

Figure S1 shows TEM images of the welded joint region. Lath martensite with a high density of dislocation tangles is clearly observed. The selected area electron diffraction patterns further confirm a body-centered cubic crystal structure.

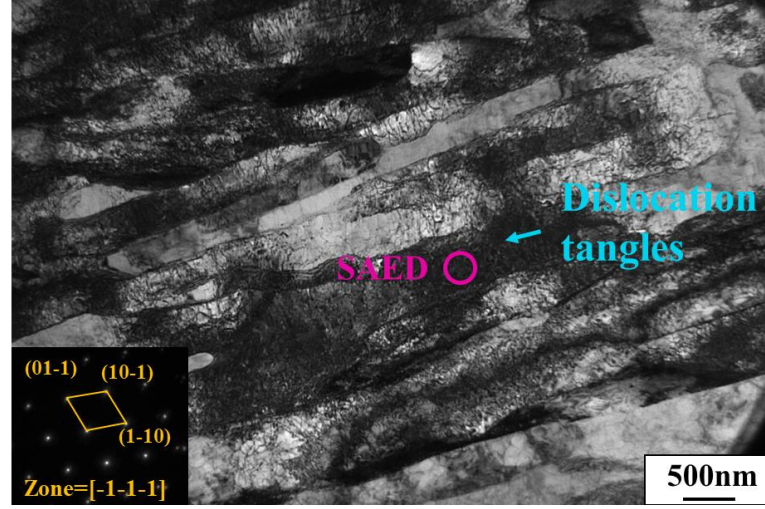


Figure S1. TEM image of lath martensite.

In the fatigue tests, at least three valid specimens were tested at each stress level. For data analysis, the fatigue life values were transformed using a common logarithm (base 10) prior to statistical evaluation.

The main statistical parameters include the standard deviation and the coefficient of variation, which are calculated as follows:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (S1)$$

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}} \quad (S2)$$

$$C_v = \frac{s}{\bar{x}} \quad (S3)$$

$\bar{x}$ — the mean value of all measurements in a test group ($i = 1, 2, 3, \dots, n$);

s — the standard deviation of the measurements, with larger s indicating greater data dispersion;

C_v — the coefficient of variation of the specimens in the test group.

During data processing, all fatigue life values were transformed into logarithmic form. The number of tested specimens should satisfy the following criterion:

$$\frac{\delta_{max} \sqrt{n}}{t_y} \geq \frac{s}{\bar{x}} (C_v) \quad (S4)$$

$\delta_{\max}$ — allowable error limit, typically taken as 1%–10%; a value of 10% was adopted in this study.

t_γ — parameter corresponding to the specified confidence level (95%)

Fatigue life was obtained at different stress levels and processed according to the above calculation methods. The results of the data analysis are presented in Tables S1, S2, S3, and S4. The calculation indicates that testing three specimens is feasible.

Table S1. Standard deviation and coefficient of variation of fatigue life for the ACS-FM at different stress levels.

s	C_v
0.04781	0.007449
0.04019	0.007158
0.09479	0.011771
0.12241	0.02333
0.02965	0.006079

Table S2. Standard deviation and coefficient of variation of fatigue life for ACS-FM-WJ at different stress levels.

s	C_v
0.01774	0.00291
0.01626	0.002781
0.2047	0.03893
0.12381	0.02387
0.03747	0.007505

Table S3. Standard deviation and coefficient of variation of fatigue life for the ACS-BMA at different stress levels.

s	C_v
0.05516	0.009684
0.09286	0.01719
0.007855	0.001486
0.02096	0.00399
0.04295	0.008608

Table S4. Standard deviation and coefficient of variation of fatigue life for ACS-BMA-WJ at different stress levels.

s	C_v
0.04047	0.007052
0.02120	0.003782
0.01258	0.002298
0.14115	0.02662