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An investigation on fatigue life of borided AISI 1010 steel

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Properties

ABSTRACT

Purpose: This study aims to investigate the fatigue life of box borided AISI 1010 steel materials.
Design/methodology/approach: Fatigue specimens firstly have been prepared according to ASTM E466-96 standard and normalized. Then their surfaces have been cleaned by polishing. Boriding heat treatment has been applied in solid media with the help of Ekabor2 powder. Specimens have been borided at 1173-1223-1273 and 1323 K temperatures for 2-4 and 6 hours respectively. Fatigue tests have been made in rotating-bend test device. Separate S-N diagram has been formed for each boriding condition and then their results were compared with the results of the specimens on which any heat treatment has not been made.
Findings: As a result it has been seen that boriding has no positive effect on fatigue life of AISI 1010 steel materials. And also it has been determined that fatigue life of the materials on which boriding heat treatment applied, decreases in between 14 %-55 %.
Research limitations/implications: It can be noted that the reasons of short fatigue life determination are the boride layer's much higher hardness than the substrate material's, and the micro cracks existed between boride phases formed onto the surface.
Originality/value: The investigations on fatigue life of borided AISI 1010 steel were made.
Keywords: Boriding; Fatigue life; AISI 1010 steel

1. Introduction

Improvement of metallic materials' surface properties influences fatigue life. General judgment seems to be that fatigue stregths of the materials will increase if their surfaces are hardened [2]. Actually when the relevant studies are scrutinized, it appears that this judgment is not acceptable all the time, and the results may change dependent upon the material chosen to be searched and the type of heat treatment chosen to be applied.

Boriding is a thermochemical surface hardening treatment. Depending on substrate material and boriding conditions, single or double phase boride layer can be formed. Generally, because of different thermal expansion coefficients of boride phases, single phase boride layer is preferred [9]. The thermal expansion differences can cause micro cracks between phases.

Asrafizedeh [1] reported that fatigue life of C45 steel increased 50 % approximately when plasma and gas nitriding was applied to it. Nevertheless, [4] concluded that fatigue life of D3 tool steel decreased in between 29 % and 50 % when nitro-carborizing and nitriding was applied to that material.

In reviewing the literature about borided specimens, a case in which fatigue life is directly searched was not met. Meanwhile Matuschka [8] has pointed out that the researches made for explaining the effect of boriding on fatigue life were not adequate, yet. But in spite of this, he guessed that boriding would affect fatigue life negatively.

Fundamentally fatigue begins with a microcrack which initially exists on the specimen's surface and goes forward its inner part. To take precautions for preventing the formation of cracks on the surface will increase fatigue life. Basic surface hardening treatments such as nitriding and shot peening are expected to increase fatigue life [5]. But sufficient number of experimental studies about the effect of boriding which is also a surface hardening method, on fatigue life does not exist.

Thus the aim of this study has been defined as investigating the variation of fatigue life of borided AISI 1010 steel.

2. Experimental studies

Specimens produced from AISI 1010 material has been used in the experiments. All of them has been processed in CNC lathe with the same measurements (Figure 1). Chemical composition of the material which was used is given in Table 1.

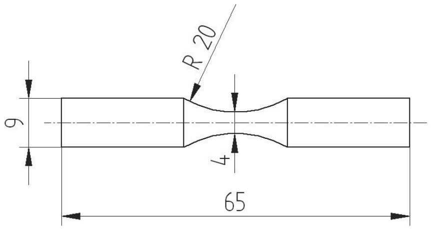


Fig. 1. Rotating-bend fatigue test specimen

Table 1.
Chemical composition of the test specimens

C	Si	Mn	S	P	Fe
0.1	0.2	0.2	<0.003	<0.003	Bal.

After the specimens have been produced, they were normalized at 1193 K for one hour. And then their surfaces were cleaned with the help of 1200 mesh SiC emery paper. Fatigue tests were realized in Hi-Tech rotating-bend fatigue device.

Seperate S-N diagrams of normalized but not borided specimens and the specimens which were borided at 1173-1223-1273 and 1323 K temperatures for 2-4 and 6 hours have been compared.

