of properties (strength and ductility). In This process, firstly reheating of the hardened plain steel done then that will be quenched by any liquid solution like water, oil etc. this reheating of material is done below the lower critical temperature from the holding temperature, with any desired rate of cooling by water or air for inducing hardness as explained by Kempster[1].

Krauss and Repas[2] explains that to resist shock and fatigue, tempering treatment can be done on steel like materials. That is because of the releasing internal stress which reduces brittleness. As better combinations of strength and resilience we may get from the martensitic structure from the heat treatment processes like quenching and tempering which is also previously described have long been applied to steels. That's why Avner[3] gives a fundamental idea to relate the change in hardness with change in ductility which also effect the impact load capacity. Here, the described microstructures, carbide precipitate with ferrite is obtained due to the variation in tempering temperature.

Zahid[4] et.al. describes that hardness changes as the tempering temperatures changes. It also gives the best result as compare to the other than tempering treatment. It is due to the formation of martensite. M.F. Garwood[5] et.al. evaluates the microstructures of quenched and tempered materials, by using the electron micrographs. This shows the thin carbide films changes the stress concentration effects because of decreasing tempering temperature during. The hardness value is varied from Rc 45 to Rc 55 because of microstructural changes at a decreasing tempering temperature.

Smith[6] et.al. guaranteed that in high carbon steel, melting point and temperature resistance brings down because of high percentage of carbon. High carbon steel can sustain higher strength which enhances the material weldability, in contrast with this low carbon steel has low strength. That's why medium carbon steel shows the best property variations among all.

Fadare[7] et.al. explained by experimenting on NST 37-2 steel's that mechanical properties can be modified by different heat treatment processes. The tempered samples give best results in terms of tensile strength and hardness than the samples under without heat treatment because of development of ferrite and brittle martensite structure that were acquired. Tempered specimen had the most astounding hardness and tensile strength when contrasted with the other heat-treated specimens. The outcomes acquired affirmed that NST 37-2 steel in different heat treatments change its properties.
we may presume that steels are ordinarily hardened and tempered to enhance their mechanical properties, especially strength and ductility as per several researches. To get optimum yield strength, the steel ought to have 100% martensite which is exceptionally brittle which may be obtained in hardened condition. That's why quenched steel is not utilized for many engineering applications. As tempering time and temperature can alter the martensite structure, which employs a pivotal role in change in properties, our goal is to dispense with the disarray the variation of properties in steel and its correlations with the microstructures which is well explained by Biswal[8]. But the effect of tempering temperature and time on variation of properties of steel is still under review. That's why Our motivation is to build up a central comprehension. To do this, I propose in any case unadulterated iron likewise plain carbon steels with other alloying elements to choose for examination. Along these lines, the focal point of our exploration depends on the medium carbon steel with balance high strength and better ductility in comparisons with low steel at various conditions. Here, Ck55 steel has been taken and the impacts of heat treatments on mechanical properties of Ck55 have been assessed.

3. Methodology

Steel has been used in this investigation Ck55. Dimensional specification of the tensile test specimen is given in the Figure 1. The chemical composition and properties of as received sample is described in Table 1 and Table 2.
The entire document should be in Times New Roman. The font sizes to be used are specified in Table 1.

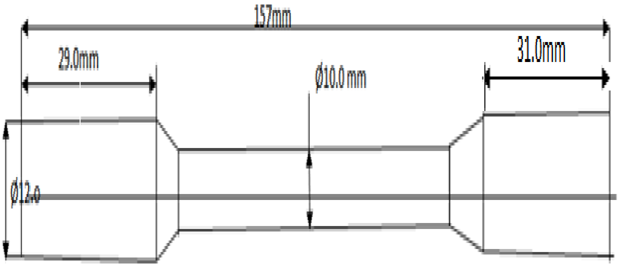

Figure 1: Specimen used for Tensile Test

Table 1: Chemical Composition (wt. %) as received specimen

C	Mn	P	S	Mo	Si	Fe
0.55	0.74	0.021	0.034	0.049	0.19	Balance

Table 2: The mechanical properties of the as received samples

Specimen Specification	Yield Stress (MPa)	Ultimate Tensile Stress (MPa)	% Elongation	Maximum Load (KN)
Specimen without treatment	397.61	583.16	21.60	45.795

Afterwards, the specimens were heated treated in the following conditions as given in Table 3.

