

FATIGUE STRENGTH OF SINTERED POWDER STEEL OF DISTALOY AE+0.5% C WITH ADDITION THE PHOSPHOR

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Abstract

In this paper examined to research on the fatigue strength sintered steel of Distaloy AE+0.5 % C with addition the phosphor. 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. Fatigue tests with stress levels above the endurance limit have been carried out to determine Woehler curves. The effect addition of different amounts of phosphorus of 0.3, 0.45 and 0.6 wt.% to Distaloy AE on the consequences for the fatigue properties studied.

Keywords: *Distaloy AE, fatigue strength, sintered steel*

INTRODUCTION

Fe-P steels are mainly used in soft magnetic DC applications. Fatigue results from noncarburizing sintering conditions are compiled in [1-7] for steels containing 0.45 % phosphorus (Fig.1). Four data from [2, 4] had to be canceled because they are far higher than those shown here and it must be suspected that the specimens had been sintered in endogas by error because the strength level would roughly correspond with that of endogas sintered Fe-P alloys [8] and Fe- 0.45 % P- 0.2 % C steels [6]. The rotating bending results from [9] are omitted here since they exceed the values in [1-7] by about 75 %.

If pure iron is sintered in endogas, the surface is carburized to the carbon potential of the atmosphere. Under normal operating conditions this will correspond to about 0.2 % C. Data with carbon contents between 0.1 and 0.3 % in pure iron and endogas sintered iron data are gathered in [8, 10-12] for mainly plane bending. With higher carbon contents a clear systematic change of fatigue strength with density can only be recognized for rotating bending with water atomized iron base powder, [11, 13-16]. Because of the large discrepancies a trend line was not calculated.

There seems to be no superiority of high temperature sintering, but it must be born in mind that almost all high temperature data are very old already. Newer careful investigations prove that under axial loading high temperature sintering increases the endurance limit by about 5 % [17, 18]. Papers [2, 4, 17, 18] contain the axial data which were mainly obtained with ordinary frequencies. The results from [5] were generated with only 5 Hz and are clearly lower than the majority from other investigations, which is again an indication of a possible frequency effect.

Binary Fe-Cu alloys with higher copper contents are not so well documented, [17], a trend can be recognized only for the rotating bending data. The strength level is noticeably raised by higher copper contents.

The data from [5, 20] deviate to lower strength levels, the ultrasonic data from [21] are shifted to so much higher values that the effect cannot be attributed to high

temperature sintering alone. The trend curve was calculated only for the water atomized data from normal frequency testing.

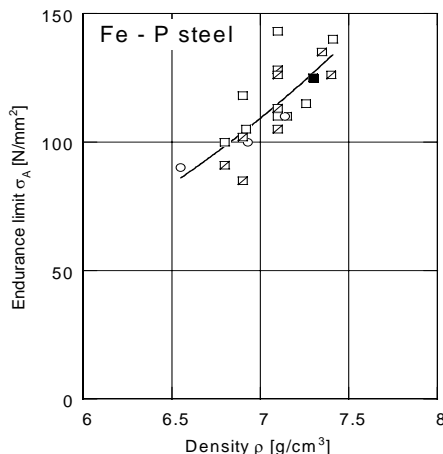


Fig.1. Effect of density on endurance limit; Fe - 0.45 % P; atmosphere: $N_2 + H_2$; $2 \cdot 10^6$, $5 \cdot 10^6$ or 10^7 cycles [1-7]. Open squares: water atomized iron; plane bending; open circles: sponge iron; plane bending; filled squares: water atomized iron; plane bending; crossed squares: water atomized iron; axial loading.

High temperature sintered Fe-Cu-Ni steels has been quite popular in Japan and Europe for their balanced strength-toughness performance. Axial and plane bending fatigue test results are presented in [2, 3, 11]. Excluding the nonconforming forging data from the evaluation, the scatter bands of plane bending and axial loading overlap with a statistical superiority of the bending results.

Plane bending data for steels based on 0.85 % prealloyed molybdenum, up to 2 % elemental nickel and about 0.5 % carbon deviate to the higher end, yet, it must be born in mind that all strength characteristics of materials forming hard microstructural constituents like bainite or martensite on cooling from the sintering heat depend very much on the cooling rate, predominantly the cooling rate between 800 and 500°C which is generally not reported. Therefore, the data scatter, including the forged versions, is not necessarily due to machining effects, but could well be blamed on different cooling rates. In [19] 2 % elemental Ni were added to prealloyed 0.85 % Mo steel with fine and coarse particle size. The steel with the coarse Ni particles had significantly inferior fatigue properties in comparison with the fine addition which is the industrial standard, particularly at normal sintering temperature.

