CYCLIC STRESS-STRAIN RESPONSE AND FATIGUE LIMIT OF SELECTED SINTERED STEELS

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Three sintered steels of the same density and sintering temperature but differing in composition were fatigue tested. Specimen were subject to axial tension-compression (R=-1).The experimentally determined characteristics included hysteresis energy and plastic deformation. The tests were done in the HCF/LCF region and especially at the endurance limit stress level. It was found that characteristics associated with dynamic properties as hysteresis energy or plastic deformation assumed numerical values which were by two orders of magnitude smaller than those for conventionally manufactured steels (wrought steel). It necessitated working out a new highly accurate measurement method. Along with the above finding the coefficients in the Morrow model were determined.

INTRODUCTION

P/M steels are becoming a promising choice in design of dynamically loaded machine elements. There is much need for evaluating their properties under varying load conditions. The following characteristics were considered to be especially indicative of the P/M steel behaviour: ΔW, ε_{ap}, S_f, k', n' and n''. The present investigation was aimed at:

- determining the deformation work (hysteresis-loop area) ΔW,
- determining plastic strain amplitude ε_{ap},
- evaluating selected cyclic properties.

The experiments turned out especially difficult at the endurance limit region where the anelastic characteristics (damping) of P/M steels are much less marked than those found in wrought steels.

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EXPERIMENTS

Material

The specimens had a rectangular cross-section 6×8 mm and were fabricated from iron powder (WPL 200) with an addition of 0%, 1.2% and 2.5% Cu (referred later to as A, B and C, respectively). The sintering density was 7 g/cm^3. The sintering process was conducted at 1280^o C. Static properties of the materials in tension are shown in Table 1 (in addition properties for wrought carbon steel Ck45, 0.45% C).

TABLE 1 - Static Properties of P/M Steels investigated.

P/M steel	Cu (%)	UTS (MPa)	E (MPa)	A_5 (%)
A	0.0	252	152 500	10.0
B	1.2	305	142 100	6.5
C	2.5	315	124 400	5.0
Ck 45	---	683	211 000	23.2

Measuring Method

In the course of the experiment discrete values of stress and strain were recorded and the corresponding Fourier coefficients were determined on an on-line basis. Next, energy ΔW and plastic strain ε_{ap} were computed in a fully analytic fashion on a scheme proposed by Błotny and Kaleta (1). The adopted method enabled a precise software filtration of disturbances and compensation of the phase shift angle between the channels of the measuring device.

Mode of Loading. Apparatus.

The specimens were tested in one sided tension-compression (R=-1). A sinusoidal loading spectrum was applied. At the fatigue limit the experiments were carried out at σ_a=const. They were interrupted after $5 \cdot 10^6$ cycles following the observation that the ΔW and ε_{ap} values became constant (saturated condition). Along with the above some tests were made applying an increasing load. The minimum load was much lower than the fatigue limit. The load was increased in a continuous way at a rate of 1kN/hr up to failure. The main body of the experiments were conducted by Piotrowski on a Schenck resonance pulser equipped with a set of A/D converters and an IBM PC AT computer (Essen Univ., FRG). Some control tests were also conducted at TU Wrocław, Poland on a hydraulic MTS 810 pulser with similar computer positions. The results from both series of tests were found to be in full agreement.

Results

Table 2 shows plastic strain amplitude ε_{apf} and deformation work ΔW_f at the fatigue limit S_f for P/M steels compared with those obtained for a conventional wrought Ck45 steel. Example plots of $\Delta W_f(N)$ and $\varepsilon_{apf}(N)$ are shown in Figs 1 and 2.

TABLE 2 - Selected Properties of P/M Steels under Cyclic Loading.

P/M steel	S_f (MPa)	ΔW_f (MPa/cycle)	ε_{apf}	k'	n'	n''
A	95	0.0004	5.0×10^{-6}	199.8	0.05	0.50
B	115	0.0006	5.5×10^{-6}	883.5	0.16	0.47
C	100	0.0003	4.8×10^{-6}	6106.3	0.31	0.60
Ck45	240	0.0514	7.6×10^{-5}	546.8	0.085	0.157

A common characteristics used for describing CSSCs of materials is Morrow (Ref.2) relationship

$$\sigma_a = k' \cdot (\varepsilon_{ap})^{n'} \qquad (1)$$

Values of cyclic strength coefficient k' and cyclic strain-hardening exponent n' are shown in Table 2 and Fig.3. The hysteresis-loop area ΔW can be expressed in the form

$$\Delta W = 4 \cdot \sigma_a \cdot \varepsilon_{ap} \cdot \frac{1-n''}{1+n''} \qquad (2)$$

The experimentally determined values of n'' are listed in Table 2.