Table 3: Heat Treatment Conditions

Condition	Hardened	Tempered 1	Tempered 2	Tempered 3
Temperature,0C	800	200	400	600
Holding time, min	60	60 90 120	60 90 120	60 90 120
Cooling medium	Water	Air	Air	Air

The specimen was subjected to the following testing methods:

3.1. Hardness Test

Hardness testing on specimens were done by means of Rockwell hardness tester. The specimen is adjusted to maximum load of 150kg and 10 kg of minor load. Here all the specimens are subjected to major load testing. The hardness value is represented in Rc scale.

3.2. Ultimate Tensile Strength Test

INSTRON 8502 servo hydraulic testing machine is used for tensile test of the specimens which has cross head speed 1mm/min. The maximum load capacity was fixed at 150 KN. Percentage of elongation, ultimate tensile strength, yields strength are measured from this tensile test.

3.3. Morphology Test

For the macrostructural and fractographical study, specimen was properly cleaned and polished using different polishing mediums. Scanning Electron Microscope (SEM) is used to study tensile test specimens after tensile test and Optical Microscope is used to study the micro structural changes after heat treatments.

4. Results

4.1. Ultimate Tensile Strength Test

The mechanical properties found from tensile tests with varying tempering temperature and time conditions are listed below in Table IV. Endeavors have likewise made to set up the structure–property relationship. The as received specimens were heated at 800^0C for 1 hour and quenched in water before the tempering treatment. The maximum values evaluated from tensile test results are as follows, the maximum tensile strength 978 MPa, yield strength 819 MPa, hardness 62 Rc with minimum percentage of elongation (ductility) 11.00% respectively. Looking at the mechanical properties of tempered specimens at various treating temperatures for a specific tempering time, tensile strength and hardness was changed drastically, which also effected the ductility. This can be related to the graphitization of the precipitated carbides and the development of ferrite structure. This demonstrated the level of hardening of the martensite and softening the matrix is due to the increment in treating temperature. This also decreased its resistance of plastic deformation. Nevertheless, the test outcomes demonstrated that at a specific hardening temperature, by changing the treating time instigates ductility (expanded in % of elongation) with slight variety in strength.

Table 4: The mechanical properties of tempering treatment samples

Heat treatment Specification	Time in hours	Yield Stress in MPa	Ultimate Tensile Stress in MPa	% of Elongation	Maximum Load in KN	Hardness in Rc
Quenched from 800^{0}C and Tempered at 200^{0}C	1	819	978	11	55.57	62
	1½	812	969.78	12	76.157	59
	2	728	951.69	18	74.736	56
Quenched from 800^{0}C and Tempered at 400^{0}C	1	619	934	22.5	73.347	58
	1½	507	894	23	70.205	55
	2	465	762	24	59.839	53
Quenched from 800^{0}C and Tempered at 600^{0}C	1	741.12	891	24	69.970	55
	1½	623.43	783	25	61.488	52
	2	618.51	783	26	60.625	50

As like tensile test, Hardness test also comes out with the variation in hardness value reference to both time and temperature. Table IV shows the interpreted results which can give a better idea to choose heat treatment processes. This composes and additionally assists us with understanding the component behind the property modification. Specimens relating to all heat-treatment temperatures demonstrated higher hardness when related with the untreated specimens of a similar steel. Here we can mention that the cooling time additionally influences the hardness properties of the material. The aftereffect of stress concentrations impacts of the thin carbide films which are shaped amid the development of martensite in hardening at lower temperature gives hardness Rc 56 to Rc 62 which is more than that of the other tempered conditions. Finally, we can interpret that Mechanical properties are upgraded as the materials experienced the different heat treatment processes.

4.2. Impact of Tempering Treatment on Microstructure

As discussed above, following interpretations can be made. 1. Images of microstructures taken by SEM and metallurgical investigations demonstrated that the surfaces of tempered specimens are martensitic at low temperature as appeared in Fig. 2. 2. It was seen that the different tensile properties took after a specific sequence concerning microstructures.