EXPERIMENTAL AND RESULTS

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. The powders Distaloy AE were blended with 0.5 fine graphite and in most cases with additions, which were expected to change the pore morphology. As additions ferrophosphorus were used. Further the standard grade, Distaloy AE, based on water atomised iron was made from a coarse powder $> 45 \mu m$ and a fine fraction $< 45 \mu m$ 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, where 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. Details on the as-sintered densities and some mechanical properties are provided in Table 1.

Tab.1. Materials investigated, 4 % Ni, 1.5 % Cu, 0.5 % Mo, 0.5 % C.

Base powder	Addition, modification	Density, average [g/cm ³]	Hardness [HV 10]	R _m [MPa]	A [%]
Distaloy AE	-	7.105	265	715	2.0
Distaloy AE	0.30 % P	7.093	335	390	0.09
Distaloy AE	0.45 % P	7.016	370	298	0.02
Distaloy AE	0.60 % P	6.897	373	293	0.02

Fatigue tests with stress levels above the endurance limit have been carried out to determine Woehler curves. The obtained curves for the different series of samples are shown in Fig.2 and Fig.5 include the fatigue limits at 5, 10, 50, 90 and 95 probability of survival. The points in the diagrams correspond to the raw data, each open circle indicates a failure and each filled circle a run out. 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 or survival probability of 50 %. The dependence of fatigue endurance on the probability of survival of the material Distaloy AE + 0.5 % C + 0.3 % P and of the material Distaloy AE + 0.5 % C + 0.6 % P are shown in Fig.3 and in Fig.6. The dependence of the number of cycles on the probability of survival of the material Distaloy AE + 0.5 % C + 0.3 % P and of the material Distaloy AE + 0.5 % C + 0.6 % P are shown in Fig.4 and in Fig.7.

Tab.2. Endurance limits at 10⁷ cycles at 50 % survival probability and retained austenite.

Materials	Endurance limit		Retained austenite %
	R = -1 MPa	R = 0 MPa	
Distaloy AE	264	192	23.0
Distaloy AE + 0.30 % P	274	182	17.3
Distaloy AE + 0.45 % P	266	176	16.0
Distaloy AE + 0.60 % P	246	135	16.3

The endurance limits obtained for 50 % survival probability are listed in Table 2 together with information on the amount of retained austenite from X-ray diffraction measurements. Here the austenitic phase increased from 16.3 % to 23.0 % and the fatigue limit at 50 % probability of survival increased from 246 to 274 MPa (R = -1) and from 135 to 182 MPa (R = 0). This means that the presence of austenite has an effect on the fatigue endurance limit. Due to its ductility and its martensitic transformation induced by strain, the austenite consumes some energy which cannot be used for the initiation and propagation of microcracks.

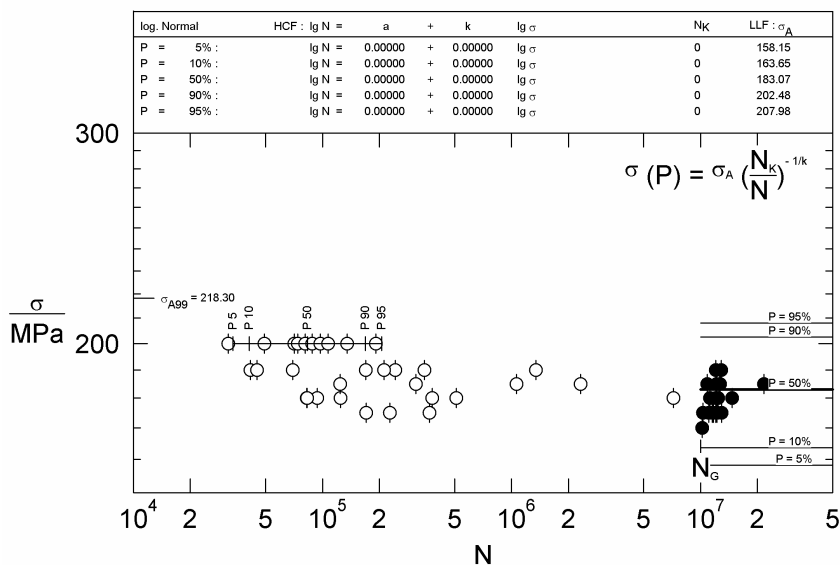


Fig.2. Fatigue endurance limit and probability of survival of the material Distaloy AE+0.5%C+0.3 % P.