3. Results

3.1. Microstructure and hardness

Microstructure photographs of AISI 1010 steel materials can be seen in Figure 2. And optical microstructure photographs given in Figure 3 is belonging to the borided specimens.

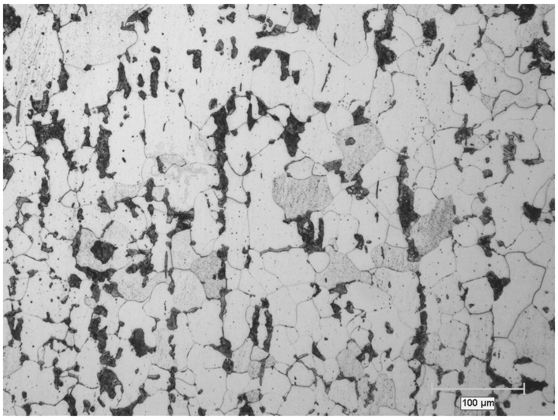
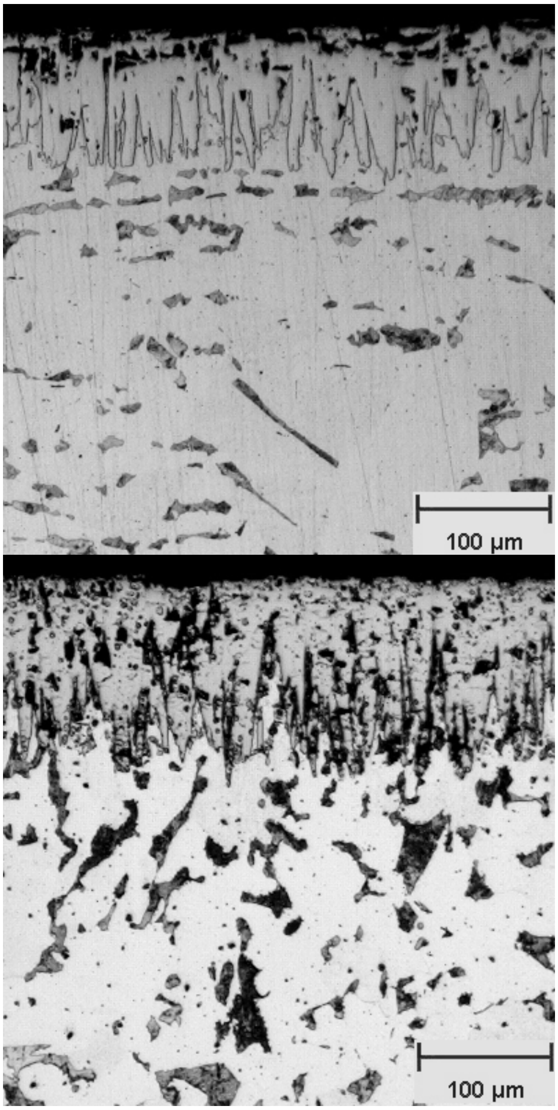


