Use of Carborundum-Soda Bath for Liquid Carburization of Plain Carbon Steel

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Abstract : Plain carbon steel containing 0.3 percent carbon has been carburized in carborundum-soda bath at 850°C, 900°C and 950°C for the durations of 5, 25 and 50 minutes at each temperature and then quenched in water. The microstructure of the hardened specimens was studied by optical microscopy. The amount of retained austenite was investigated by both optical microscopy and X-ray diffraction technique. Case depth and hardness on surface were measured and the hardness versus penetration distance profiles were investigated. It was found that both higher temperatures and longer periods of carburizing coarsened the structure and increased the case depth. Highest hardness at the surface was obtained at lower holding time and higher carburizing temperature. With increase in holding time, retained austenite content increased and hardness decreased.

INTRODUCTION

Some machine parts such as gears, shafts, cams, steering parts, balljoints, crankshafts, etc. require a hard and wear resistant surface supported by a tough and ductile core. Several chemico-thermal/thermal processes are available to achieve the above mentioned properties. One of them is to increase the carbon content at the surface of low carbon steel parts by carburizing without changing the carbon percentage in the core. In parts so treated a very hard surface and a tough core can be engineered by subsequent heat treatment.

For carbon saturation at the surface of a low carbon steel various carburizing techniques such as pack carburizing, gas carburizing, liquid carburizing, etc. are available. Liquid carburizing have some unique advantages [1] over pack and gas carburizing such as: (1) freedom from oxidation and sooting problem, (2) uniform case depth and carbon content, (3) higher thermal conductivity of the bath, etc. Usually liquid carburizing is carried out in a bath of molten cyanide and alkaline

earth salts [2]. Operation of cyanide salt bath is complex and risky because of the toxic gases evolved. Lately, some work has been done to study the behavior of urea-soda bath for nitriding [3]and cyaniding [4]. Nowadays, these processes are being used in a number of local industries. Urea-soda bath also evolves toxic gases and at higher temperature the tendency of the molten salt to overflow makes the operation difficult [4]. Carborundum-soda bath can be used for liquid carburizing where the probable chemical reactions are:

$$SiC + 2Na_2CO_3 = Na_2SiO_3 + Na_2O + 2CO + C_{atm}$$
$$2CO = CO_2 + C_{atm}$$
$$3Fe + C_{atm} = Fe_3C$$
$$3Fe + 2CO = Fe_3C + CO_2$$
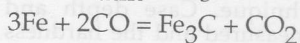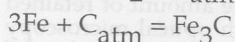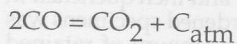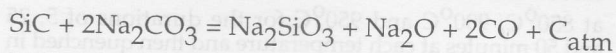
Here Na_2SiO_3 and Na_2O make slag which is removed from the surface of the molten bath from time to time and CO_2 escapes to the atmosphere. Among the other salts, neutral sodium chloride acts as a carrier material. In this bath ammonium chloride dissociates with the evolution of ammonia and hydrogen chloride gases and stirs the liquid bath. Due to this stirring action, a homogeneous composition is maintained throughout the bath, subsequently, the carburizing process is accelerated [4]. But very little about the behavior of carborundum-soda bath and the properties of the steel part carburized in such a bath is known. Therefore, this work has been undertaken to evaluate the adoptability of this bath for liquid carburizing.