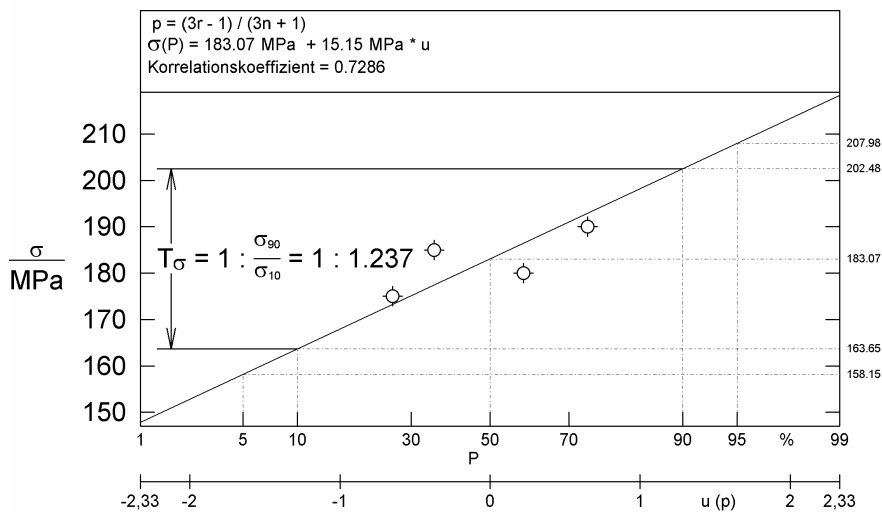


Fig.3. Dependence fatigue endurance of probability of survival of the material Distaloy AE+0.5 % C + 0.3 % P.

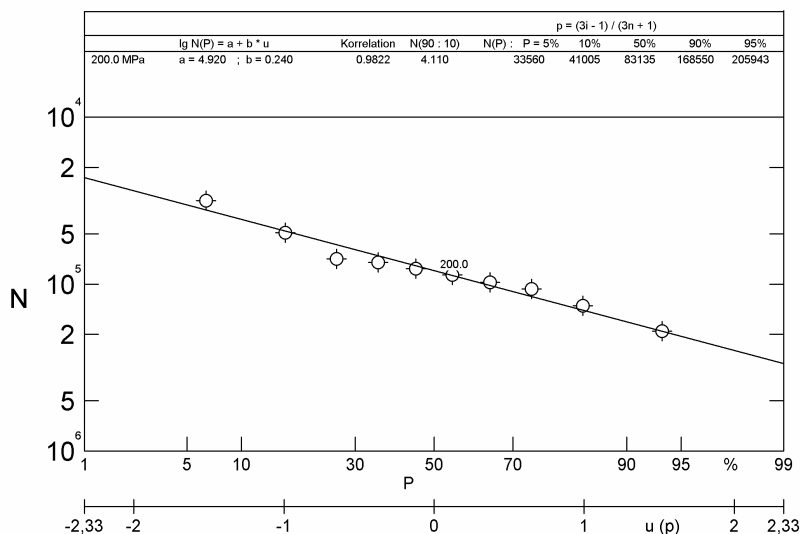


Fig.4. Dependence number of cycles of probability of survival of the material Distaloy AE+0.5 % C + 0.3 % P.

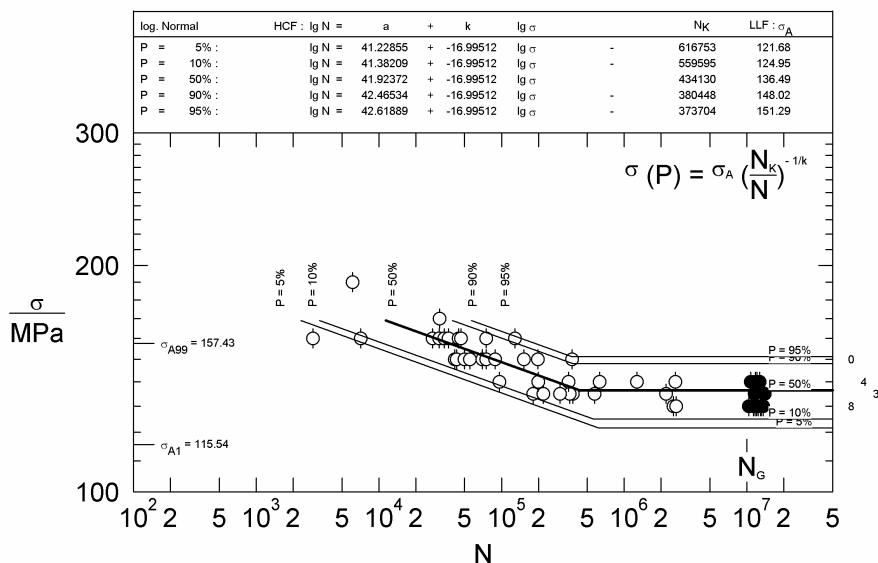


Fig.5. Fatigue endurance limit and probability of survival of the material Distaloy AE+0.5 % C + 0.6 % P.

