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A NEW FORMULATION OF MEAN STRESS EFFECTS IN FATIGUE

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A common method of treating the mean stress effect on fatigue life is to displace the elastic line on a Manson-Coffin-Basquin diagram while retaining the position of the plastic line. Manson and Halford pointed out that this procedure implies that mean stress significantly affects the cyclic stress-strain curve (ref. 1). Actually, however, they showed experimentally and by more general reasoning, that mean stress has little, if any, effect on the cyclic stress-strain curve. Thus, they concluded that it is necessary to displace the plastic line as well as the elastic line in order to keep the cyclic stress-strain curve unaltered. Another way of expressing the common displacement of the two lines is to keep the lines in place and change the horizontal coordinate to include a term relating to the displacement. Thus, instead of life, $2N_f$, as the horizontal coordinate, a new coordinate can become $2N_f [1 - \sigma_m/\sigma_f']^{1/b}$, thereby displacing both the elastic and plastic lines by an amount $[1 - \sigma_m/\sigma_f']^{1/b}$ where σ_m is the mean stress and σ_f' is the intercept of the elastic line at $N_f = 1/2$ cycles and b is the slope of the elastic line.

Such a procedure does not, however, always produce the proper effect on the Goodman diagram in which mean stress is plotted against alternating stress for selected values of life. The Goodman diagram for this case would necessarily be straight lines for all materials. While some materials do, indeed, produce straight lines, others are known to be concave, while still others have convex curvature. In fact, for some materials, the Goodman diagram may be concave for one life level, straight for another life level, and convex for a third life level. A more generalized behavior can, therefore, be achieved by using, as the horizontal coordinate, the parameter

$$2N_f \left[1 - \left(\frac{\sigma_m}{\sigma_f'} \right)^{A + B \log N_f} \right]^{1/b}$$

Depending on the values of A and B, the curvature of the Goodman lines can then change according to life level.

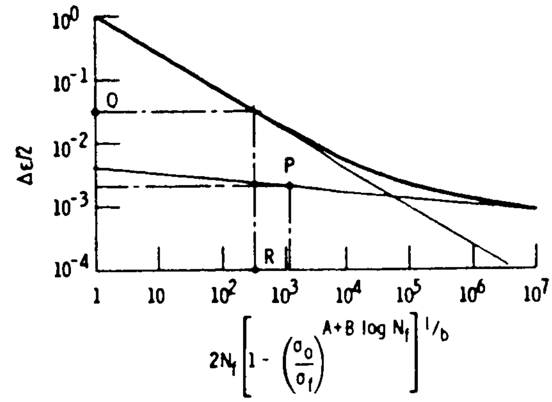
We have examined a number of materials for which various degrees of curvature have been observed, as well as one material for which the curvature changed from convex to concave as life was changed.

Figure 1 shows schematically the concept behind the procedure we have developed. Figure 1(a) shows the coordinate axes in a Manson-Coffin-Basquin plot, while figure 1(b) shows an example whereby curvature is altered at different values of life level for particular parameter values of A and B, as shown.

Figure 2 shows the application of this type of analysis to various aluminum and steel alloys for which extensive data are available in the literature. The lines drawn in these figures are derived from the diagrams of figure 1(a) for the specific constants shown for each material. The experimental points are derived from faired curves through the data. Good agreement is seen in all cases. Note especially the 9Ni-4Co-0.45C material for which different curvatures appear at different life levels.

REFERENCE

1. Halford, G.R.; and Manson, S.S.: Discussion of Paper: M. Doner, K.R. Bain, and J.H. Adams; Evaluation of Methods for the Treatment of Mean Stress Effects on Low-Cycle Fatigue. J. Eng. Power, vol. 104, no. 2, Apr. 1982, pp. 403-411: J. Eng. Power, vol. 104, no. 2, Apr. 1982, p. 411.