Fig. 2. Microstructure photograph of AISI 1010 steel 200x, %5 Nital



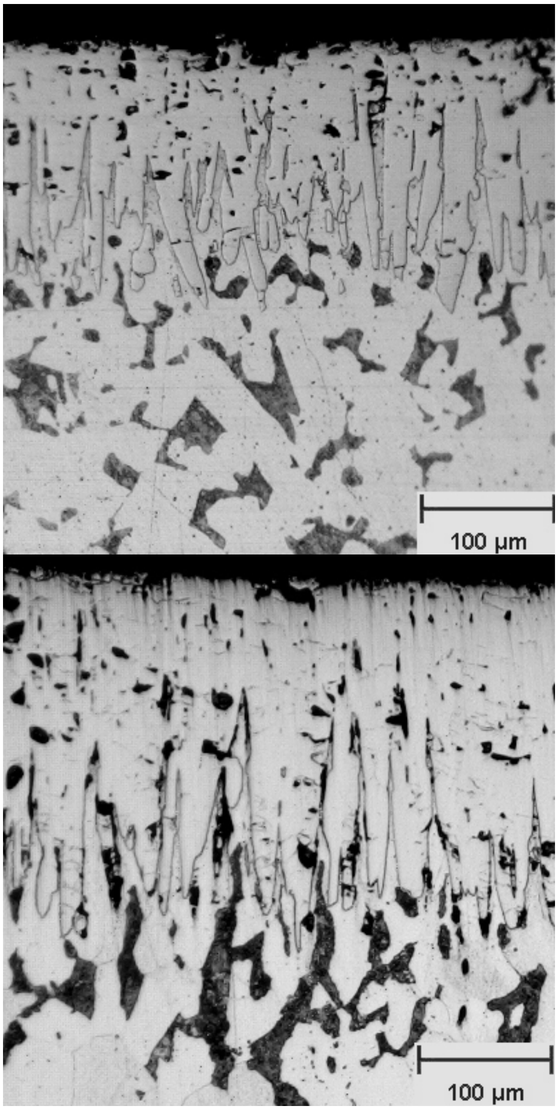


Fig. 3. Microstructure photograph of the material borided at 1173-1223-1273-1323 K temperatures for 4 hours, 100x, 5% Nital

In normalized state, AISI 1010 material containing ferrite and pearlite phases has a boride layer in saw teeth form on its surface after it had boriding heat treatment.

Boride layer thickness changes according to heat treatment time and temperature. And the thickness of boride layer depending on heat treatment time and temperature is depicted in Figure 4.

As a result of boriding heat treatment Fe_2B and FeB phases comes into being on the surface of the specimens. XRD results of the borided specimens are shown in Figure 5. After boriding heat treatment matrix structure of FeB-Fe_2B-transition zone is seen beginning from the surface. Some studies is in literature supported this by reporting that microcracks parallel to the surface appeared in FeB-Fe_2B phases after boriding [3,6,7].