EXPERIMENTAL

The carburizing was conducted in a gas fired furnace. The experimental set-up used in this work was shown and explained earlier [4]. A mixture of 77% Na_2CO_3, 10% NaCl, 4% NH_4Cl, 5% NaOH and 4% SiC by weight was melted in a cylindrical vessel of about 6 inches diameter and 12 inches height. The temperature measurement was done by means of a chromel-alumel thermocouple inserted into a stainless steel tube. The temperature of the furnace was controlled automatically by controlling the gas flow into the burner with the help of a solenoid valve actuated by a controlling pyrometer. Plain carbon steel sheets of 3 mm thickness and containing 0.3% C, 0.2% Si, 0.60% Mn, 0.03% S and 0.025% P was cut into specimens of 25 mm X 20 mm size. The test pieces were then mechanically cleaned, degreased and stored in a desiccator prior to carburizing.
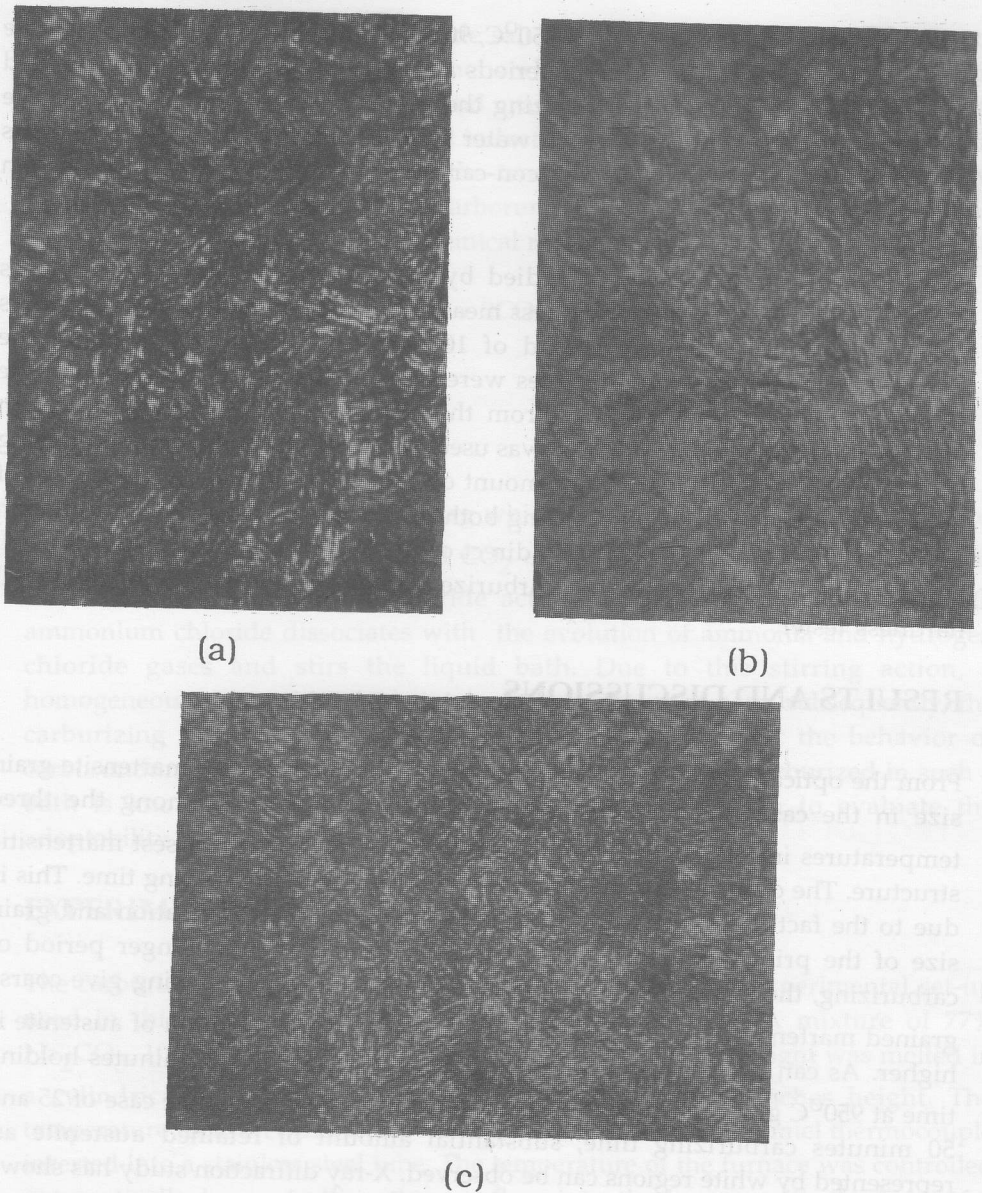
Fig. 1   Optical micrographs showing variations of martensite grain size   with temperature in the case of specimens quenched in water after 25 min of carburizing: (a) 850°C, (b) 900°C and (c) 950°C.
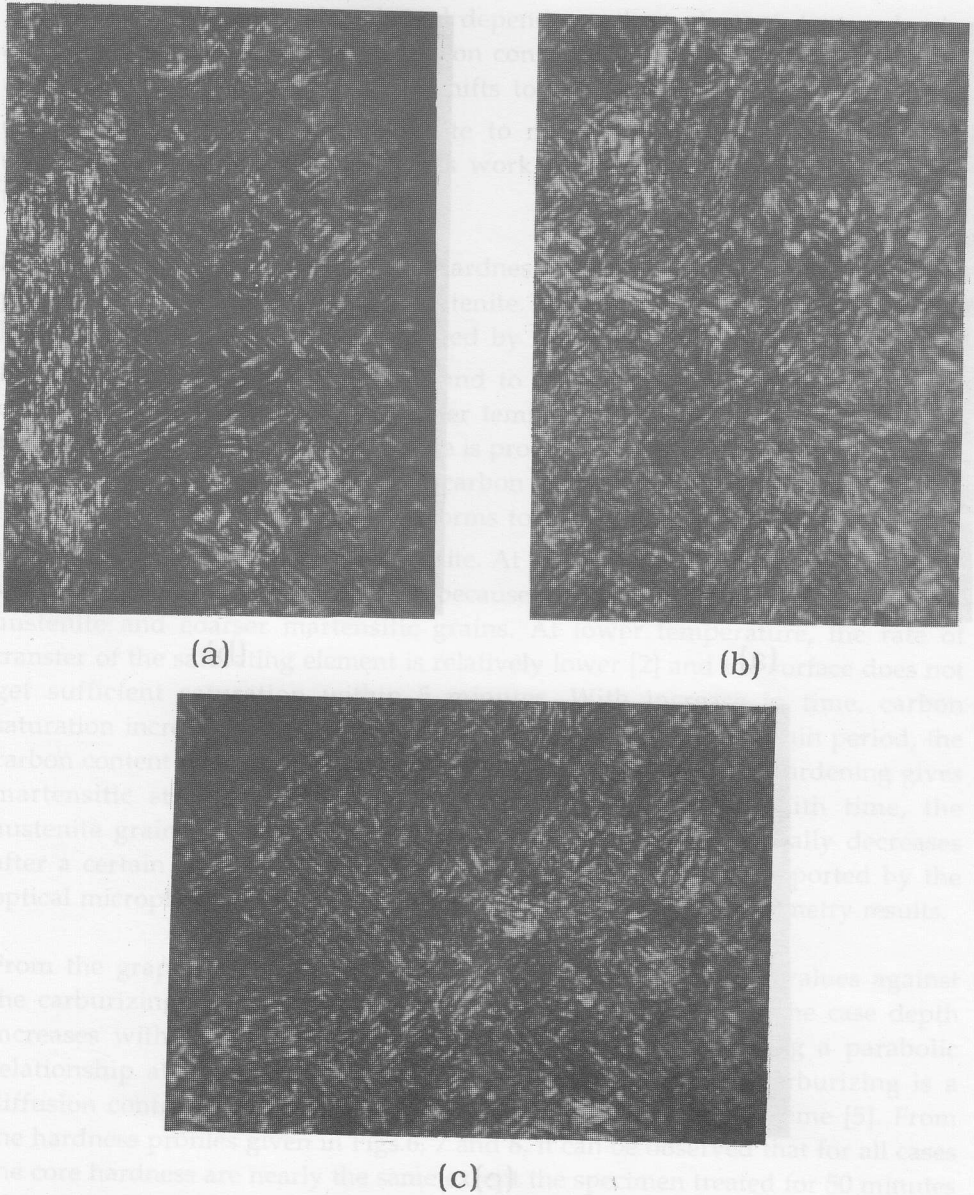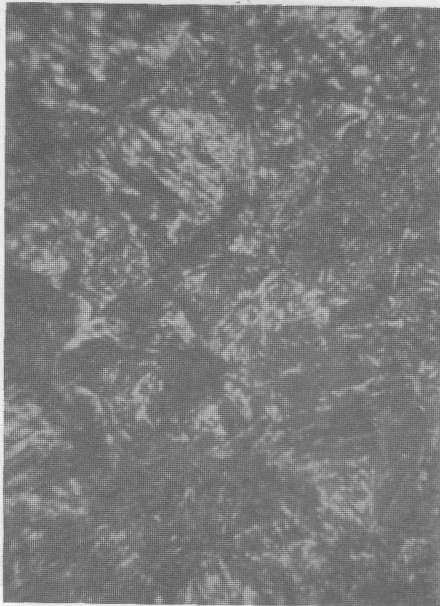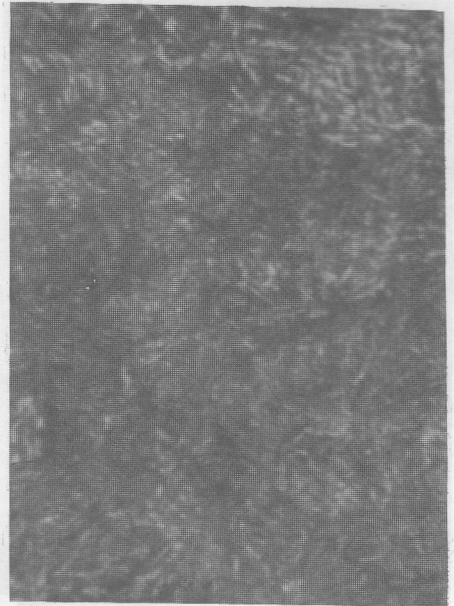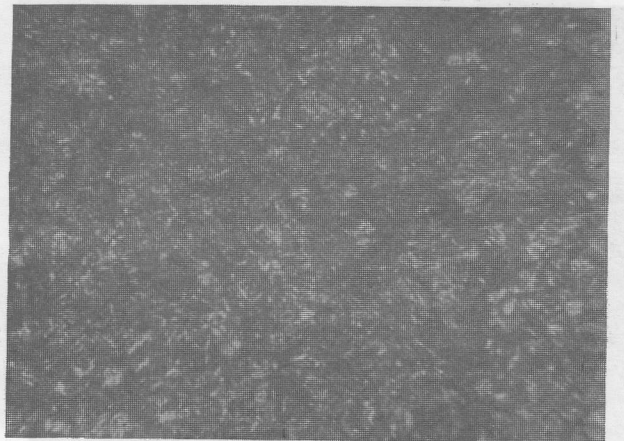
Fig. 2   Optical micrographs showing variations of martensite grain size with temperature in the case of specimens quenched in water after 50 min of carburizing: (a) 850°C, (b) 900°C and (c) 950°C.

