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DECREASING HEAT TREATMENT COST OF SURFACE HARDENED MACHINE PARTS BY CASE CARBURIZATION

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ABSTRACT

Machine parts are surface hardened to increase fatigue strength and wear resistance. Carburization is the most common surface hardening process in practice. In order to have optimum properties, a machine part must have certain hardness depth. To obtain required hardness depth, the parts must be kept in a carburizing medium at certain temperature for certain time. As the time and temperature is increased hardness depth increases. In practice, carburization temperature is about 930 °C. Machine parts are kept at this temperature for required time depending on required hardness depth. The increase of temperature reduces treatment time, considerably. But, heat treaters do not tend to use high temperatures due to the concern of distortion of parts, and deterioration of mechanical properties. In this study, the increase of temperature for reducing carburization time in salt bath, and consequently change of mechanical properties have been investigated using DIN C20 case carburization steel. As a result of experiments, it was found that mechanical properties were not effected negatively.

Key Words : Heat treatments, Carburization, Grain size, Fatigue strength, Hardness depth

KARBÜRİZASYONLA YÜZEYİ SERTLEŞTİRİLEN MAKİNA PARÇALARININ ISIL İŞLEM MALİYETLERİNİN AZALTILMASI

ÖZET

Hareket eden makina parçalarının pek çoğu, aşınmasının azaltılması ve yorulma mukavemetinin arttırılması için yüzey sertleştirme işlemlerine tabi tutulmaktadır. Makina parçasının optimum özelliklerde olabilmesi için belirli bir sertlik derinliğine sahip olması gerekir. Gerekli sertlik derinliğinin elde edilmesi, karbürizasyon ortamında belirli bir sıcaklıkta belirli bir süre bekletilmekle olur. Sıcaklık ve süre artarken sertlik derinliği de artmaktadır. Pratikte karbürizasyon 930 °C civarında yapılmaktadır. Bu sıcaklıkta makina parçaları istenilen sertlik derinliğine göre belirli bir süre bekletilir. Halbuki sıcaklığın arttırılması, süreyi önemli miktarda azaltmaktadır. Fakat ısıl işlemciler parçanın çarpılması, mekanik özelliklerinin zayıflaması vs. gibi nedenlerden dolayı daha yüksek sıcaklıklara çıkmamaktadırlar. Bu çalışmada, DIN C20 karbürizasyon çeliği kullanılarak, tuz banyolarında karbürizasyon süresinin kısaltılması için sıcaklığın artırılması ve bunun neticesi mekanik özelliklerdeki değişmeler araştırılmıştır. Deneyler neticesi mekanik özelliklerin olumsuz yönde etkilenmedikleri görülmüştür.

Anahtar Kelimeler : Isıl işlemler, Karbürizasyon, Tane büyüklüğü, Yorulma dayanımı, Sertlik derinliği

1. INTRODUCTION

Reducing the cost is the most important subject for machine manufacturers. Cost of heat treatment of parts may excess the cost of materials needed for parts. Any part exposed to surface hardening by carburization must be kept for a long time in a carburizing medium. It is clear that, if treatment time becomes shorter, the cost of heat treatment will be considerably reduced. Taking this fact into consideration, some heat treatment plants and researchers have initiated some investigation to study the subject.

Stephen (1986), in the experiments made on AISI 8620 and AISI 4118 case carburization steel, has shown that plasma carburizing time is 50 % shorter than gas carburizing and has 14.5 % greater carbon potential.

Mahler (1979), carburizing a series of case carburization steel between 925-1090 °C in gas medium, has investigated mechanical properties of steels, and determined that there is no outstanding change. Milano (1979) has ensured 50 % energy saving by increasing gas carburization temperature from 925 °C to 1010 °C. Different factories have obtained important savings in heat treatment costs by designing furnace working over 1000 °C (Vinton, 1988).

Because salt bath method is a widely used method in Türkiye, in this work, the effect of salt bath carburizing at high temperature on mechanical properties of materials and carburization time (thus on case carburization cost) has been investigated.

2. INFLUENCE OF TIME AND TEMPERATURE ON CASE CARBURIZATION DEPTH

Diffusion of carbon into steel takes place according to,

$\delta C/\delta t = D\cdot(\delta^2 C/\delta x^2)$ (Fick's II. law).

