Case Carburizing of Low Carbon Steel with Different Temperatures and Time

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الخلاصة :

تعتبر المعالجة الحرارية والكربنة من وسائل تحسين الخصائص المختلفة للمعادن والسبائك. وفي هذا البحث تمت الدراسة الميكانيكية والمجهرية للفولاذ الخفيف المكربن عند درجات حرارة 850 و900 و 950 م^0 في فترات زمنية 1 و 2 و 3 واربع ساعات .

قبل التبريد السريع بالماء (الغمر) تم تمييز وتحديد التركيب الكيميائي والمجهري لهذه العينات بواسطة مقياس الطيف والمجهر الضوئي وتم قياس الصلادة على سطح العينات وكذلك قياس الشد لهذه العينات.

أظهرت النتائج تشكل حالة صلادة كبيرة نتيجة لتكون حالة مارتينسيت بينما احتفظ التركيب الاساسي للعينة بالخصائص الاصلية وكانت أكثر ليونة وأكثر قساوة .

تم إعادة تسخين العينات بدرجات حرارة 200 و 400 و 600 م^0 وذلك من أجل زيادة قساوة العينات مع نقص مقبول في الصلادة .

Abstract:

The heat treatment and carburization has been acknowledged by some means of improving the various properties of metals and alloys. In the present investigation the mechanical and microstructure of mild steels carburized at different temperature range of 850, 900 and 950 C^o at different times of 1,2,3 and 4 hours have been studied before water quenching,the chemical composition and the microstructures of these samples were characterized by spectrometry and optical microscopy. The microhardness of the surface of each sample was measured and preliminary tensile testing was conducted. The results showed the formation of a significant hardened case due to the formation of martensite, while the core retained its original ferrite-carbide microstructure and was softer and tougher. Tempering was carried out at $200C^{O}$, $400C^{O}$ and $600C^{O}$ in order to stress relieve the quenched samples and to increase the toughness of the steel case with an acceptable reduction in hardness.

Keywords: case carburizing, low carbon steel, Case depth, Tensile strength, Quenching and Tempering.

1. Introduction:

The carburization provides a gradual change in carbon content and carbide volume from the surface to the bulk, resulting in a gradual alteration of mechanical and wear properties. The heat treatment and carburization increases the mechanical and wear resistance. Carburizing is the addition of carbon to the surface of low-carbon steels at temperatures generally between 850 and 950°C (1560 and 1740°F), at which austenite, with its high solubility for carbon, is the stable crystal structure. Hardening is accomplished when the high-carbon surface layer is quenched to form martensite so that a high-carbon martensitic case with good wear and fatigue resistance is superimposed on a tough, low-carbon steel core. Carburizing steels for case hardening usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at between 0.8 and 1% C. However, surface carbon is often limited to 0.9% because too high carbon content can result in retained austenite and brittle martensite. Carburizing is one of the most widely used surface hardening processes. The process involves diffusing carbon into a low carbon steel alloy to form a high carbon steel surface. Carburizing steel is widely used as a material of automobiles, form implements, machines, gears, springs and high strength wires etc. which are required to have the excellent strength, toughness, hardness and wear resistance, etc.because these parts are generally subjected to high load and impact. Such mechanical properties and wear resistance can be obtained from the carburization and quenching processes. This manufacturing process can be characterized by the key points such as: it is applied to low carbon workpieces, workpieces are in contact with high carbon gas, liquid or solid, it produces hard workpiece surface, workpiece cores retain soft.

2. Experimental Method:

Case hardening

The carburization of low carbon steel was carried out in the Heat Treatment Department of the Research and development center Tripoli Libya. The carburizing was conducted using case hardening temperatures of 850C^o, 900C^o and 950C^o with a heating time of 1, 2 3 and 4 hours at each temperature, followed by water quenching for 60 s. The details of the carburizing process are carried out by using iron pipe closed form lift side and open from the other side the dimensions of the mold are 50cm length, 5cm diameter and 3mm thickness. The sample used was a rod of 10 mm diameter and 170 mm length.

Tempering

After the hardening process, tempering was carried out temperature of 200C^o for 30 minutes in a tempering oven, followed by air cooling.

Characterization of low carbon steel

The initial hardness measurement for the raw material was conducted using a Rockwell hardness testing machine with a load of 150 kg. Then micro hardness measurements were made at intervals of 0.50 mm through the surface layer of carburizing low carbon steel using a Rockwell hardness testing machine with a load of 5 kg. Cross-section samples of the rod were then mechanically polished and etched in a 2% nital solution to reveal the microstructure by optical microscopy.

3. Results :

Nominal Composition

The composition of the low carbon steel was determined by spectrometry, Table 1.