(a)   (b)

(c)

Fig. 3 Optical micrographs showing retained austenite at the surface of the specimens carburized at 950°C and quenched in water: (a) 5 min, (b) 25 min and (c) 50 min.

retained austenite in hardened steel depends on the carbon content and prior austenite grain size. When the carbon content in a plain carbon steel exceeds about 0.65%, the M_f temperature shifts to below room temperature. For the conversion of the retained austenite to martensite, cold treatment or cold stabilization is required. But in this work, no attempt was made for such a treatment.

Microhardness tests give variable hardness values on the surface due to the presence of distributed retained austenite. To avoid this problem, an average hardness at the surface was measured by Rockwell hardness tester [8]. From Fig.4, hardness at the surface is found to be highest at 950°C for 5 minutes carburizing. This is because at higher temperature, the diffusing element can transfer at a faster rate and a 5 minute is probably sufficient for the surface of the specimens to achieve about 0.65% carbon at this particular temperature. On hardening, the surface region transforms to fine grained martensite with no or very small amount of retained austenite. At 950°C, the hardness values decrease with an increase in carburizing time because of the increased amount of retained austenite and coarser martensitic grains. At lower temperature, the rate of transfer of the saturating element is relatively lower [2] and the surface does not get sufficient saturation within 5 minutes. With increase in time, carbon saturation increases giving rise to a higher hardness. After a certain period, the carbon content on the surface probably exceeds 0.65% which on hardening gives martensitic structure with distributed retained austenite. With time, the austenite grains are also coarsened. So, surface hardness gradually decreases after a certain carburizing period. The above cases are well supported by the optical microphotographs given in Figs.1, 2, 3, and X-ray diffractometry results.

