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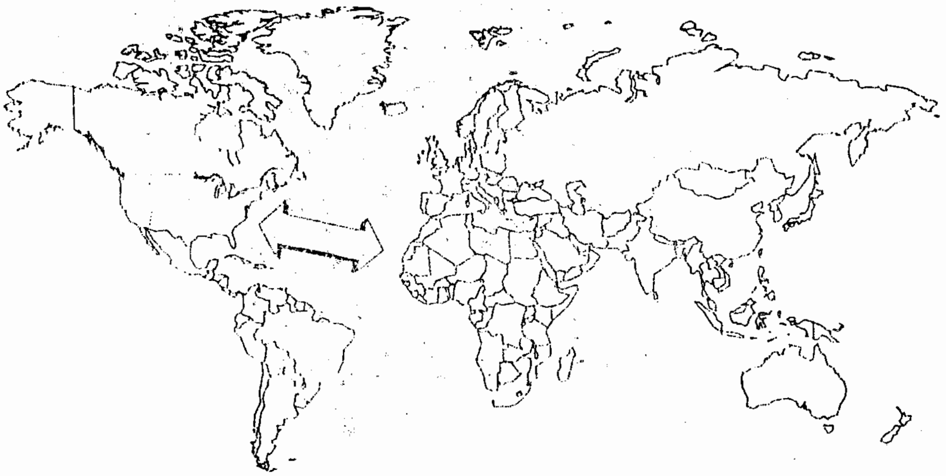

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HEAT TREATMENT OF SOME NIGERIAN CONSTRUCTIONAL STEELS AND ITS TECHNOLOGICAL APPLICATION

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Abstract

Two of Nigerian constructional steels, NST 37-2 and NST 60Mn, were heat treated in various temperature and quenching media of water, mineral oil and air to ascertain the [illegible] hardness for manufacturing purpose. Results indicate that water seems to be the most efficient quenching media where maximum hardness is required. However, where hardness can be used for quenching. NST 60Mn steels, with higher Mn and C contents, showed greater hardness at fast cooling rates. This greater hardness was due to the greater amount of martensitic transformation and precipitation hardening of carbides (Fe_3C). The air-cooled samples did not show much increase in hardening because the steels transform more into ferrite with very little pearlite. The technological importance of these results are discussed in this paper to help the local manufacturing companies in adopting any of the quenching media above, which would suit their needs after the heat treatment. By so doing, the much needed spare parts for machinery in Nigeria in particular, and Africa in general can be produced locally.

1. Introduction

In order to accelerate technological processes, Nigeria has embarked on indigenous efforts towards development of carbon steels to be used mainly in the construction industry. This led to the establishment of steel plants at Ajaokuta, Aladja and three inland rolling mills at Osogbo, Jos, and Kastina by the Federal Government of Nigeria. These inland rolling mills would turn semi-products (billets) into round finished products (wire rods and bars). The main input material for the rolling mills would be carbon steel billets from Aladja Steel Plant which is presently the only producing plant out of the two steel plants.

These billets from Aladja Steel Plant, on arrival at the inland rolling mills would be used to produce merchant bars from 12 mm to 40 mm (round 12-40 mm or reinforcement bar 12-25mm) and wire coil from 6mm-12mm or reinforcement wire 8mm-12mm. They can be straightened in cold work.

616

These products of low alloy steels are used mostly for constructional purpose. They could also be used for making nails, bolts, nuts, rivet, wiremesh, machine parts, shafts, connecting rods, automobile components and other engineering purposes.

However, in order to use the product in manufacturing, there are needs for secondary processing using heat treatment. Heat treatments represent a major part of the thermomechanical processing of most engineering materials. It is one of the features that control the microstructures of steel. Heat treatment also affects the proportion, size and distribution of the phases, together with the grain size, composition of the phases by an equilibrium or none-quilibrium partitioning, dislocation structure and defect structure. The effects which result to soften the steel for further working operation, improve its mechanical properties including impact hardness and wear resistance.

