Research Paper

Study of E ect of Heat Treatment Processes On Material Properties of Manganese Steels

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Abstract

Heat treatment on manganese steel improves ductility, toughness, hardness and tensile strength and to relieve internal stress developed in the material. The hardness test, impact test, wear test, compression test and microstructure analysis were conducted on heat treated manganese steel, which has extensive uses in all industries including electronic, research and development elds.

The manganese steel properties can be varied with the various heat treatment processes such as annealing, tempering, normalising, hardening and spheroidising. The material is given a micro nish for performing the microstructure analysis. The micro nish of the heat-treated specimen was super- nished in the single disc polishing machine. The polished specimens were etched for nding the exact microstructure. The optical microstructure images were taken at di erent magni cations and were studied.

The test results show that tempering can be done to increase the toughness, annealing can be done to increase the toughness and ductility, normalising can be done to improve the hardness with some ductility and spheroidising to increase the machinability.

Keywords:-annealing, charpy test, hardening, normalizing, spheroidising and tempering.

1 Introduction

Steel has many practical applications in every aspect of life. The manganese steel is very important material for the industries working on metals including electronics. Manganese is hard and very brittle, di cult to fuse, but easy to oxidize. Manganese steel having manganese content of 1-1.5% makes the steel strong and tough and manganese content from 2-5% makes the steel hard and brittle. When manganese is from 11-14%, steel becomes very hard, tough, and nonmagnetic and possesses considerably high tensile strength. Manganese steel shows high percentage of elongation. It can be forged easily but di cult to be machined. Speci c gravity of manganese steel is 7.2, melting point 1343°C. Compositions of manganese steel are: Carbon 1.2-1.6%, Manganese 11-14%, Chromium 1.5-2.5% and Silicon 0.5%.

The manganese content in carbon steels is often increased for the purpose of increasing hardening and improving strength and toughness. Manganese is a silvery-gray metal resembling iron. Manganese is present in all steels as a de-oxidizer. When manganese is absent or very low, the predominant sulphide is iron sulphide (FeS), which forms the eutectic with iron, has a nity to form thin continuous lms around the primary crystals during solidi cation of the steel. A higher content of manganese in the presence of carbon substantially increases the wear resistance.

The process of heat treatment is carried out rst by heating the metal and then cooling it in water, air, oil and brine water. The purpose of heat treatment is to soften the metal, to change the grain size, to modify the structure of the material and relieve the stress in the material. The various heat treatment processes are annealing, normalizing, hardening, tempering and spheroidising.

Heat Treatment is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape.

The most important heat treatments and their purposes are:

a) Normalizing - it will improve strength along with some ductility;
b) Surface hardening - Produces a local wear resistant hard surface by induction, ame, or laser;
c) Hardening and tempering - it will increase hardness and gives improved strength and higher proof stress ratio;
d) Stress relieving - to reduce or relieve Internal stresses remained after casting and a low-temperature heat treatment;
e) Austempering - it will yield to give bainitic structures of high strength along with signi cant ductility and good wear resistance;
f) Annealing - It will improve ductility and toughness and reduce hardness.

L.A. Dobrzanski et al [1] have investigated high-manganese austenitic steels with Nb and Ti microadditions in variable conditions of hot-working, which showed microstructure evolution in various conditions of plastic deformation. Microstructure of steel was subjected to solution heat treatment at temperature of 900°C and obtained ne-grained microstructure of austenite phase.

In their subsequent work [2] they have determined the force-energetic parameters of hot-working in hot-compression tests carried out in a temperature range of 850 to 1050°C. They reported that the dynamic recrystallization leads to structure re nement at temperature 850°C.

J. Adamczyk et al [3] have determined the in uence of the initial structure and heat treatment conditions on mechanical properties of DP-type steel. They have realized DP-type structure of desirable ferrite and martensite fractions by heat treatment of the low-carbon steel. Mechanical properties were determined by means of tensile test. They have reported that heat treatment conditions can be useful for manufacturing DP-type steel sheets of high strength and ductile properties and a good suitability for metalforming operations.

K.D. Clarke et al [4] have studied the induction hardening heat treatments using dilatometry on 5150 steel with ferrite-pearlite and tempered martensite initial microstructures to assess e ects of prior microstructure and heating rate. They opined that transformation temperatures are signi cantly higher for a ferrite-pearlite initial microstructure than for a tempered martensite prior microstructure. They have found that maximum hardness is independent of starting microstructure, for a given thermal cycle.