From the Fig. 2(a), (b) & (c) we can find changes with respect to the parameter changes. The micrographs taken in amplification at 20X shows the variation of microstructures in the following manners. Ferrite starts to develop at 200^{0}C to 600^{0}C. At tempering temperature (200^{0}C), tempered martensite is framed due to fast cooling and cementite are less in no and size. Whereas in the intermediate tempering (400^{0}C) both the globular cementite and martensite formed which is the main reason behind balance strength and ductility. In the case of 600^{0}C we start to find more softer ferrite and more globular cementite which induces ductility in the specimens at low temperature tempering.

Previously We discussed that at a high tempering temperature 600^{0}C, more ductility prompted in the tempered specimens. From the Fig. 2 (a), (b) and (c) demonstrated that more carbides as well as ferrites are available with the increase in tempering temperature, which is the principle motivations to actuate ductility inside the material as the ferrite and cementite are softer than others. As given in Table IV, increase in the tempering time (keeping the treating temperature consistent), more is the ductility incited in the specimen because carbide and ferrite starts to form while tempered martensite likewise vanish which might be another reason. As the holding/treatment time extended further, the hardness esteems were again diminished because of the event of coarse bainite or carbide accelerate in a matrix of ferrite structure. From all the discussions considering the test comes about demonstrates that treating at 200^{0}C at 1 hour gives the best outcomes for hardness Rc 62 at various hardening temperature for different time lengths.

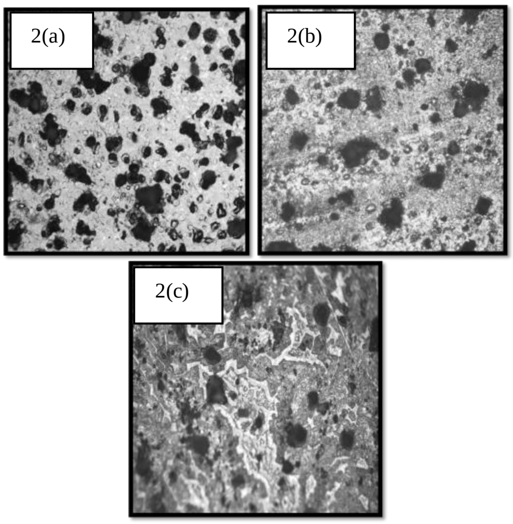

Fig. 2 (a), (b) & (c) Optical micrographs of Specimen tempered at 200^{0}C, 400^{0}C & 600^{0}C at 20X

For a given hardening time, an extension in the treating temperature diminishes the Ultimate tensile strength esteem and the yield strength of the specimen because of the ferrite development though then again it builds the % of elongation and thus the ductility. One recognizable change happened from 400^{0}C to 600^{0}C; here we had seen that Yield strength is more at 600^{0}C than 400^{0}C, which contradict the typical basics however Ultimate Tensile Strength follows the trend. This might be happened because of more carbide formation from 400^{0}C to 600^{0}C or may be due to some other extraneous factors. The change of tempering time as referred to temperature and the other way around likewise demonstrates great outcomes. The value of Hardness decreases as the tempering temperature which is clearly visible from Table IV. Quenched martensite transformation to tempered martensite may be the reason behind these changes. Because holding the materials at a higher temperature, the structure of martensite becomes less brittle may be because of carbon diffusion. Thus, quenched martensite is hardest. This is because of the change of martensite to tempered martensite. structure of martensite turns out to be less stressed in the wake of holding but holds them at a higher temperature but not as much as the lower basic temperature considering carbon dispersion. As we increase, the tempering time martensite starts to vanish which results in decrease of hardness from 1 hour to 2-hour time. higher hardness was obtained by Lowering tempering time which produce better martensite structure with lesser amount of cementite.

The images of the tensile test specimens are as shown in Figure 3 (a), (b) & (c) demonstrates the morphology of the fractured surfaces after tensile test. As steel demonstrates a completely dimpled crack, the fracture pattern indicates that ductility get increases with respect to increase in tempering temperature, the bigger size and more dimples are seen in the Fig. 3 as the temperature varied from 2000C to 6000C. This gives a clear idea that at higher tempering temperature ductility induces.