From the graphical representations of the effective case depth values against the carburizing time as shown in the Fig.5, it is observed that the case depth increases with the increase in the carburizing time maintaining a parabolic relationship at all temperatures. This is due to the fact that carburizing is a diffusion controlled process which proceeds parabolically with time [5]. From the hardness profiles given in Figs.6, 7 and 8, it can be observed that for all cases the core hardness are nearly the same except the specimen treated for 50 minutes at 950°C. This is believed to be due to grain coarsening favored by longer treatment time and higher temperature.
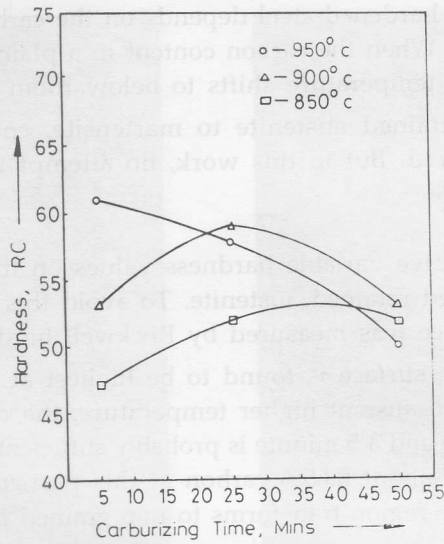
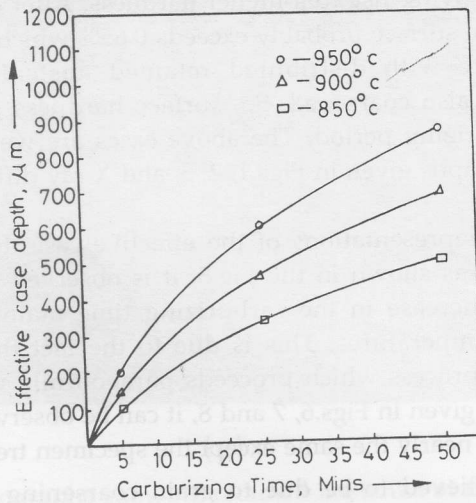**Fig. 4** Variation of Rockwell hardness at the surface of the carburized and quenched specimens with time.

Fig. 5 Variation of effective case depth with carburizing time at different temperatures.
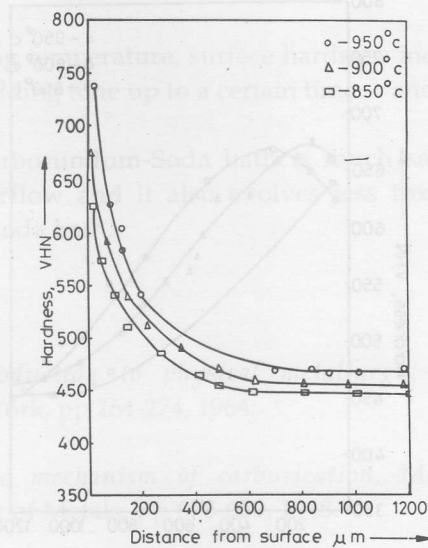
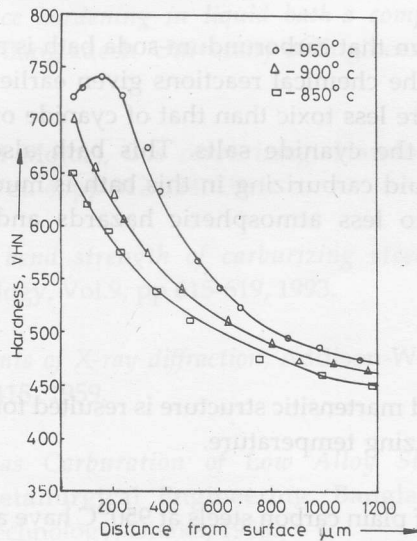**Fig. 6** Microhardness profiles of the quenched specimens developed after 5 minutes of carburizing.