L.A. Dobrzanski et al [5] have determined the in uence of hot-working conditions on microstructure evolution and phase composition of high-manganese austenitic steels. They found that steels have a ne-grained austenite microstructure with many twins at an annealing temperature of about 1000°C. This microstructure of steel can be useful in determining power-force parameters for hot-rolling of sheets.

2 Experimental

The experimental procedures adopted for this research work can be listed as follows:
Specimen preparation
Heat treatment
Hardness measurement
Impact testing
Wear measurement
Compression strength measurement
Microstructure study

The specimens were prepared from grade 3 manganese steel based on required volume of material. The properties can be varied with the various heat treatment processes such as annealing, tempering, normalising, hardening and spheroidising which were carried out on manganese steel by varying the soaking time of each heat treatment to three di erent timings i.e., 30,45 and 60 min.

The heat-treated materials were then subjected to di erent material testing processes like hardness test, compression test, wear test and impact test. Vickers hardness testing machine is used for nding the hardness, pin on disc machine for wear test, Charpy impact testing machine to nd the impact strength and universal testing machine (UTM) is used to nd the compression strength. The material testing is done for the entire specimens with di erent heat treatment processes and also for the specimens without heat treatment.

Microstructure analysis and metallography are usually conducted to determine the material's response to thermal heat treatment. The sample to be studied is often wet abrasive sectioned, cleaned and mounted in bakelite or a resin to hold it during grinding and polishing.

Later the material is given a micro nish for performing the micro structure analysis. The surface of the heat treated specimen was super nished in the single disc polishing machine. The polished specimens are etched for nding the exact micro structure. The microstructure was studied at di erent magni cations.

3 Results and Discussions

3.1 Test results

The hardness test, compression test, wear test and impact test were conducted on these manganese steel test specimens before and after heat treatment processes. The material testing like compression test, impact test, wear test, hardness tests and microstructure analysis were conducted to nd the e ect of heat treatment process on the specimens. The values were calculated and tabulated in Table 1.

Table 1: Vickers hardness test speci cation before heat-treatment.

Load (kgf)	30
Diameter (d1) (mm)	0.440
Diameter (d2)(mm)	0.439
Mean diameter (d)(mm)	0.439
Vickers Hardness Number (VHN)	286.42

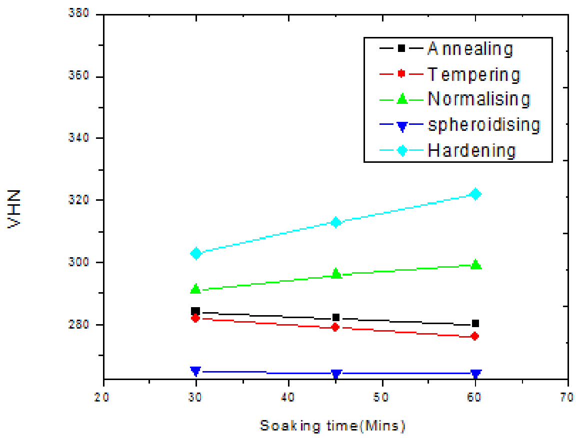


Figure 1: Variation of VHN with soaking time.

Figure 1 shows hardness of specimens under various heat treatment processes. Spherodising process makes the material softer. Hardening process makes the material harder with soaking time and all other processes come in between.

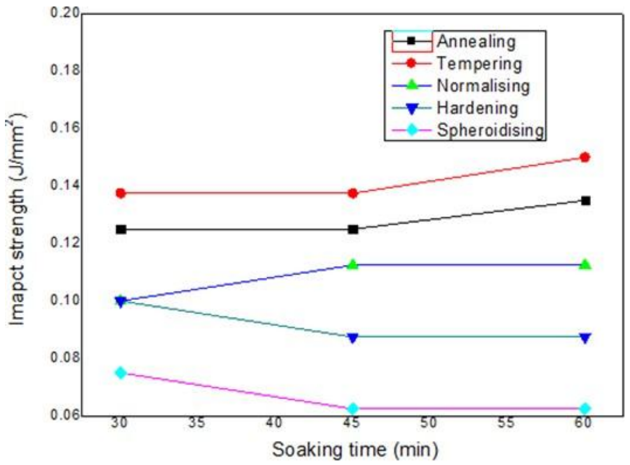


Figure 2: Variation of impact strength with soaking time after heat treatment.