From this result and discussions, we may say that the mechanical properties have connection with micro-structural changes. It is essential to mention a sharp objective for these testing results. And finally properties like physical and mechanical get altered after heat-treatments as there is changes in the micro-structures.

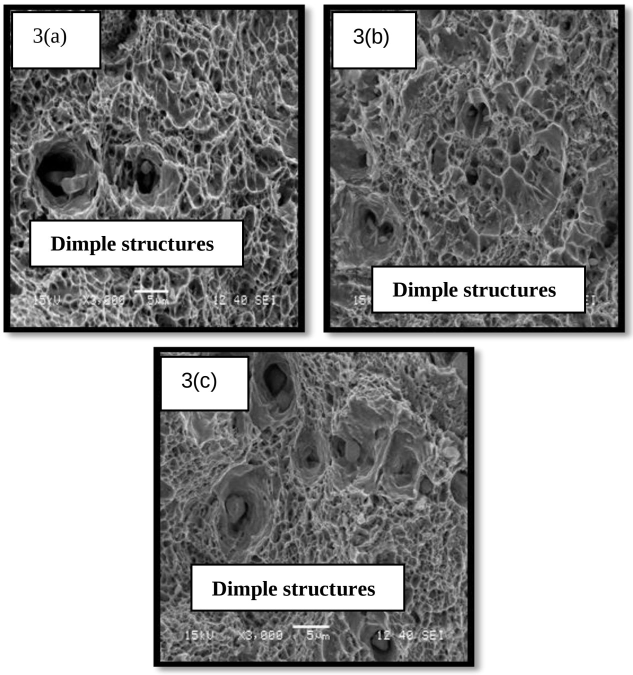

Figure 3: (a) 200^{0}C tempering, 3(b) 400^{0}C Tempering & 3(c) 600^{0}C Tempering (Tensile Test images at 3000X)

5. Conclusion

From this examination, it might be inferred that the increase of tensile strength is conversely corresponding to increment in tempering temperature and specifically relative to tempering time. The optimal outcomes are gotten for tempered at low temperature (2000C). This treatment is recommended as the best among all heat treatments. These specimens have additionally demonstrated the most astounding hardness value. This is maybe because of the way that these specimens have high strength with significant ductility. when strength and hardness are the main criteria for selecting materials for design, then hardening is strongly recommended. Some of the important implications we may derived as follows: both tempering time and temperature improves mechanical properties. From this investigation, it might be expressed that reasonable heat treatments can be performed to enhance the ductility without sacrificing in strength by increasing the tempering time at a low tempering temperature.

References

[1] Kempster, M.H.A (1976) 'Material for Engineers. Hodder and Stoughton', London, England, pp.74-75.
[2] Krauss, G., Repas, P.E.(Eds.) (1992) 'Fundamentals of Aging and Tempering In bainitic and Martensitic Steel Products', ISS-AIME, Warrendale, PA, USA.
[3] Avner, S.H. (2009) 'Physical Metallurgy', McGraw Hills', 2nd Edition.
[4] Zahid, S., Hector, P.P., Salam, A. and Ahmad, J. (2009) 'Effect of different phase proportion of martensite on the mechanical properties of a dual phase steel', Journal of Scientific Research, Vol. XXXIX No. 2.
[5] Garwood M.F., Zurburg H.H. and Erickson M.A. (1951) "interpretation of tests and correlation with service," American society of metals park, Ohio.
[6] Smith, W.F. and Hashemi, J. (2006) 'foundation of materials science and engineering', McGraw's- hill Book, 4th edition, pp 28-36.
[7] Fadare, D. A., Fadara, T. G. and Akanbi, O. Y. (2011) 'Effect of Heat Treatment on Mechanical Properties and Microstructure of NST 37-2 Steel', Journal of Minerals & Materials Characterization & Engineering, Vol. 10, No.3, pp.299-308.
[8] Biswal, S.R. (2013) 'Fatigue Behaviour Analysis of Differently Heat treated Medium Carbon Steel'.