Table 1 Nominal compositions (wt%) of the low carbon steel

elements	C	Si	Mn	S	P	Ni	Cu	Cr	Fe
%wt	0.16	0.03	0.32	0.05	0.02	0.01	0.01	0.01	Bal

Optical Microscopy of low carbon steel

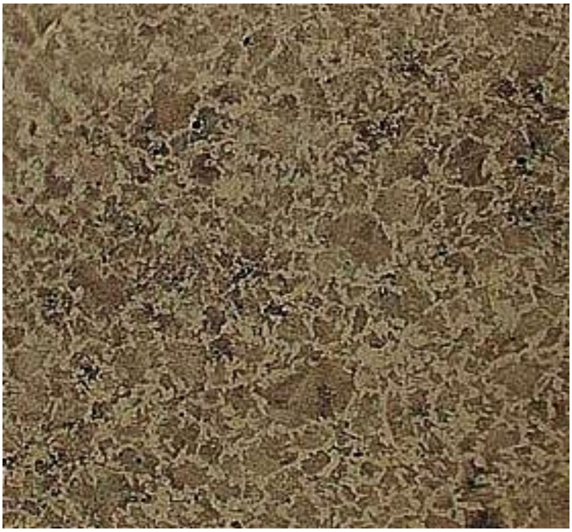
The microstructure on the low carbon steel substrate had a ferrite-pearlite appearance, while the surface layer consisted of a martensitic structure. Fig. 1(a) shows the microstructures resulting from hardening without tempering and the other microstructures represent tempering at 200C^o, Fig. 1(b); tempering at 400C^o, Fig. 1(c); and tempering at 600C^o, Fig. 1(d).

Fig. 1(a) shows an acicular structure that is due to the formation of martensite with mixed plate and lath morphologies. With increasing tempering temperature the acicular structure becomes less evident as the martensite progressively decomposes to a mixture of ferrite and carbide, Figs. 1(b-d).

Micro hardness of Surface Layer of Hardened Low Carbon Steel

The micro hardness of the surface layer of low carbon steel subjected to a carburizing hardening temperature of 850C^o was about 462 HV. This hardness level is consistent with that of untempered martensite in steel containing 0.16 % C. In comparison, 618 HV was measured for a hardening temperature 950C^o. In this case the peak temperature did not produce a fully austenitic structure and therefore a limited volume fraction of martensite was produced on quenching with the untransformed matrix consisting of coarsened grains of ferrite and carbide.

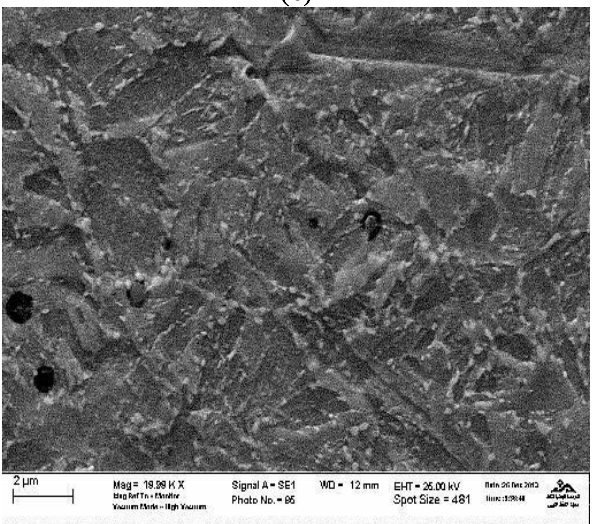
The micro hardness of the surface layer of low carbon steel after tempering at 200C^o was about 206.7 HV for a hardening temperature of 950C^O compared with 256.7 HV after tempering at 400C^O and 312.7 HV after tempering at 600C^O.



(a)

(b)

(c)



(d)

Fig.1 Optical micrographs of samples of low carbon steel subjected to a hardening temperature of 950C^o, followed by water quenching. (a) Untampered, (b) tempered at 200C^o, (c) tempered at 400C^o and (d) tempered at 600C^o.

Hardening and Tempering Treatments

Fig. 2 shows that the surface hardness increased steeply with increasing hardening temperature, but flattened out above about 950C^{o}. The effect of tempering is shown by Fig. 3, the surface hardness decreased with increasing tempering temperature. The effect of tempering on the tensile strength is recorded in Fig. 4. The tensile strength decreased as the tempering temperature increased from 200C^{o} to 600C^{o}.

Case Depth

Fig. 5 shows that the case depth increased with hardening temperature.

4. Discussion

The results from the tests conducted for carburizing hardened low carbon steel showed that a lower hardening temperature resulted in incomplete martensite formation and a reduced surface hardness. A completely martensitic structure was obtained for the tests conducted at 900C^{o} as shown in Fig. 1(a). Well as 950C^{o} a completely martensitic structure was obtained For hardening temperatures of 850C^{o} to 950C^{o}, the surface hardness increased consistently from 462 HV to 618 HV. It is likely that an increasing amount of martensitic structure formed as the hardening temperature was increased up to 900C^{o} and for this temperature as when the induction heated and water quenched samples were tempered, the martensite structure decomposed to a carbide-ferrite mixture. The martensite progressively lost its tetragonality by precipitation of carbide from solid solution. The carbide forms as a series of transition phases, starting with epsilon carbide and then transforming eventually to cementite dispersed in a ferrite matrix. As these structural transitions became more marked with increasing tempering temperature the surface hardness decreased, as shown by Fig. 3.