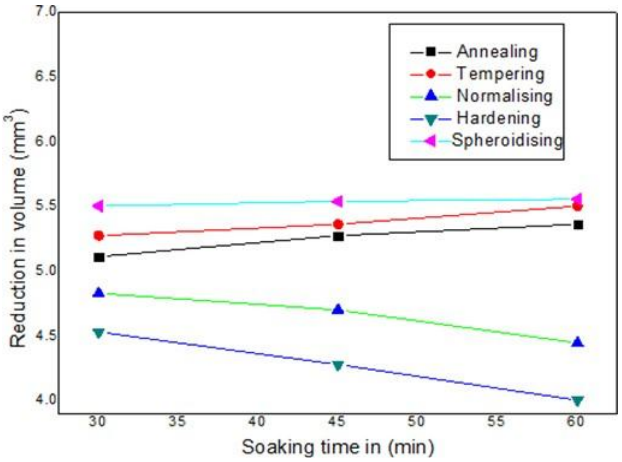


Figure 3: Variation of reduction in volume with soaking time.

The Impact strength (J/mm^2) before heat treatment was tested and found to be 0.1 J/mm.^{2} Shown in gure 2 is variation of impact strength with soaking time after heat treatment. From gure 2 it is clear that spherodising process gives low impact strength to the material. The tempering process gives high impact strength to the material and the strength increases with increasing soaking time, all other processes are seen in between.

Figure 3 reveals that spherodising process makes the material softer which results in increase in wear or reduction in volume. Hardening process makes the material harder and decreases the wear of the materials with increasing soaking time. All other processes come in between.

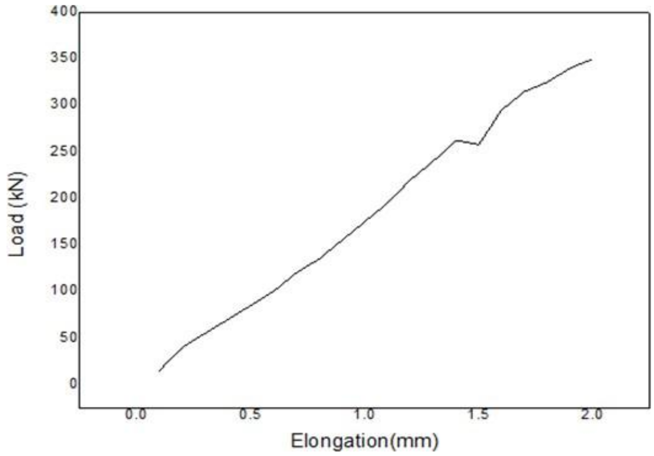


Figure 4: Variation of load with elongation of the specimen without heat treatment under compression test.

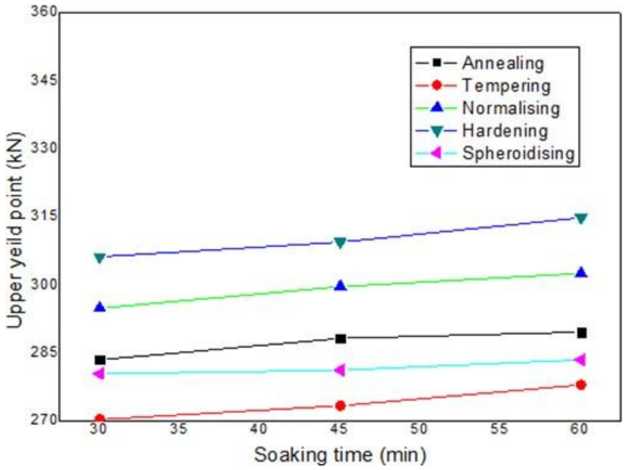


Figure 5: Variation of upper yield point with soaking time after heat treatment.

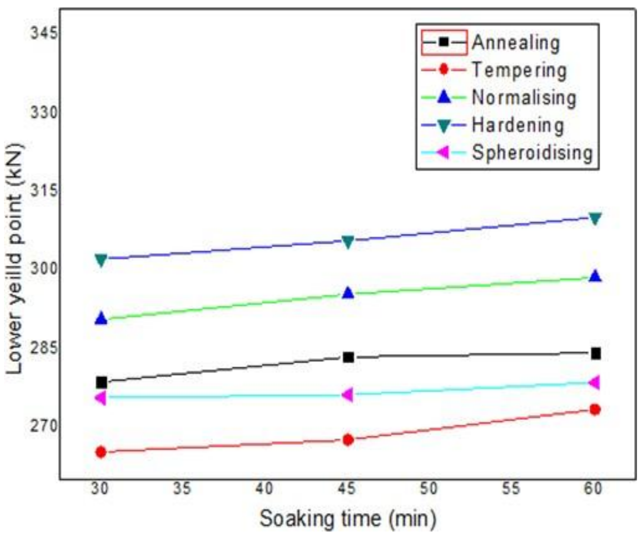


Figure 6: Variation of lower yield point with soaking time after heat treatment.