This work was undertaken in order to highlight the importance of heat treatment of those Nigerian steels which can be used in manufacturing technology.

2. Experimental Procedure

The Nigerian steels NST 37-2 and NST 60Mn were used in this experiment. The composition of these steels are given in Table 1.

Table 1 Chemical Analysis

Sample	C	Si	Mn	P	S	Ni	Cu	Sn	N	Al	Cr
NST 37 -2	0.238	0.323	0.62	0.008	0.015	0.057	0.138	0.021	0.086	0.00	0.048
NST 60 Mn	0.386	0.161	0.92	0.038	0.006	0.18	0.012	0.004	0.061	0.003	0.039

The hardness specimens were sliced from the bar about 40mm and 22mm. All the specimens were heat treated at the furnace between 750°C and 900°C for 30 minutes in soaking time.

Some of the specimens, were non-heat treated to ascertain their hardness in as rolled condition. Three media of quenching were employed, air, mineral oil and water. Prior to hardness measurement the specimens were given a standard surface finish by grinding on silicon carbide papers from 220 to 600 mesh grades after quenching.

All hardness measurements were carried out on a Vickers hardness testing machine using a diamond pyramidal indentor and a 30 kg load. The hardness number quoted in the results is the mean of at least twenty separate indentations. The specimens were reground on silicon carbide papers and polished metallographically and etched in 3% nital reagent for microstructural inspections.

3. Results

During the course of the work, a large number of results on the effect on hardness of air, oil, and water cooling, were produced, but this paper is limited to a consideration of only a few of the results on austentized temperatures. Table 2 shows the hardness of both steel in as-rolled condition. Table 3, shows the various hardness readings at the different cooling media and austentizing temperatures.

Table 2. As-rolled condition

Sample	Hardness values (Hv30)
NST37-2	143
NST60Mn	192

Table 3.

Samples	Conditions	Temperatures (^{0}C)	Hardness Values (Hv30)
NST37-2	Air-Cooling	800	150
NST37-2	Air-Cooling	900	153
NST60Mn	Air-Cooling	800	199
NST60Mn	Air-Cooling	900	206
NST37-2	Oil-Cooling	800	178
NST37-2	Oil-Cooling	900	191
NST60Mn	Oil-Cooling	800	287
NST60Mn	Oil-Cooling	900	485
NST37-2	Water-Cooling	800	225
NST37-2	Water-Cooling	900	447
NST60Mn	Water-Cooling	800	561
NST60Mn	Water-Cooling	900	630

The representative microstructure of Steel NST 37-2 at austentizing temperature of 900^{0}C and water cooled is shown in Figure 1. Figures 2-4 show microstructures of steel NST 60Mn at austentizing temperatures from 750^{0}C to 900^{0}C, air and water quenching.

Comparing the hardness at various cooling media, the air-cooling media results seem to have a little increase in the hardness compared with the two other cooling media. Tremendous increase in hardness was noticed in water cooling for both steels.

4. Discussion

The steels NST37-2 and NST60Mn comprising ferrite-pearlite microstructures form by far the largest category of high stength-low-alloy structural steels. Developing such steel is based on the relationships which have been determined between microstructure and properties.

The effects of heat treatment are much more pronounced with water and oil quenching than with air cooling. There is a marginal increase in hardness with oil cooling when compared with air cooling.

In other words, air cooled steel is more ductile than oil and water cooled samples of the steels. This is in agreement with the observations of other investigators (Hansen and Pradham, 1980). The poor ductiles at faster cooling rates are thought to be due to a harder, less ductile ferritic matrix, as a result of excess interstitial carbonaferous that are retained in solid solution during rapid cooling. The amount of total harder phase is increased as the cooling rate increased, and changed from ferrite-pearlite mixtures in most steel on air cooling to martensite at higher cooling rates. As it has been observed by (Hansen and Pradham, 1980), the amount of martensite increased more on water cooling than on oil cooling. The microstructures of these steels in figures (1-4) have indicated that the water cooled samples were transformed more into martensite.

