2006 POWDER METALLURGY
World Congress

C01-02-1
*Invited

Functional Relationships between Fatigue Data

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Abstract

Most PM components are exposed to cyclic loading over long periods of time, yet, the fatigue performance is often at best characterized by a fully reversed bending strength. The effects of density, deviating loading modes, external notches or mean stresses must usually be estimated. The amount of available data is nowadays sufficient to come to fact-based estimates.

Keywords : density, notch effect, mean stress sensitivity, fatigue

1. Introduction

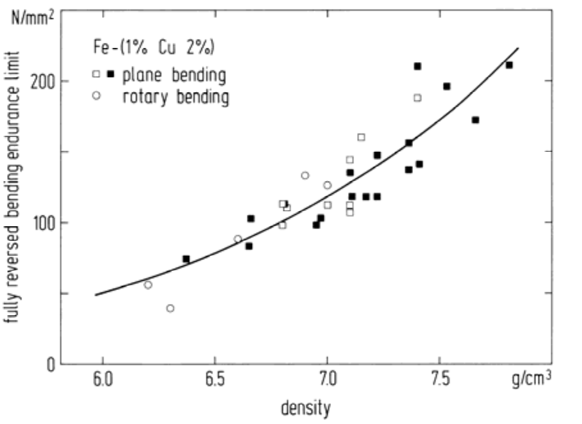

Fig. 1. Fully reversed bending endurance limit of Fe-Cu steel as depending on density for smooth speci-mens; open symbols: sintering temperature≈ 1120°C, filled symbols: 1200 °C or more

Fig. 1 gives an example for the effect of density on fatigue strength. If a larger number of materials is evaluated this way, a parabola with an exponent of m ≈ 5 proves to give reasonable results for sintered porous steels [1]:

$$\sigma_{A1} = \sigma_A(\rho_0)\cdot(\rho/\rho_0)^5 \qquad (1)$$

(σ_{A1}: fatigue strength of an unnotched specimen at density ρ, ρ_0: pore-free density, σ_A (ρ_0): fatigue strength at full density)

The ratio of fully reversed axial and bending fatigue strengths is roughly 0.85, the scatter is, however large, Fig. 2 [1, 2].

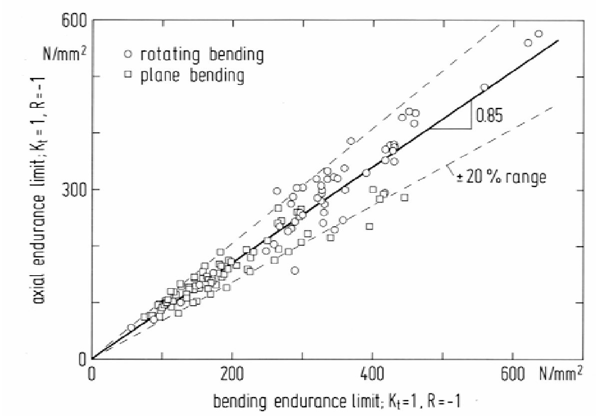

Fig. 2. Relationship between bending and axial endurance limit of unnotched geometries for as-sintered as well as quenched and tempered conditions

If a geometrical notch can be characterized by a stress concentration factor K_t, the endurable amplitude under fully reversed loading can be estimated from

$$\sigma_{A2} = \sigma_{A1}\left[K_t^{-1.19} + (1-K_t^{-1.19})\exp\left(-\sigma_{A1}/Q\right)\right] \quad (2)$$

where Q is a material specific function which can be replaced by a constant if the number of data is limited. Fig. 3 illustrates the agreement between eq. 2 and experimental results. Q-values of 165 N/mm^2 and 260 N/mm^2 were applied for heat treated or sinter hardened steels and steels which were virtually free of martensite in the as-sintered condition, respectively. The filled symbols in Fig. 3 denote recent own results which scatter much less than the majority of the older results.

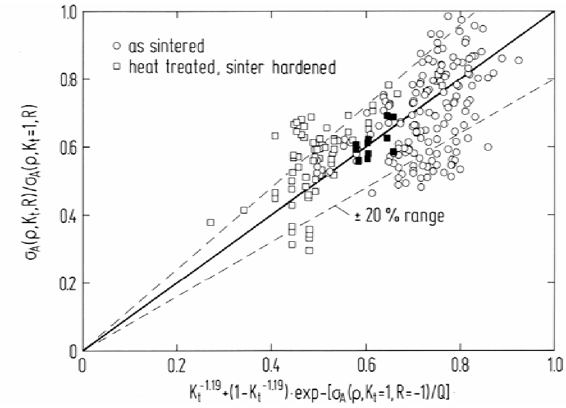

Fig. 3. Comparison of experimental fatigue strength loss by stress concentrations with the estimate according to eq. 3 [2]

The effect of mean stresses σ_m on the endurable amplitude is often described in linear Haigh diagrams with a negative slope M

$$\sigma_{A3} = \sigma_{A2} - M\sigma_m \tag{3}$$

M is usually determined from a fully reversed σ_A (R= − 1) and a corresponding pulsating σ_A (R=0) endurance limit as

$$-M = 1 - \sigma_A(R=-1)/\sigma_A(R=0) \tag{4}$$

in which R = $\sigma_{min}/\sigma_{max} = (\sigma_m - \sigma_A)/(\sigma_m + \sigma_A)$ is the socalled stress ratio. The pulsating amplitude $\sigma_{A4} = \sigma_A$ (R=0) for corresponding smooth and notched specimens can be estimated from

$$\sigma_{A4} = K(K_t\sigma_{A2})^q / K_t \tag{5}$$

(K = 1.35, q = 0.90 for non-martensitic sintered steels, determined by regression analysis). Results are plotted in Fig. 4 and show that the scatter is small when reliable experimental procedures are obeyed. [2, 3] With eq. 5, M becomes

$$-M = 1 - K^{-1}\left(K_t\sigma_{A2}\right)^{1-q}, \tag{6}$$

and the endurable amplitude with $\sigma_m \neq 0$ turns

$$\sigma_{A3} = \sigma_{A2} + \left[1 - K^{-1}(K_t\sigma_{A2})^{1-q}\right]\sigma_m \tag{7}$$

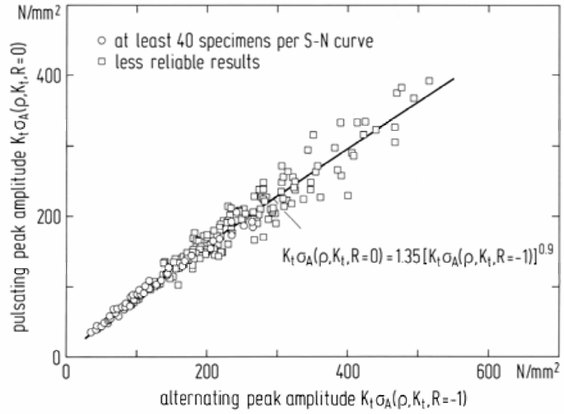

Fig. 4. Relationship between fully reversed and pulsating axial and bending endurance limit of smooth and notched specimens of porous PM steels

3. Summary

From the presently available experimental fatigue endurance limits relationships can be derived which permit to estimate the effect of density, external notches and mean stress on the endurable amplitudes, if a single reliable S-N curve is at hand.

4. References

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