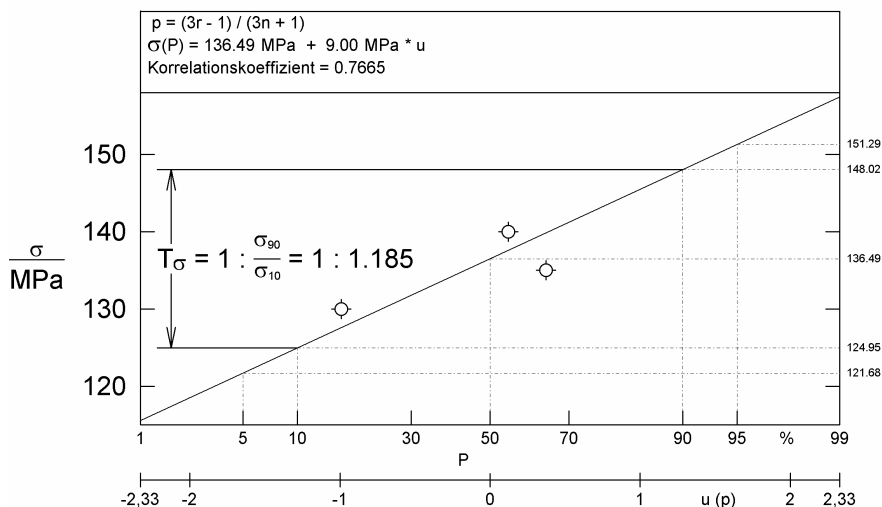


Fig.6. Dependence fatigue endurance of probability of survival of the material Distaloy AE + 0.5 % C + 0.36 % P.

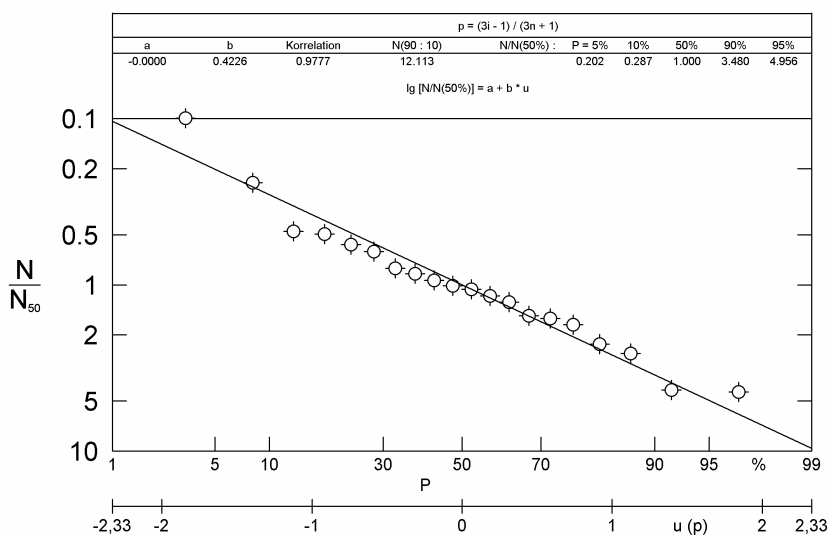


Fig.7. Dependence number of cycles of probability of survival of the material Distaloy AE + 0.5 % C + 0.6 % P.

CONCLUSIONS

In this work was studied on the fatigue strength sintered steel of Distaloy AE + 0.5 % C with addition the phosphor. 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.

Fatigue tests with stress levels above the endurance limit have been carried out to determine Woehler curves. The effect addition of different amounts of phosphorus of 0.3, 0.45 and 0.6 wt. -% to Distaloy AE on the consequences for the fatigue properties studied. The austenitic phase increased from 17.7 % to 23.0 % and the fatigue limit at 50 % probability of survival increased from 246 to 274 MPa ($R = -1$) and from 135 to 182 MPa ($R = -1$). This means that the presence of austenite has an effect on the fatigue endurance limit.

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