Figure 4 shows the variation of load with elongation of the specimen without heat-treatment under compression test. It is seen from the gure that upper yield point is 262.24 kN and lower yield point is 257.64 kN. Figure 5 shows the upper yield point in a compression test of specimens under various heat treatment processes. Tempering process decreases the compression strength of the material. Hardening process increases the compression strength of the material with increasing soaking time. Figure 6 shows lower yield point in a compression test of specimens under various heat treatment processes. Tempering process decreases the compression strength of the material. Hardening process increases the compression strength of the material with increasing soaking time. All other process come in between.

3.2 Microstructure Analysis

Figure 7 shows Optical microstructure of manganese steel before and after heat-treatment for 30,45 and 60 min. α-ferrite and pearlite phases, are seen; the pearlite structure is distributed in α-ferrite.

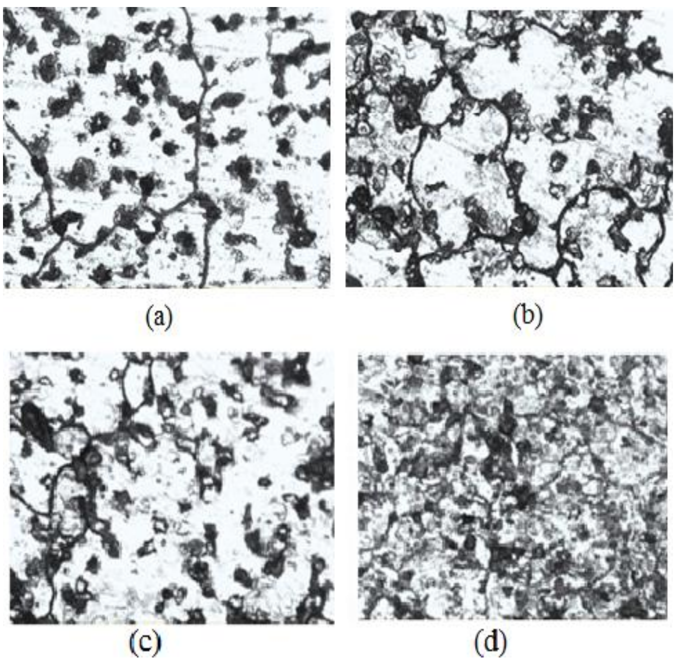


Figure 7: Optical microstructure of manganese steel:
(a) without heat treatment;
(b) after annealing with 30min. soaking time;
(c) after annealing with 45min. soaking time;
(d) after annealing with 60min. soaking time.

In gure 7 (d) the α-ferrite and pearlite phases are evenly distributed and are denser than that for 30 and 45 minutes of soaking. The property of the pearlite phase is to improve the toughness of the steel and reduce the hardness which is seen in microstructure after annealing with 60min. soaking time.

In gure 8 the α-ferrite and pearlite matrix is seen clearly. The property of the pearlite is to improve the toughness and α-ferrite is to improve the mechanical property. Thus, tempering reduces the hardness and improves toughness of the materials which is seen after tempering with 60 minutes of soaking time. The toughness increased when compared with 30 minutes of soaking time.

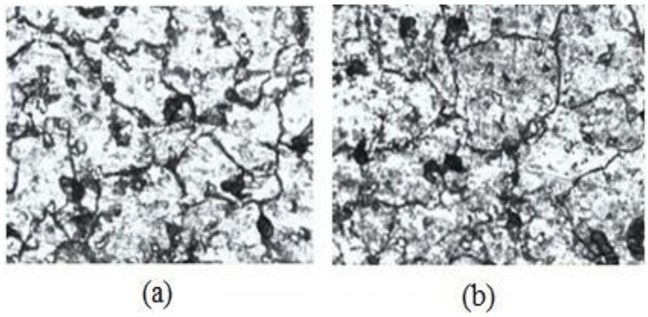


Figure 8: Optical microstructure of manganese steel:
(a)after tempering with 30min. soaking time;
(b)after tempering with 60min. soaking time.

