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# STRUCTURAL RESEARCH OF SINTERED STEEL DISTALOY AE WITH ADDITIONS BORON POWDER

# ISPITIVANJE STRUKTURE SINTEROVANOG ČELIKA DISTALOY AE SA DODACIMA PRAHA BORA

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## ABSTRACT

In this paper structural research of sintered steel Distaloy AE with additions boron powder are presented. Specimens were prepared from diffusion alloyed Distaloy AE (Fe-4 wt.-% Ni-1,5 wt-% Cu-0,5 wt.-% Mo) mixed with graphite (0,5 wt.-%). The materials were sintered under industrial conditions at 1120 °C for 30 min. In a fracture are visible pore, which have got the extended form during deformation of sintered steel. The part pores has revealed at destruction. As a whole character of a break viscous, a plenty large and fine hole is visible. At a fracture there are the pore, cracks which have revealed during distribution. The microfractography analysis has shown in the centers of fractures and near to them presence rough microfatigue strip, that testifies to action significant on size of repeated stress.

**Key words:** fatigue strength, fractography analyses, Distaloy AE , sintered steel

## IZVOD

U ovom radu su prikazana strukurna istraživanja sinterovanog čelika Distaloy AE sa dodacima praha bora. Uzorci su bili pripremljeni od legure Distaloy AE (Fe-4 wt.-% Ni-1,5 wt-% Cu-0,5 wt.-% Mo) pomešane sa grafitom (0,5 wt.-%). Materijali su bili sinterovani pod industrijskim uslovima na 1200$^{o}$C u trajanju od 30 min. Na prelomu su vidljive pore, koje su dobijale otvoren oblik tokom deformacije sinterovanog čelika. Deo pora je otkriven tokom razaranja. Data je mikrografska analiza u okolini centara preloma.

**Ključne reči:** čvrstoća loma, fraktografska analiza, Distaloy AE , sinterovani čelik

## 1. INTRODUCTION

The basic mechanical properties were evaluated mainly from the data collection of [1] which is a long term structured accumulation of results obtained under semi-industrial conditions. There is no other single source offering a similar wealth of information. The drawbacks are that the data are related almost exclusively to a single powder manufacturer and that the cooling rates from the sintering heat must not necessarily match those of industrial furnaces. This may cause deviations from the values presented here, if the material considered tends to transform at least partially into bainite or martensite.

Several times the published literature on fatigue of sintered metallic materials has been reviewed under various aspects [2 - 9]. Here, the presentation must stay restricted to endurance limits.

Elemental iron is water atomized from clean unalloyed iron melts or reduced to sponge iron by a solid state reaction from mill scale or clean ores. The powdered alloying additions must be chosen from elements, compounds or masteralloys whose oxides can be reduced during sintering. The most common elements are carbon, copper, nickel, molybdenum and phosphorus; some sintered steels contain also tungsten, cobalt, chromium, manganese, vanadium and silicon. Because of the stability of their oxides Cr, Mn, V and Si alloyed steels need special sintering equipment. Even though many powder manufacturers don't mention it in their catalogues, all sponge or water atomized iron powders contain about 0.1 to 0.2 % Mn. These small quantities are not harmful to the reduction of surface oxides on the powder and have no negative effect on the sintering result. Water atomized iron powder has very little internal porosity, sponge iron powders inherently contain internal pores. For this reason the compressibility of sponge iron powders is inferior.

The compacted more or less elemental blends are intended to alloy and homogenize by diffusion during sintering. During transport, handling and processing of powder blends the constituents are susceptible to segregation. This causes uneven alloy distribution in a production batch or even within a single part and, since alloying and homogenization go along with dimensional changes, finally a certain scatter of dimensions and properties. To prevent the negative effects of segregation, with the exception of the fast diffusing carbon, the alloying additions can be bonded to the iron particle surface in a diffusion annealing operation.

Usually repeated stressing with small frequency of the appendix of loadings accompanies any other kind stressing - to multicyclic weariness, long static stressing and consequently it is not always taken into account. However now it became clear, that repeatedly - static stressing, or so-called small cyclic weariness, renders essential influence on bearing ability of materials in designs.

## 2. EXPERIMENTAL AND RESULTS

In work [ 10 ] the effect of the addition of different amounts of boron of 0,3 and 0,6 wt.-% and carbonyl iron powder (CEP) 2,5 and 5,0 wt.-% to Distaloy AE for the mechanical properties were studied. The fatigue limit at 50 % probability of survival was for the material Distaloy AE +0,06 % B 155,7 MPa, the korrelationkoeffizient 0,934 and for material Distaloy AE+2,5%CEP 209,2 MPa, korrelationkoeffizient 0,866.