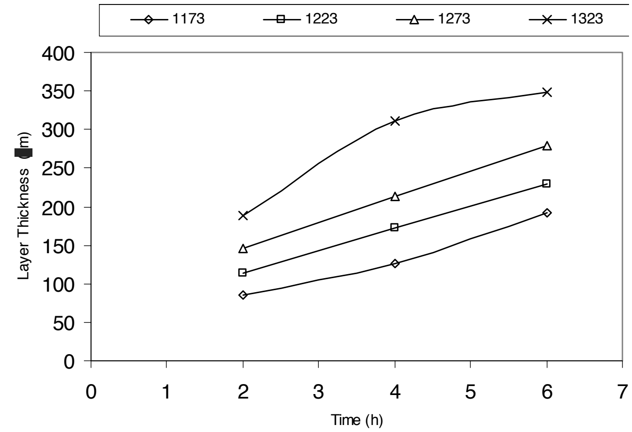


Fig. 4. Change of boride layer thickness

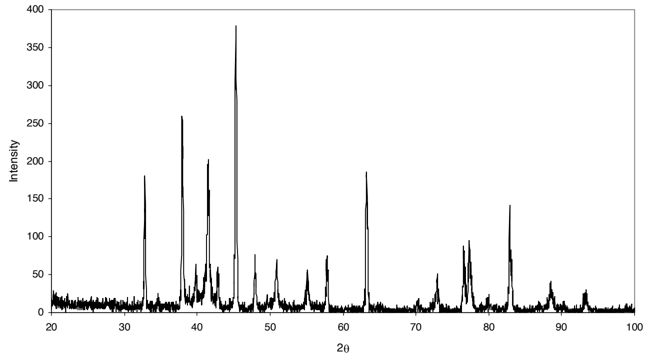


Fig. 5. XRD results for 1223 K, 6 hour borided AISI 1010 steel

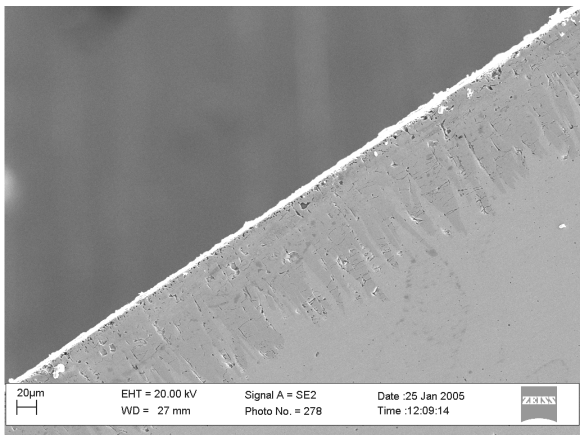


Fig. 6. SEM photograph of borided material at 1223°C for 4 hours, x200

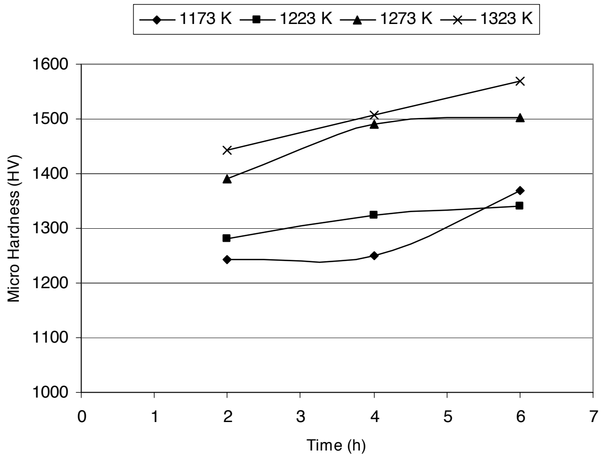


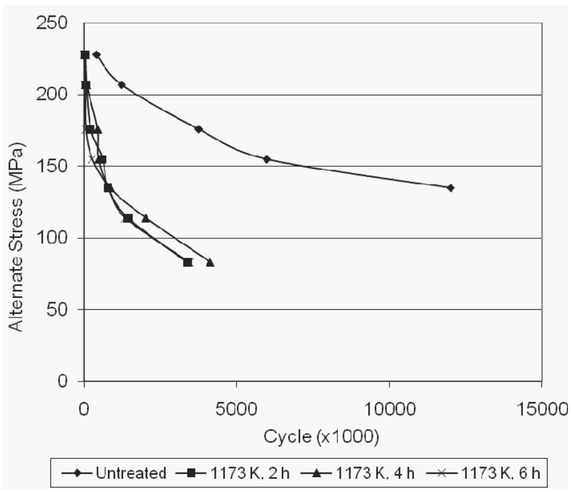
Fig. 7. Microhardness change depending on temperature and time

This kind of microcracks have not been met in metallographical investigations made on the specimens experimented. Metallographically FeB phase seems darker than Fe_2B phase. So it is possible to distinguish FeB and Fe_2B phases in the SEM photograpfh shown in Figure 6.

As for hardness change of the borided layer depending on heat treatment temperature and time, it can be seen in Figure 7.

3.2. Fatigue tests

Results of the fatigue experiments are depicted in Figure 8. S-N curves representing all of the heat treatment conditions have been compared with the S-N curves of the specimens which had no heat treatment. This comparison have pointed out that fatigue strength of the specimens which had not been borided were lower than of the borided ones. This fatigue strength difference became at least 14 % and at most 55 % depending on heat treatment conditions.