From the solution of this equation

$$\frac{C(x,t) - C_0}{C_1 - C_0} = 1 - \mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right) \qquad (1)$$

is obtained. In the equation, the terms are;

C_1 : Carbon concentration of medium (%)

C_0 : Carbon concentration of steel (%)

C(x,t): Carbon concentration at distance x from the surface layer of materials after t time (%)

t : Diffusion time (s)

$\mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$: Gaussian error function

D : Diffusion coefficient

and

$$D = D_0 \cdot e^{-Q/RT} \qquad (2)$$

where

D_0 : Frequency factor of diffusing atoms (cm^2/s)

Q : Activation energy (Cal/mol)

R : Gas constant (Cal/mol K)
T : Temperature (K)

In the case of carbon diffusion into face-centred cubic steel (that is austenit),

$D_0 = 0.21$ (cm^2/s)
Q = 33800 (Cal/mol) (Bargel, 1980).

If the steel with 0.2% C is carburized in salt bath with 0.8% C medium, and is wanted to be 0.4% C at 0.5 mm, equation (1) becomes,

$$t = 2.5\cdot 10^{-2}\cdot e^{17000/T} \qquad (3)$$

If it is calculated according to temperature, carburization times are found as in Table 1.

Table 1. Calculated Carburization Times Depending on Temperature

Temperature	T(°C)	925	950	975	1000	1025	1050
Time	t (h)	10.10	7.55	5.72	4.30	3.38	2.68

As a result of calculation, as the temperature is increased from 925 °C (the temperature applied in practice) to 1050 °C, carburization time decreases about four times. In practice, temperatures as high as 1050 °C are not used due to the thoughts such as requirement of high temperature resisting equipment, distortion care and especially grain growth which deteriorate mechanical properties of materials.

3. INCONVENIENCES DUE TO HIGH CARBURIZATION TEMPERATURE

3. 1. Distortion of Parts

The distortion of part occurs because of creep or quenching stresses. The creep can be prevented when part is well supportedly put into a furnace.

In order to decrease quenching stresses, furnace temperature can be reduced to desired temperature before quenching, or another furnace can be used for this purpose.

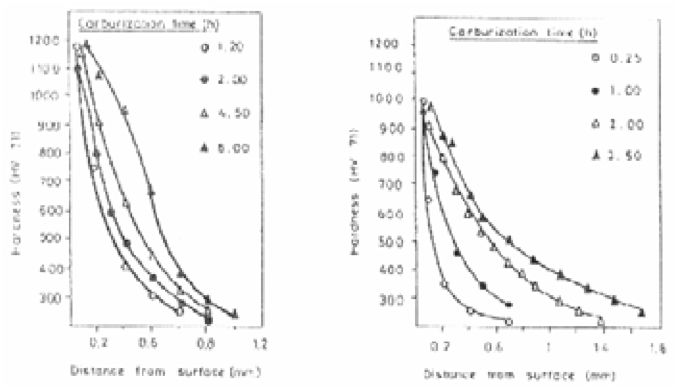
3. 2. Materials of Furnace Construction

There have been refractory materials resisting over 1200 °C. Furnace wall thickness can be enlarged for reducing heat loss. High temperature resisting steel can also be used up to 1050 °C. For these reasons, there is no problem in a furnace construction for higher temperatures.

4. EXPERIMENTAL STUDIES

Specimens with 6 mm dia. made of DIN C20 steel have been carburized in a salt bath consisting of 22 % NaCN at 950 °C, and 15 % NaCN at 1050 °C for different times. Without taking out of carburized parts from a furnace the temperature has been reduced to 900 °C, and quenched in oil at this temperature. Microhardness values obtained from the specimens are given in Figure 1.

The grain size measurement has been carried out, on specimens taken from carburized parts. The change of the grain size has been given in Figure 2 in terms of temperature and carburization time.



(a) (b)

Figure 1. Microhardness values obtained as a result of carburization at, (a) 950 °C, (b) 1050 °C and quenching in oil from 900 °C.