For the higher strength range samples were manufactured from the widely used Distaloy family of steels containing 4 % Ni, 1.5 % Cu and 0.5 % Mo which are diffusion bonded to pure iron to prevent segregations and maintain highest compressibilities. All powders were blended with 0.5 fine graphite and in most cases with additions, which were expected to change the pore morphology. As additions powder boron were used. Further the standard grade, Distaloy AE, based on water atomised iron was made from a coarse powder > 45 μm and a fine fraction < 45 μm and compared with the same alloy based on sponge iron. The specimens were compacted with 600 MPa in the R & D department of Höganäs AB, Sweden, were the sintering took place in semi-industrial equipment at 1120 °C in a non-decarburizing protective atmosphere. The cooling rate between 800 and 500 °C was 1.0 °C/s. Plane bending fatigue tests were performed with 60 specimens in six stress levels per S-N curve, which permits to evaluate the data statistically and to determine a rather reliable endurance limit for a failure of survival probability of 50 %.

Boron essentially accelerates transport of a material during time sinters, however, characteristic features pore with a growing stop of the loan change only a little.

Application of an electronic microscope has allowed to reveal laws of a microstructure of fracture which it is accepted to allocate special area fractography. It is necessary to note, that the microstructure of fracture somewhat repeats their macrostructure. On fig. 1 and figure 2 are submitted a surface of destruction of the samples deformed on 50 % at various increases. In a fracture are visible pore, which have got the extended form during deformation of sintered steel. The part pores has revealed at destruction. As a whole character of a break viscous, a plenty large and fine hole is visible. At a fracture there are the pore, cracks which have revealed during distribution, and holes, destruction's specifying viscous character (fig. 2). In the figure 3 is shown the structure received in REM of the material Distaloy AE+0,5 % C+0,06 % B. And in the figure 4 is shown distribution of elements in different points sintered of the material Distaloy AE+0,5 % C+0,05 % B shown in a figure 3.

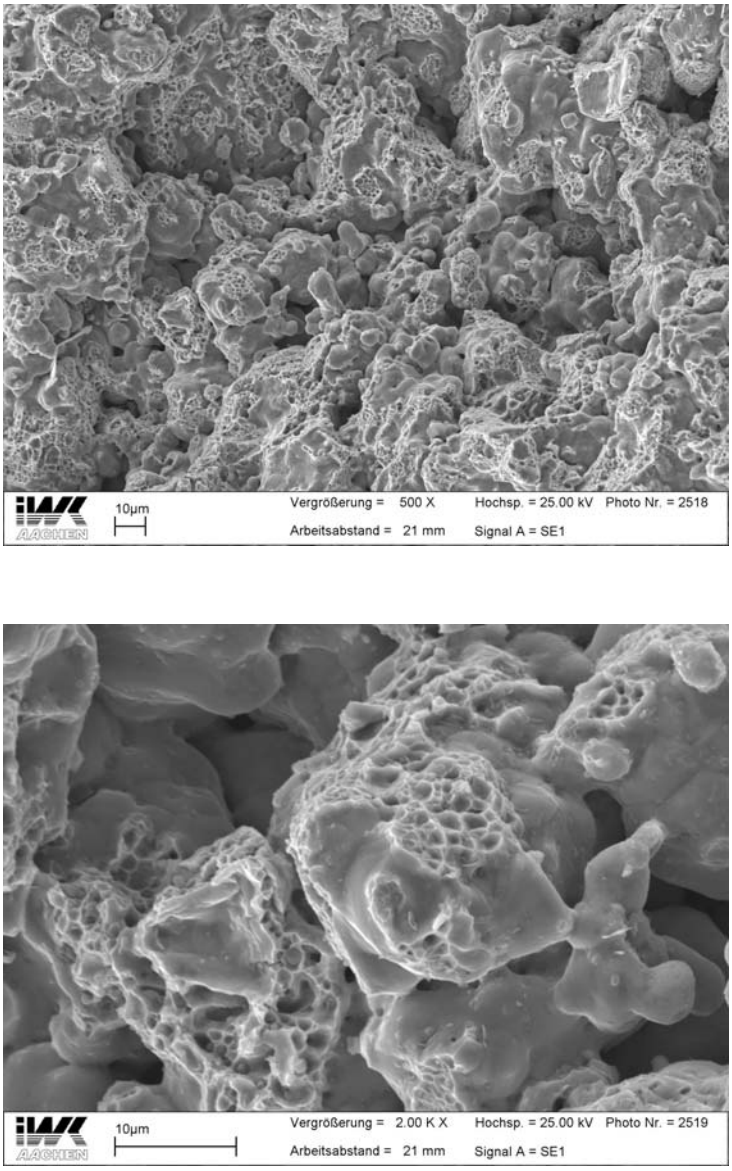


*Figure 1 - Fracture surface from the final fracture of pulsating fatigue specimens of the material Distaloy AE+0,5 %C+0,03 %B*

