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ISSN 0543-5846
METABK 49(2) 111-114 (2010)
UDC – UDK 620.193.1:669.15-194.2=111

TRIBOCORROSION OF LOW CARBON STEEL C15E IN 5 % NaCl AND 5 % NaCl + SiO_2

Received – Prispjelo: 2008-12-31
Accepted – Prihvaćeno: 2009-03-30
Preliminary Note - Prethodno priopćenje

The article represents testing results of corrosion and erosion-corrosion wear. Specimens have been made from low carbon steel C15E in four different states: delivery state and heat-treated (carburizing, boronising and carburizing + boronising). The results are shown as wear of materials (losing of surface mass in mg/(cm^2 ·d)). Surface hardness method HV1 and micro hardness per section of specimen HV0,2 method have been used during the analyses. A comparison of testing results of wear in four different states was made. The best performances have shown samples which have been treated with duplex procedure (carburizing + boronising) as was predicted.

Key words: erosion - corrosion wear, low carbon steel, carburizing, boronising, duplex procedure

Korozijsko trošenje niskougljičnog čelika C15E u 5 % NaCl i 5 % NaCl+SiO_2. Članak prikazuje rezultate ispitivanja korozijskog i erozijsko-korozijskog trošenja. Uzorci su bili izrađeni od niskougljičnog čelika C15E u četiri različita stanja: stanje isporuke i toplinski tretirani (cementiranje, boriranje i cementiranje+boriranje). Rezultati su prikazani kao trošenje materijala (gubljenje površinske mase mg/(cm^2 ·d)). Tvrdoća površine ispitana je metodom HV1, a mikrotvrdoće po presjeku uzorka metodom HV0,2. Uspoređeni su rezultati ispitivanja trošenja u četiri različita stanja. Najbolje rezultate pokazali su uzorci koji su tretirani duplex postupkom (cementirano + borirano), što je bilo i predviđeno.

Ključne riječi: erozijsko-korozijsko trošenje, niskougljični čelik, cementiranje, boriranje, dupleks postupak

INTRODUCTION

Corrosion and erosion in petrochemical industry cause increasing of material wear. Through monitoring process and plant reparation (especially of important parts) material damages have been seen. For these materials wear causes have been researched and presented [1, 2]. From construction materials, the most interesting are low carbon unalloyed steels because of good mechanical features and their adaptability to heat treatment, carburizing, and diffusion processes (boronising) [3, 4]. According to previous researching which were made from carbon steels in corrosion and erosion media low resistance has been seen.

Effective protection of these materials in aggressive suspension has to be done. Except standard techniques (heat treatment, carburizing, boronising and other diffusion layers) applying of duplex procedures (carburizing + boronising) becomes more and more common [5, 6]. Testings in aggressive suspensions gave satisfactory results but techno-economical adequacy and possibility of qualitative and accessible procedures of coating metal, non-metal and other diffusion layers were discussable. In practice the most efficacious procedures are diffusion processes in solid state (carburizing, boronising, carburizing + boronising) due to application of standard equipments in heat treatment laboratories [7, 8]. This convenience and necessity of process industry are reasons of detail researching of duplex coating in corrosion, erosion and erosion-corrosion media [9, 10].

The article presents researching of low carbon steel C15E: carburized, boronised and carburized + boronised in aggressive solution (5 % NaCl salt bath) and in erosion-corrosion suspensions (5 % NaCl with quartz sand).

EXPERIMENT AND RESULTS

Researching has been made with low carbon steel C15E with known chemical composition: 0,14 % C; 0,18 % Si; 0,4 % Mn; 0,018 % P and 0,016 % S. From this steel tensile specimens have been made according to EN 10002:2002, (DIN 50125).

According to plan of testing, specimens have been treated:

1. Carburizing (Figure 1)
2. Boronising in Ekabor 3 (Figure 2)
3. Carburizing + boronising (duplex) treatment.

Before finishing of heat treatment and specified operations surface hardness (HV1) was measured and microstructure analysis of diffusion coatings were done,

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while after heat treatment micro hardness (HV0,2) was measured (Table 1, Table 2).

After heat treatment specimens were analysed on corrosion wear in salt bath (5 % NaCl, 24, 48, 72 h) and erosion-corrosion wear in 5 % NaCl with quartz sand with granulation 0,1 - 0,8 mm (through rotation in water suspension). Specimens have been treated in three different states: carburized, boronised and carburized + boronised (duplex). Duration of researching was 72 hours, and after each 24, 48, 72 hours losing of surface mass (mg/(cm^2·d)) was measured. A number of specimens after corrosion researching have been cut and examined through microstructure analysis of diffusion coating (damages) and measured towards micro hardness (HV0,2).