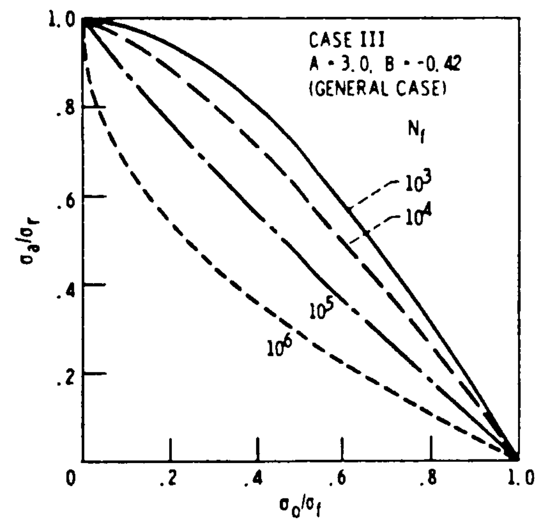


Figure 1. - Framework for new method.

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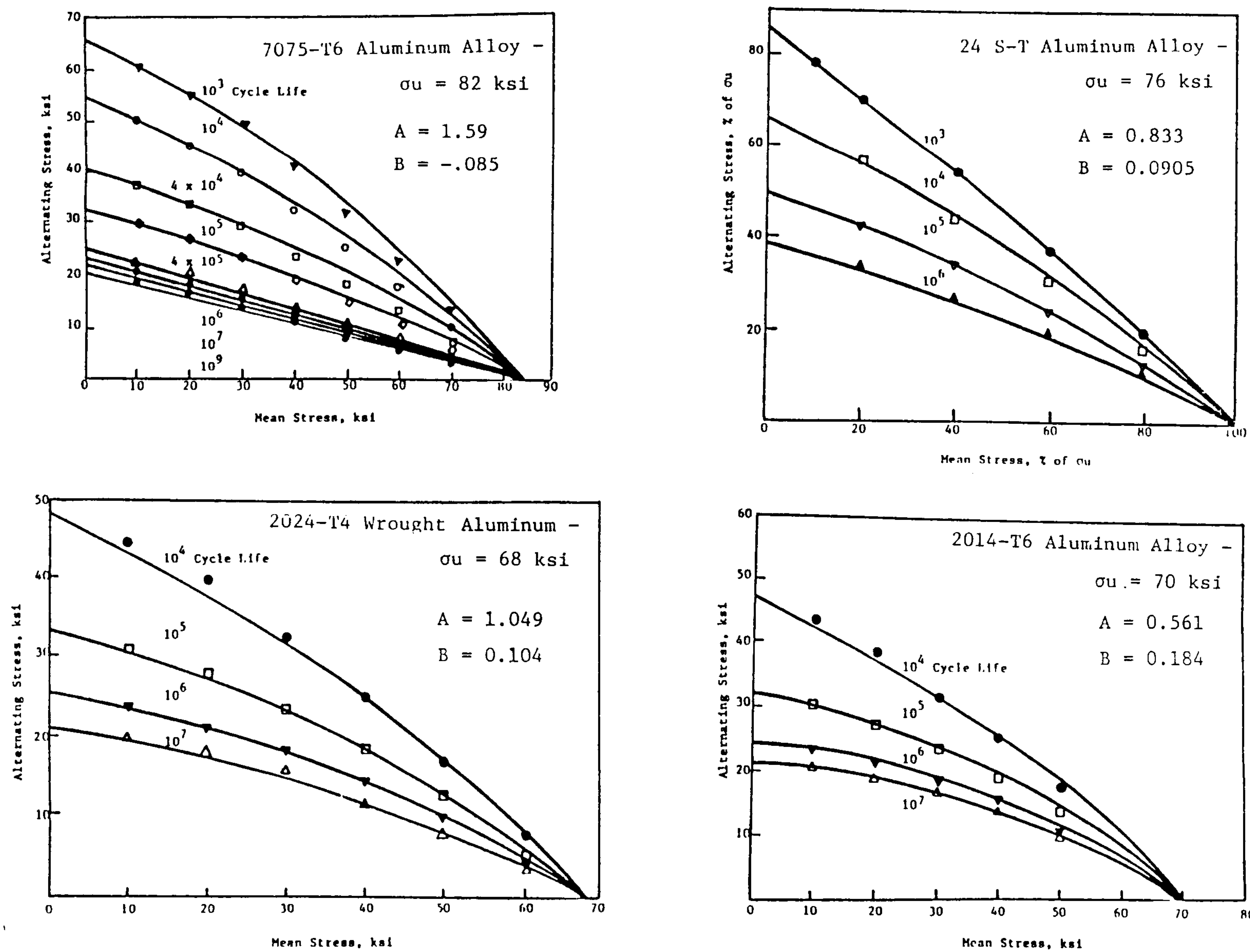