Fig. 7 Microhardness profiles of the quenched specimens developed after 25 minutes of carburizing.
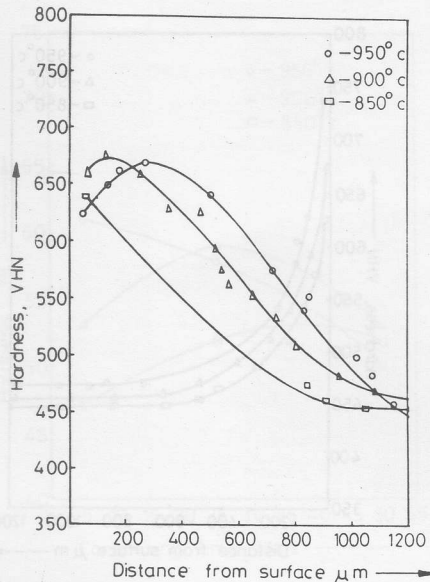
Fig. 8   Microhardness profiles of the quenched specimens developed after 50 minutes of carburizing.

This study has shown that carborundum-soda bath is an effective bath for liquid carburizing. From the chemical reactions given earlier, it can be observed that the evolved gases are less toxic than that of cyanide or urea-soda baths because of the absence of the cyanide salts. This bath also have less tendency to overflow. Thus, liquid carburizing in this bath is much safer for the personnel under work due to less atmospheric hazards and simplicity in technical operation.

CONCLUSIONS

1. Coarse grained martensitic structure is resulted for longer holding time and higher carburizing temperature.

2. Carburizing of plain carbon steels at 950°C have a higher tendency to form retained austenite in the hardened cases.

3. At 950°C, the surface hardness is the highest and the hardness gradually decreases with the increase in holding time.

4. For lower working temperature, surface hardness increases gradually with the increase in holding time up to a certain time and then decreases.

5. Operation in Carborundum-Soda bath is much safer because of lower tendency to overflow and it also evolves less toxic gases than that of cyanide or urea-soda bath.

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The specimens were carburized at 850°C, 900°C and 950°C. In order to study the effect of time, three different time periods as 5, 25 and 50 minutes were selected at each temperature. After carburizing the specimens were removed from the bath and quenched immediately in water at room temperature. The specimens were then sectioned by using a silicon-carbide disc cutter to reveal the section orthogonal to the treated surface.

The effect of carburizing was studied by metallography and microhardness measurements. For the microhardness measurement, a Shimadzu microhardness tester was used employing a load of 100 gm for 10 seconds to cause the indentations. Microhardness profiles were used in this work to determine the extent of penetration of carbon. From the microhardness profiles, the depth corresponding to 540 VHN (50 RC) was used as the effective case depth following the procedure of Stickels [5]. The amount of retained austenite on the surface of the specimens was investigated using both metallography and X-ray diffraction technique. In X-ray diffractometry, direct comparison technique [6,7] was used. Hardness at the surface of the carburized case was measured by Rockwell hardness tester.

RESULTS AND DISCUSSIONS

From the optical micrographs showing the microstructures and martensite grain size in the case given in Figs.1 and 2, it is evident that among the three temperatures investigated the treatment at 950°C gives the coarsest martensitic structure. The coarseness of the structure increases with carburizing time. This is due to the fact that martensitic structure depends on the orientation and grain size of the prior austenite [1]. For higher temperature and longer period of carburizing, the austenite grains are coarsened which on hardening give coarse grained martensite. At 950°C, the tendency toward the retention of austenite is higher. As can be seen from the microphotographs in Fig.3, 5 minutes holding time at 950°C gives rise to very little retained austenite. But in the case of 25 and 50 minutes carburizing time, substantial amount of retained austenite as, represented by white regions can be observed. X-ray diffraction study has shown that at 950°C the retained austenite is approximately 10% for 50 minutes of carburizing while that for 25 minutes of treatment is 6%. Higher retained austenite deteriorates the dimensional stability under severe friction which makes the applications of the carburized part limited [5]. The presence of