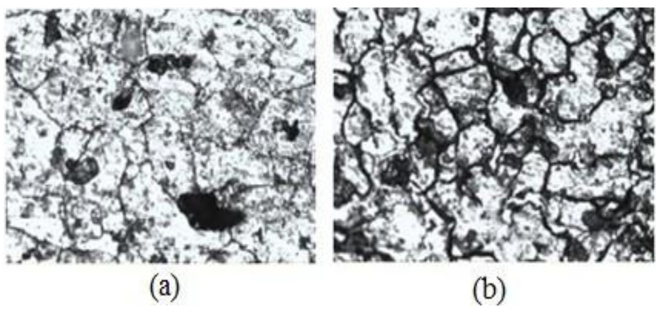
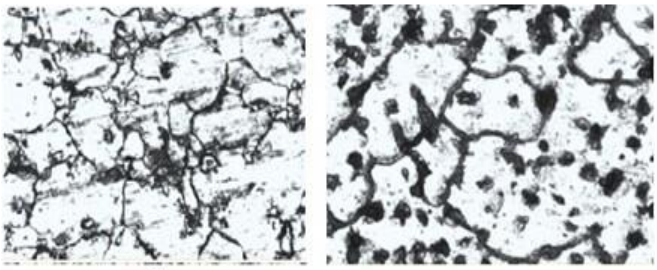


Figure 9: Optical microstructure of manganese steel:
(a) after hardening with 30min. soaking time;
(b) after hardening with 60min. soaking time.

The α-ferrite and pearlite in martensite matrix is seen in gure 9(a). The property of the martensite is to improve the hardness of the material. The hardness of the material is due to the presence of martensite as seen in microstructure after hardening with 30 minutes of soaking time. The Martensite reduces the toughness.

Figure 9(b) shows the presence of α-ferrite and pearlite in martensite matrix. The martensite found in gure 9(a) is denser than the martensite seen in hardening with 60 minutes soaking time. The property of the martensite is to improve the hardness. And it is seen in the gure that soaking increases the hardness of the material and the increase in hardness is due to the presence of martensite phase.



(a) (b)

Figure 10: Optical microstructure of manganese steel:
(a) after normalising with 30min. soaking time;
(b) after normalising with 60min. soaking time.

Figure 10 shows the normalising behaviour of manganese steel. The distributed pearlite with martensite matrix is seen in gure. The property of martensite is to improve the hardness and the pearlite to improve the toughness. It is seen in the result that normalising increases the hardness, wear resistance and toughness of the manganese steels with the increase of soaking time.

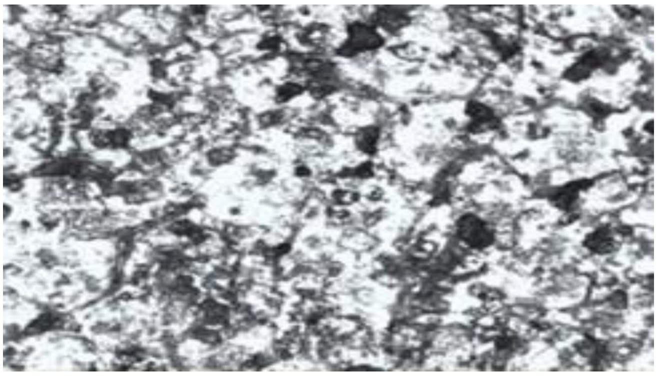


Figure 11: Optical microstructure of manganese steel after spheroidising for 60 min.

Figure 11 shows the optical microstructure after spheroidising where pearlite or graphite granules in α-ferrite are seen. The properties of granules are to reduce the hardness of the material. So, it is seen from the result that spheroidising reduces hardness, which can be used to improve the machinability of the manganese steel.

4 Conclusion

From various results obtained during this work it can be concluded that heat treatment mainly improves the hardness of the manganese steel; it is found from the observations that the hardness increases as the soaking time increases. Similarly, the hardening increases wear strength, impact strength and also yield strength of the manganese steel with increasing soaking time. Hence, hardening can be used to improve the mechanical properties of manganese steel.

The tempering heat treatment process is used for increasing the strength, with signi cant ductility and good wear resistance. From the result obtained after tempering it is found that hardness, wear strength, impact strength and yield strength of the manganese steel also increase with increase in soaking time. But the change in the mechanical properties after tempering is comparatively lower when compared with the hardening heat treatment.

The normalising heat treatment is carried out mainly to improve strength with some ductility. From the results obtained after normalising it is found that hardness, wear strength, impact strength and yield strength of manganese steel also increases with increase in soaking time. But the increase in these mechanical properties is comparatively lower when compared with hardening and tempering heat treatment processes.

The annealing heat treatment process is carried out to reduce hardness and to improve machinability such as to facilitate cold working. From the results obtained after annealing it is found that hardness, wear strength and impact strength of manganese steel decreases with increase in soaking time. But the yield strength increases with increase in soaking time. The Spheroidising heat treatment process is also carried out to improve machinability. From the results obtained after annealing it is found that hardness, wear strength and impact strength of manganese steel decreases with increase in soaking time. But the yield strength increases with increase in soaking time. Hence, to improve machinability, the spheroidising heat treatment should be carried out on manganese steel.

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