Table 1. **Measured values of surface hardness (HV1) in delivery state**

		Surface hardness / HV1			Average value / HV1
Delivery state		1	2	3	
	1	293	302	312	302
	2	306	306	297	303
	3	244	283	316	291

Table 2. **Measured values of micro hardness (HV0,2) after carburizing, boronising and carburizing + boronising**

Distance from edge / mm	Average values / HV0,2		
	Carburizing	Boronising	Carburizing + Boronising (duplex)
0,025	855	1670	1594
0,050	790	1497	1423
0,075	790	1488	1242
0,10	780	1302	753
0,15	765	299	750
0,25	760	306	735
0,35	760	300	730
0,45	750	300	700
0,55	695	295	690
0,65	690	295	660
0,75	690	297	655
0,85	680	297	650
0,95	680	300	620
1,05	670	300	605
1,15	650	305	600
1,25	600	305	450
1,35	500	295	306
1,45	480	295	300
1,55	300	295	295

After weights in the specimens were exposed to testing fluids for 72 hours. The exposure caused the formation of loose particles of corrosion/erosion products on

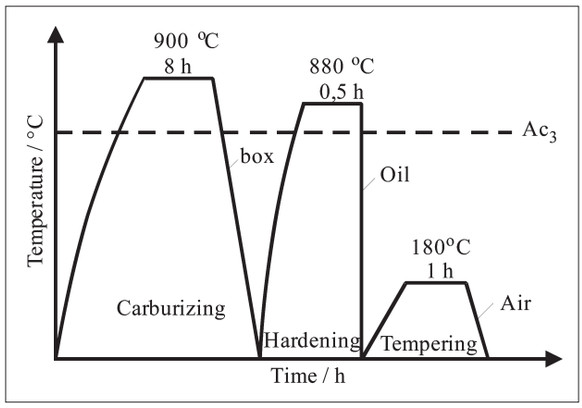


Figure 1. Schematic preview for carburizing process of low carbon steel C15E

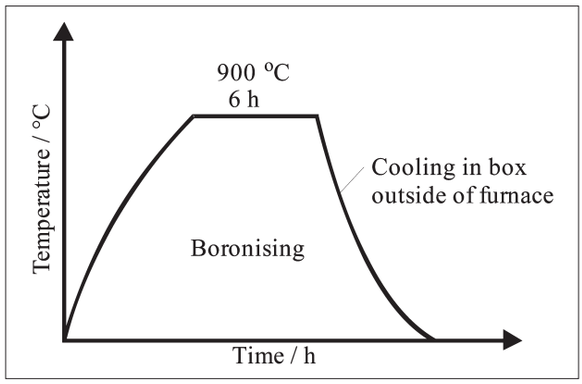


Figure 2. Schematic preview for boronising process in solid suspension Ekabor 3

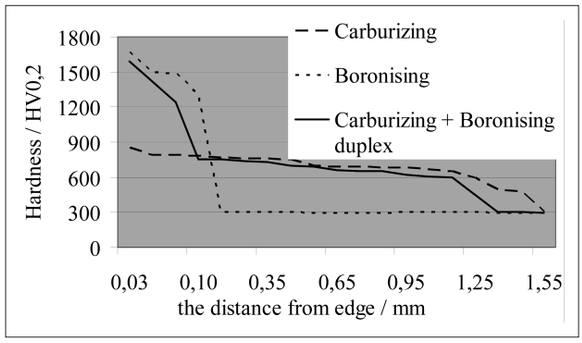


Figure 3. Diagram of average micro hardness HV 0,2 values

specimens surface. After 24, 48 and 72 hours they were removed from the device, cleaned by rinsing with detergent solution and water as well as by rubbing with polyamide brush. Dried specimens were reweighed. On cross sections of surface treated specimens micrographical examinations and microhardness measurements were carried out after the exposure too.

DISCUSSION

Low carbon steel C15E, according to mechanical features and microstructure, is accessible for heat treatment: carburizing, carburizing + boronising. Researching

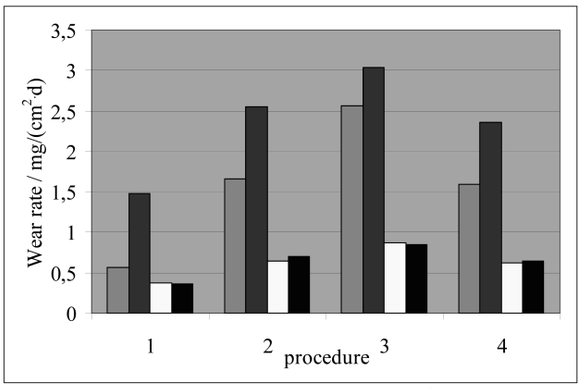


Figure 4. Preview of wear C15E in mg/(cm^2·d) in salt spray for:
1 – Delivery state
2 – Carburizing
3 – Boronising
4 – Carburizing+ boronising (duplex)

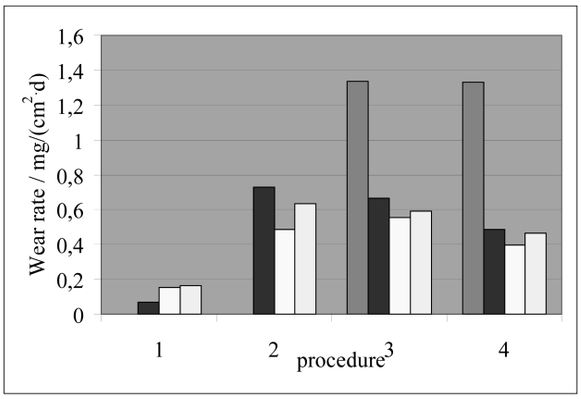


Figure 5. Preview of wear C15E in erosion corrosion suspension for:
1 – Delivery state
2 – Carburizing
3 – Boronising
4 – Carburizing + boronising (duplex)

shows weakness of boronising coating because of large difference in hardness between boronising coating (cca 1600 HV0,2) and substrate (cca 250-300 HV1). Such a kind of differentiation causes damages and less resistance against erosion-corrosion wear.