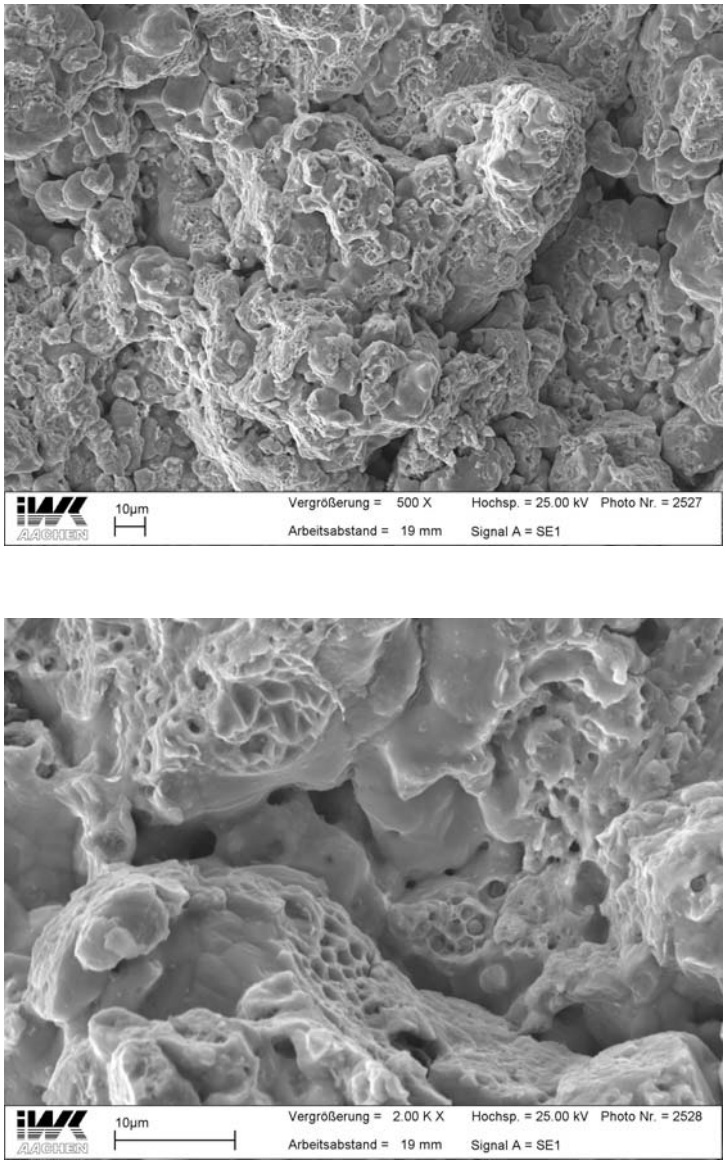


*Figure 2 - Fracture surface from the final fracture of pulsating fatigue specimens of the material Distaloy AE+0,5%C+0,06 %B*