In steel NST37-2 the carbon content was loss than 0.3%, it can be deduced that about 80% ferrite and 20% pearlite are formed in this steel, which invariably have an effect on the hardness. While on the other hand, if steels contain about 0.5 and 0.87% of carbon content, the formation of pearlite will be 60 and 100% respectively. Any further increase in carbon gives rise to free cementite at the grain boundaries or as needles (Rollason, 1984). Again in steel containing about 0.4% carbon, on quenching in water the steel will contain 50% ferrite and about 50% martensite (Thelning, 1984).

Looking at the results of the quenching media of these steels, oil quenching has not raised the hardness significantly. This implies that where hardness can be sacrificed, oil quenching is used. The quenching velocity of oil is much less than water, [illegible] and troosite are formed even in small section (Rollason, 1984). Troosite is softer than martensite, and small amounts in the steels lessen the risks of cracking and distortion.

The tremendous increases in hardness of steel NST60 Mn at these various heat treatment temperatures and cooling media, are attributed to two major factors, which are the martensitic transformation and the precipitation hardening of carbides on the grain boundary. The microstructures of these steels have revealed these two phenomena to be responsible for the strengthening of these steels by these treatments. The martenstic transformation which accompany water quenching in these steels, has played the same role of strengthening as the strain induced martensite which was observed during deformation meta-stable alloy Fe-Mn-Mo recently (Inegbenebor, et al, 1989).

In ferrite-pearlite steels it has been observed that grain refinement benefits both yield strength and the ductile to cleavage fracture transition temperature Hall, (1951), Petch, (1953) and Petch, (1962), and that there is an additional gain in strength as a result of precipitation hardening by microalloying (Morrison, 1966). Even though these steels have not been alloyed, the precipitation of carbides at the grain boundary, have taken the roles of microalloying. Recently, the effect of precipitates of strength and toughness of vanadium structural steels were studied, (Bepari, 1990). It was observed that the rapid cooling rate which results to precipitation of vanadium carbide contributed more to

Fig. 1. NS137-2
At 900^{0}C and
water cooled.

Fig. 2. NSI 60Mn
At 750^{0}C and
water cooled

Fig. 3. NSI 60Mn
At 800^{0}C and
water cooled

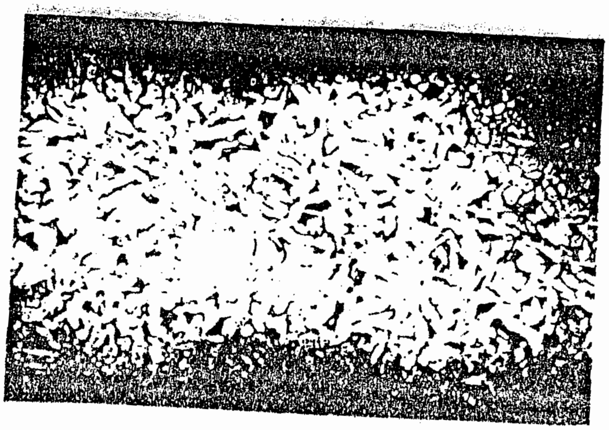

Fig. 4. NSI 60Mn
At 900^{0}C and
and Air cooled

yield strength. These additions contribute to an increase in strength, partyly by precipitation hardening due to carbides (Fe_3C) and partly by martenstic transformation have opened way for further developments of these steels in HSLA and Dual-Phases. This will help greatly in our automotive industry and other related industries.

The technological importance of these results in this era of Structural Adjustment Programme (SAP) are:- NST37-2 has wide applications in industry where ductilities and toughness are required. This will depend on temperature of heat treatment and quenching media. On the other hand, NST60 Mn has been shown to be a candidate steel for further development into wear-resistant applications especially in agricultural and mining sector.

Small-scale industries can be encouraged to use this simple heat treatment method to produce surface wear-resistance on NST60Mn. Where hardness is to be sacrificed for ductilities, oil quenching can be used.

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322