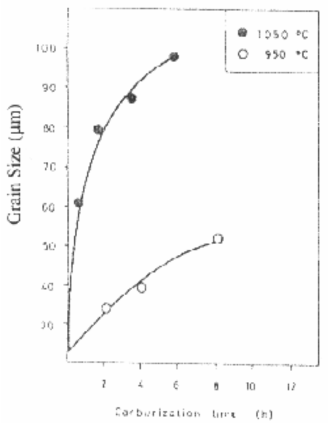


Figure 2. Effect of carburization time and temperature on grain size

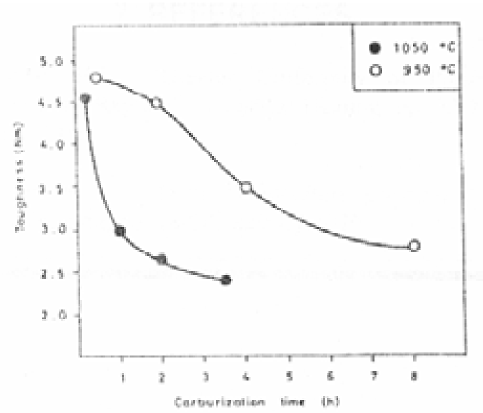


Figure 3. Effect of carburization time and temperature on impact value, A_v

The specimens prepared for impact tests have been carburized at the same bath and quenched. A_v values have been measured by Charpy test method. The results obtained have been given in Figure 3.

The fatigue strength values obtained at $N=10^6$ cycle from rotating bending fatigue test have been given in Figure 4.

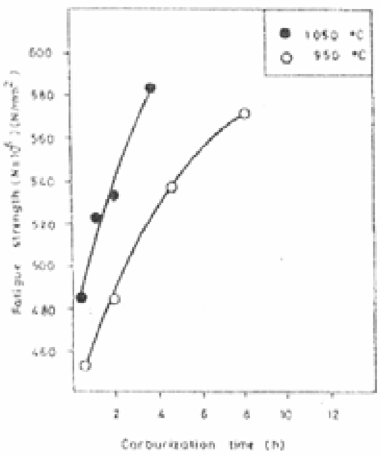


Figure 4. The effect of carburization time and temperature on fatigue strength

5. DISCUSSION OF TEST RESULTS

It was seen that, as a result of carburization for the same hardness depth, the rise of temperature from 950 °C to 1050 °C shortens the carburization time considerably. If an active hardness depth distance accepted up to 500 HV, the results in Figure 5 are obtained from Figure 1.

As it is seen in Figure 5, by rising of temperature from 950 °C to 1050 °C carburization time is reduced to half for 0.5 mm hardness depth. Although it is required (10-15) % more energy by increasing temperature, (35-40) % energy saving can be obtained by shortening time. Especially, in parts, to which deeper cementation application is required, the time at high temperature will shorten, too. Then, the cost is remarkably reduced.

Carburization time has been reduced by the rise of temperature, but as it is seen in Figure 2, the grain size of material has been increased rapidly. The grain size of material cause deterioration of mechanical properties, i.e., fatigue strength. However, as it is seen in Figure 4, the decrease of fatigue strength has not been occurred, on the contrary some improvement has been obtained. Impact value, A_V, has been hardly reduced, and difference between the two cases has disappered after prolonged carburization times.

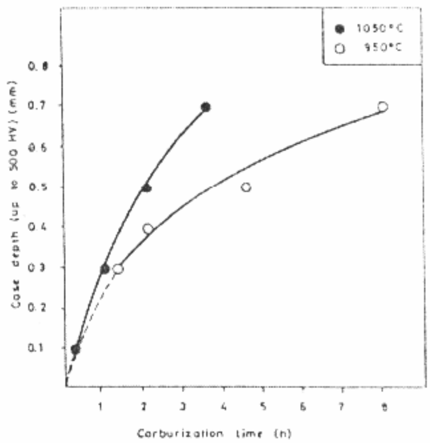


Figure 5. Hardness depth (up to 500HV) versus carburization time and temperature

6. CONCLUSIONS

1. By rising carburization temperature from 950 °C to 1050 °C carburization time and cost were considerably reduced. For 0.5 mm hardness depth carburization time was reduced by half, and the cost was decreased by 40 %.

2. By rising carburization temperature to 1050 °C, fatigue strength of DIN C20 steel was not decreased.

3. No important change in impact value, A_v, was obtained.

4. For 950 °C, 22 % NaCN, for 1050 °C, 15 % NaCN gave the appropriate hardness levels.

7. REFERENCES

Bargel, H. J. 1980. Werkstoffkunde, VDI-Verlag GmbH, Düsseldorf.

Mahler, F. J. 1979. High Temperature Carburizing. Heat Treating. pp. 18-20.

Milano, N. P. 1979. Heat Treating Conference, ASM, Heat Treatment of Metals. (1), 2-3.

Stephen, H. V. 1986. Greater Uniformity of Plasma Carburizing Rapidly. Industrial Heating. p. 22-25.

Vinton, B. 1988. High-Temp., Gas-Fired Furnace Completes Field Testing, Heat Treating, September.