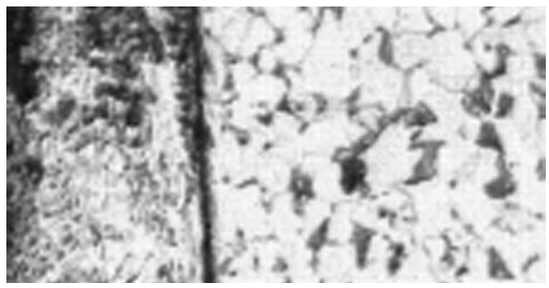
In practice these problems are tried to be solved through carburizing, boronising and carburizing + boronising analysis (HV1, HV0,2 etc.) (Table 1, 2). The main goal is to equalise hardness near the surface and on the surface (to reduce effect of "glass" surface on soft weak substrate). Analysis of hardness (HV1) and micro hardness (HV0,2) affirms wear of diffusion coating on some specimens more than is expected and that problems have to be solved in further researching (Table 1, 2 and Figure 3).

Decrease in measured hardness values from coating surface to substrate has been shown in Table 2 and Figure 3.

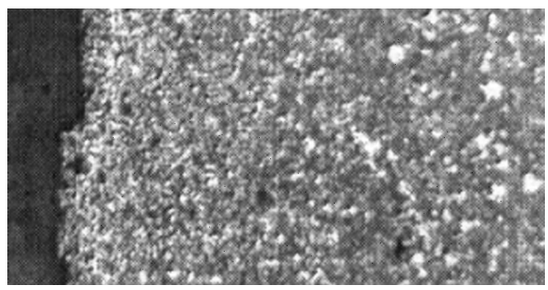
Corrosion researching (Figure 4) in salt spray shows the increasing of resistance of carburized + boronised (duplex) coating according to single carburized and boronised steel.

Wear of steel with duplex coating in erosion corrosion suspension (5 % NaCl with quartz sand) is lower in comparison with as delivered, carburized and boronised specimens (Figure 5).

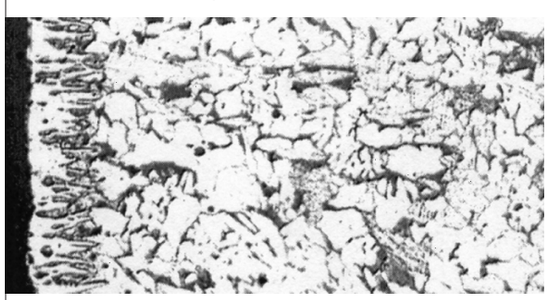
Metallographical analysis of specimens:



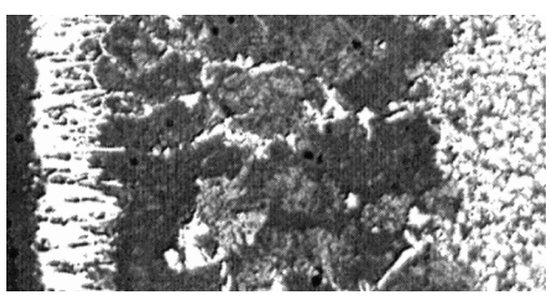
Procedure 1: 100×, 3 % nital



Procedure 2: 100×, 3 % nital



Procedure 3: 100×, 3 % nital



Procedure 4: 100×, 3 % nital

Figure 6. Microstructure of steel C15E in:
1 – Delivery state
2 – Carbonisied
3 – Boronised
4 – Carbonised+boronised (duplex) after erosion-corrosion treatment in 5 % NaCl/SiO_2

Metallographical analysis (Figure 6) presents given results, which shows damages that are consequences of damages on diffusion coating, and refer on material structure during carburizing, boronising and presence of them in corrosion-erosion suspension, as well.

CONCLUSION

Through thermal diffusion procedures of boronising and carburizing the high values of hardness (cca 1600 HV0,2/800 HV0,2) are achieved. Average depth of boronised coating is 75 to 100 μm what is optimal for researching in erosion-corrosion suspension. Corrosion wear (salt bath) of duplex coating is much better in comparison with delivery, carburized and only boronised specimens, which implicate further researching.

Erosion-corrosion wear in 5 % NaCl with quartz sand confirms that duplex proce-dure (carburizing + boronising) can be applied in aggressive suspensions.

Delivery state of steels show increase of wear in comparison with carburizing, boronising, carburizing+boronising steels.

The best performances have shown samples which have been treated with duplex treatment (carburizing + boronising) as was predicted.

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Note: The responsible translator for English language is Željka Rosandić, prof.