Fig. 5 shows that case depth was influenced by the hardening temperature. For treatment at 950C^{o}, the hardened layer is much deeper than at the lowest hardening temperature, 850C^{o}. For tempered samples, the apparent thickness of the hardened layer decreased with increasing tempering temperature. However, quenching from a given temperature, say 950C°, should produce hardening to the same depth regardless of the subsequent tempering temperature. The apparent decrease shown in Fig. 5 is probably due to difficulty in defining the extent of the hardened layer as the overall hardness deceases towards the hardness of the as received steel

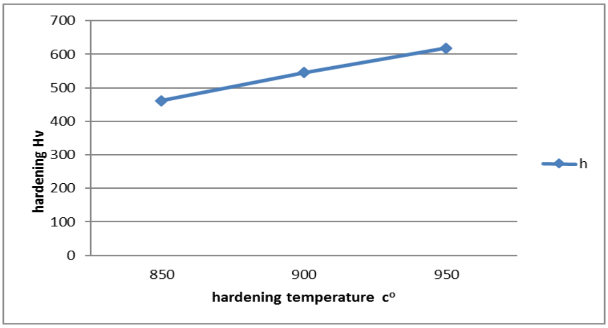


Fig.2 Graph of case carburizing as a function of hardening temperature

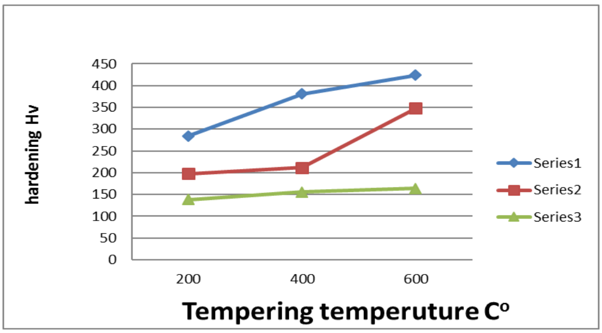


Fig.3 Graph of case carburizing as a function of tempering temperature

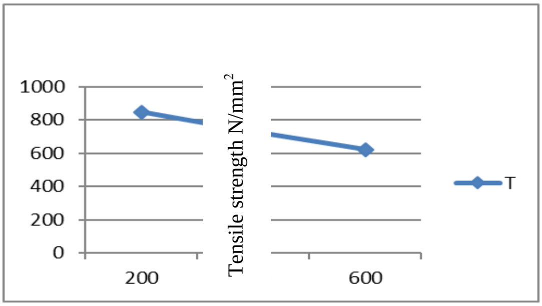


Fig.4 Graph of tensile strength as a function of tempering temperature following induction hardening at 950C°

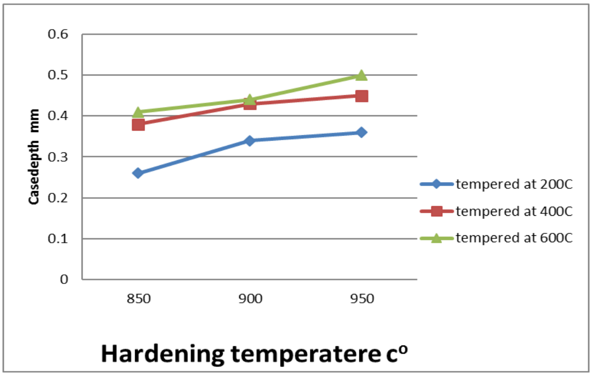


Fig.5 Graph of case depth as a function of hardening temperature

As Fig. 4 shows, the tensile strength decreased with increased of tempering temperature. At a hardening temperature of 850C° and tempering temperature 200C°, the tensile strength was 848 N/mm^2. For the same hardening temperature and a tempering temperature of 400C°, the tensile strength was lower 762 N/mm^2 Moreover, with the same hardening temperature and the higher tempering temperature of 600C°, the tensile strength was much lower 623 N/mm^2 . The tensile strength before case carburizing was only 410 N/mm^2. Therefore, tempering significantly lowered the strength of the hardened steel. However, tempering is necessary to reduce internal stresses and to produce a microstructure of ferrite and dispersed carbide which greatly increases the toughness.

5. Conclusion

Carburizing hardening of low carbon steel at the highest temperature investigated (950C^o), followed by water quenching, produced the highest hardness (618 HV), while lower hardness were obtained for the other temperatures (850C^o – 950C^o). Water quenching produced high surface hardness due to the presence of the hard and brittle martensitic structure. Tempering caused the decomposition of the martensite into a ferrite-carbide mixture with higher toughness and lower hardness and strength. By means of induction hardening, low carbon steel can be processed to produce a hardened case or surface layer, while the core of the steel remains soft and tough. However, the case requires tempering to reduce the risk of cracking and spalling.

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