Figure 2. - Comparisons between observed and calculated axial fatigue strengths. (——— Predictions; ●□Δ From experimental curves)

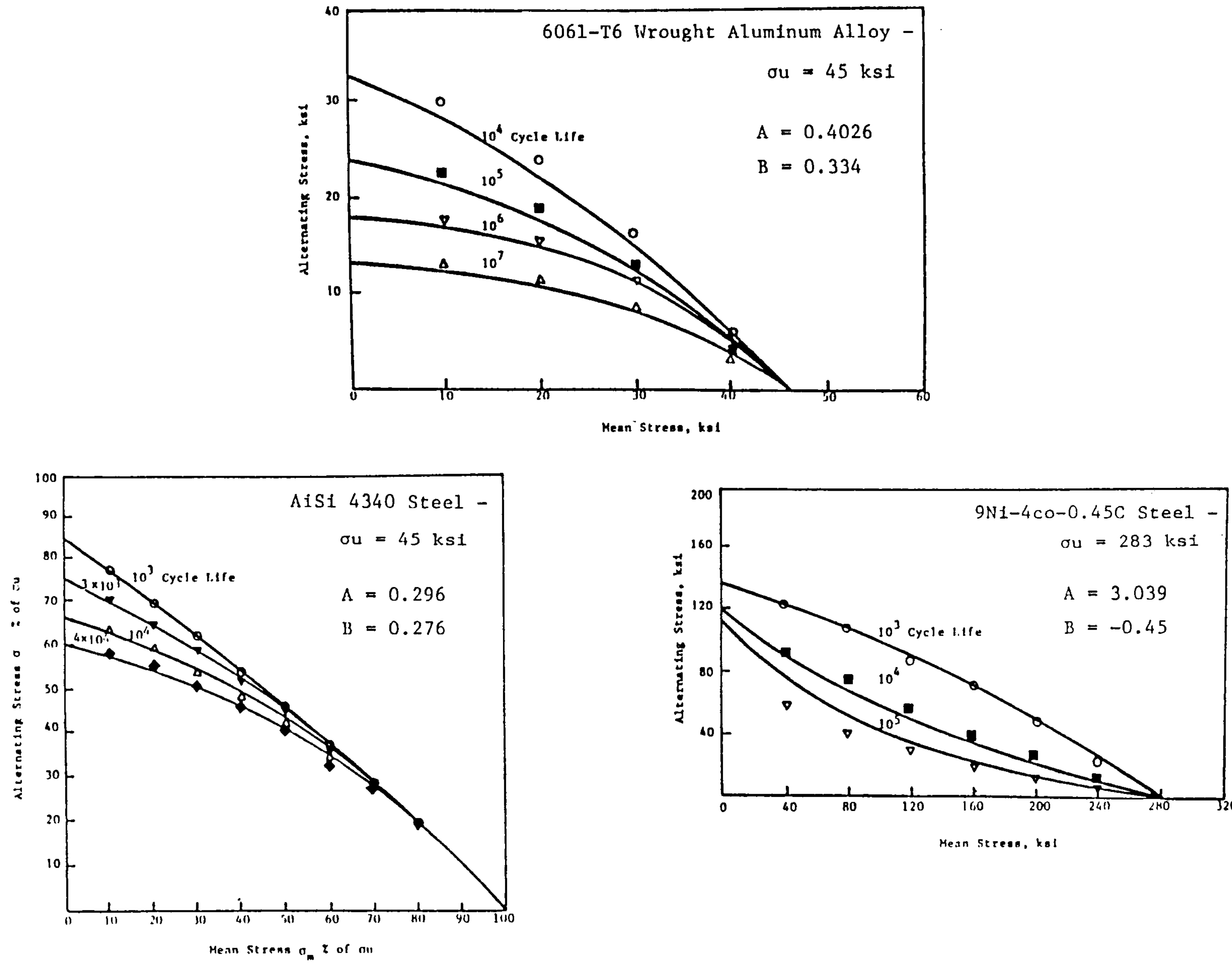

Figure 2. - Continued.