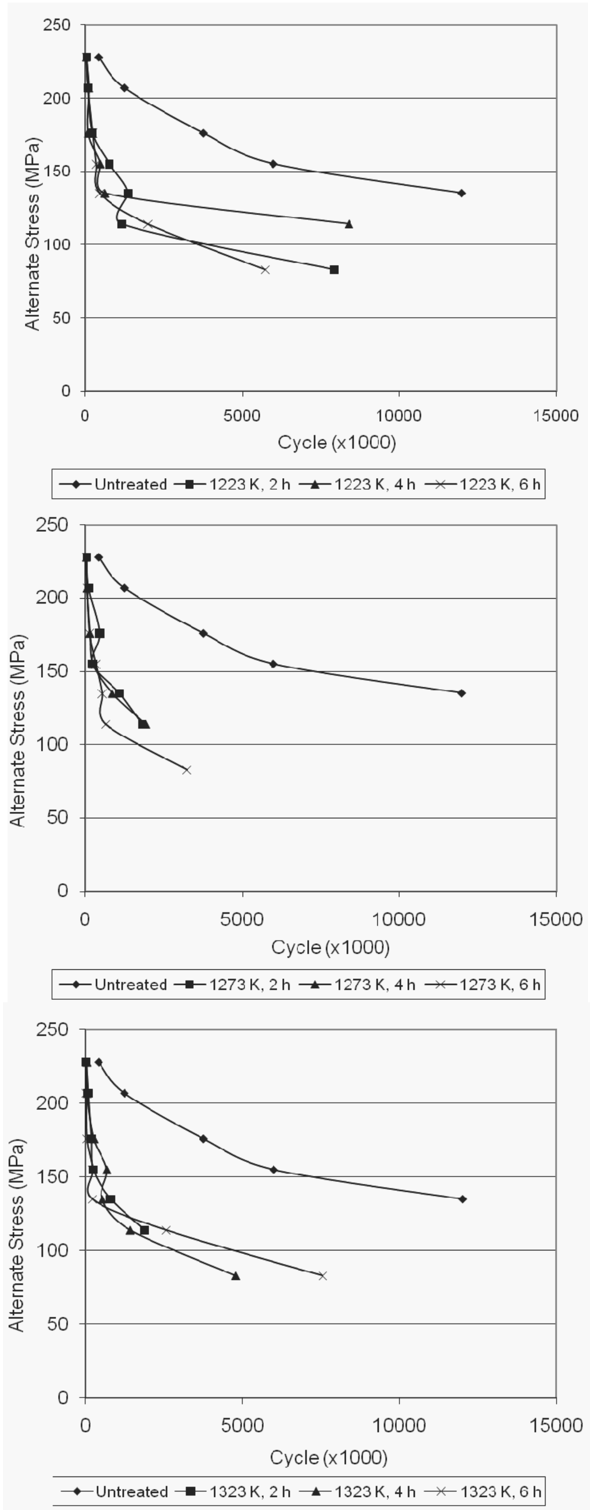


Fig. 8. S-N curves of borided AISI 1010 steel

In the end of heat treatment microstructures of the obtained surface layer was examined and the boride layer which existed was found to be rather smooth and porous free. But it might be thought that because of the boride layer's structure which is extending straightly to inner part from the surface in the form of saw teeth, it has microcrack formation risk. Additionaly, in the fracture surface SEM pictures, some cracs that occure between FeB and Fe_2B phases were found. These cracs can also promote fatigue fracture (Fig. 9).

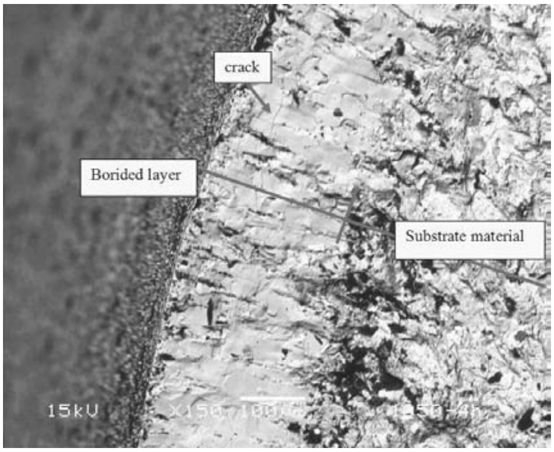


Fig. 9. Fracture surface of 1323 K, 4 h, borided specimen

4. Conclusions

The effect of boriding heat treatment on fatigue life of AISI 1010 steel has been investigated in this study. Boriding heat treatment have been made at four different temperatures and for different times. Optical microscope, electron microscope, XRD and hardness experiments have been made for the characterization of the boride layer. Fatigue experiments have been made in rotating bend fatigue device and S-N curves have been formed.

Results of the experiments denoted these following conclusions:

1. Into each of the borided specimens rather smooth, porous free boride layer was formed in saw teeth form.
   FeB and Fe_2B phases existed on their surfaces depending on experimental conditions.
2. Maximum 286 μm and minimum 37 μm of boride layer thicknesses were measured according to applied heat treatment conditions.
3. Maximum hardness value was found to be 1485 HV as a result of boriding.
4. In all of boriding heat treatment conditions fatigue life seemed to be decreasing. This decreasing occured to be at minimum 14 % and at maximum 55 %.
5. It can be noted that the reasons of short fatigue life determination are the boride layer's much higher hardness than the substrate material's, and the micro cracks existed between boride phases formed onto the surface.

Acknowledgements

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