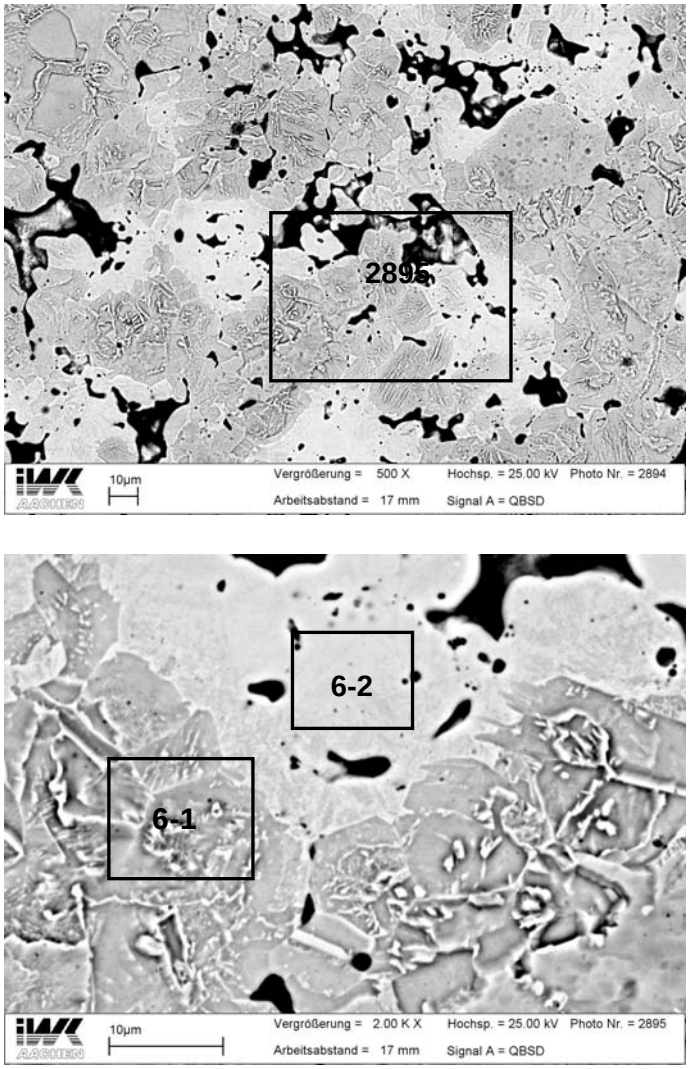


*Figure 3 - Structure received in REM of the material Distaloy AE+0,5%C+0,06 % B.*

The small cyclic weariness is in most cases connected to action of high stress, therefore features of a structure, characteristic for fracture of a cyclic overload are inherent in fractures.

Fractures considered by us are characterized by presence of appreciable traces of plastic deformation, is especial on a site of final destruction. The microfractography analysis has shown in the centers of fractures and near to them presence rough microfatigue strip, that testifies to action significant on size of repeated stress.

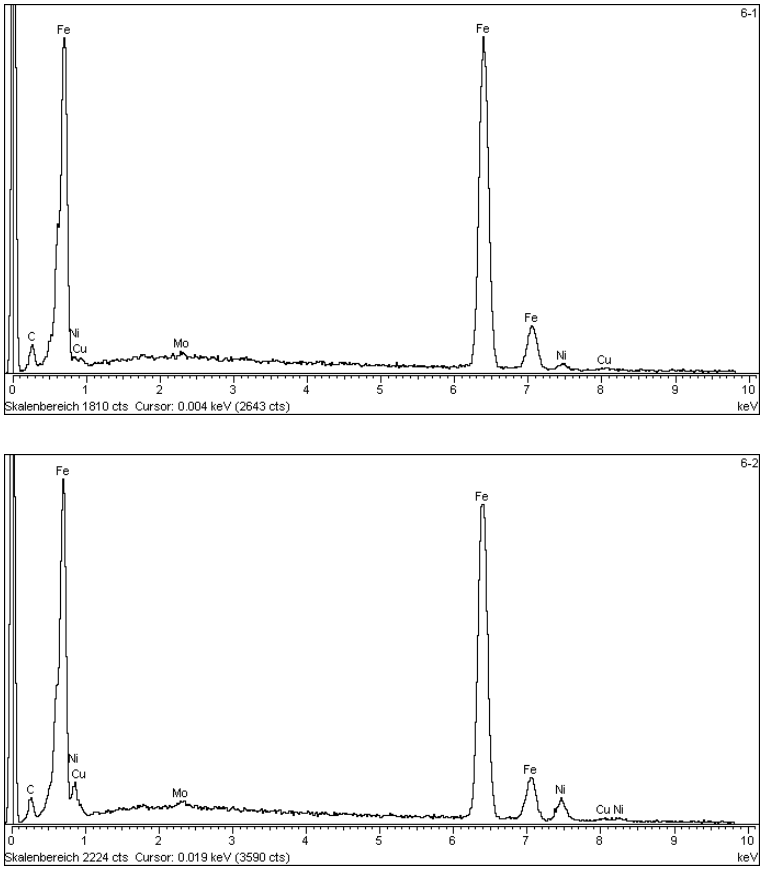


*Figure 4 - Distribution of elements in different points sintered of the material Distaloy AE+0,5%C+0,06 % B shown in a fig. 3*

## 3. SUMMARY

Boron essentially accelerates transport of a material during time sinters, however, characteristic features pore with a growing stop of the loan change only a little. In a fracture are visible pore, which have got the extended form during deformation of sintered steel. The part pores has revealed at destruction. As a whole character of a fracture viscous, a plenty large and fine hole is visible. At a fracture there are the pore, cracks which have revealed during distribution, and holes, destructions specifying viscous character. The microfractography analysis has shown in the centers of fractures and near to them presence rough microfatigue strip, that testifies to action significant on size of repeated stress.

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