Conclusions

1. Values of deformation work ΔW_f and plastic strain ε_{apf} at the fatigue limit S_f are many times lower than those found for wrought carbon Ck45 steel.

2. Cyclic properies of P/M steels are conveniently characterized (both in LCF and HCF regions) by such common quantities as k',n' and n''. Numerical values of these coefficients are considerably different from those found for conventional steels.

REFERENCES

(1) Błotny, R. and Kaleta, J., Studia Geotechnica et Mechanica, Vol.III, No. 1, 1981, pp.45-56.

(2) Morrow, J.D. in ASTM STP 378, 1965, pp.45-84.

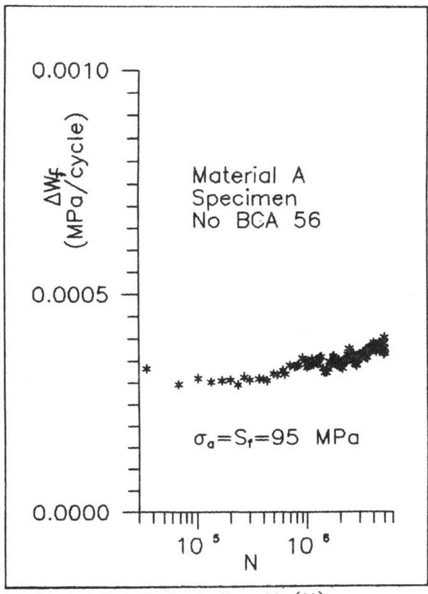

Figure 1 Plot of $W_f(N)$ at $\sigma_a = S_f$

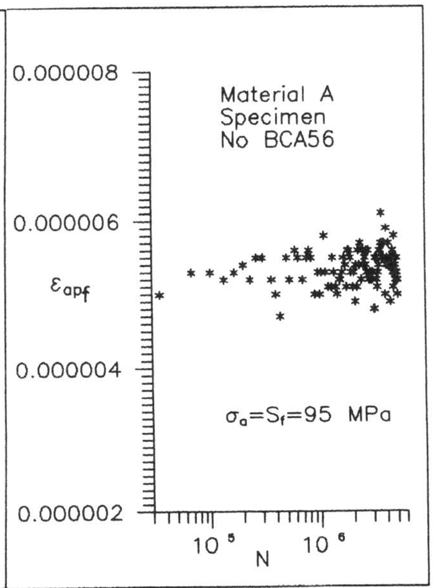

Figure 2 Plot of apf(N) at $\sigma_a = S_f$

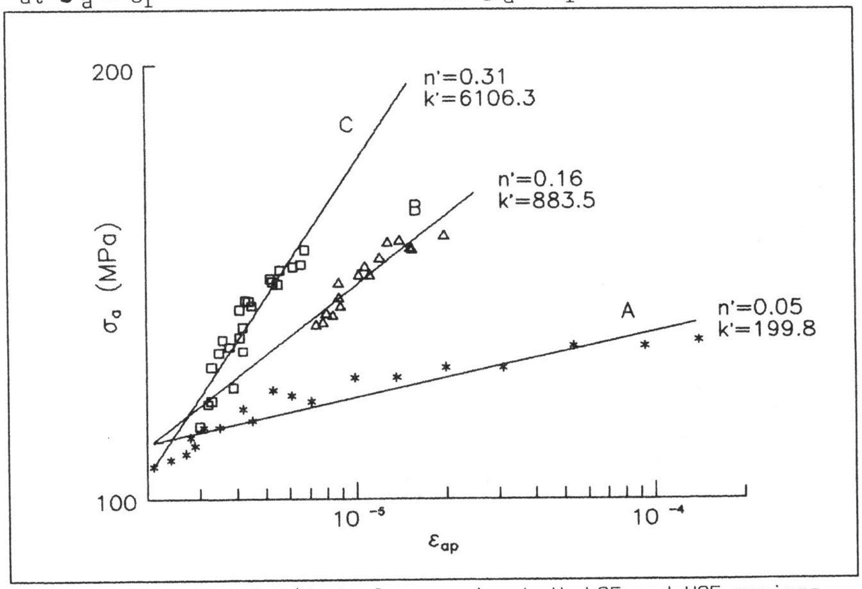

Figure 3 CSSCs of P/M steels covering both LCF and HCF regions