An Experiment on the Effect of the Pre-strain on the Fatigue Strength of Mild Steel

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NOTE

An Experiment on the Effect of the Pre-strain on the Fatigue Strength of Mild Steel

By Shigetoshi SHIMIZU* and Ryoichi IMAI**

A number of experiments on fatigue of the pre-strained metals have been investigated by various investigators[1)~11)].

This paper presents the experimental results of rotary-bending fatigue test of pre-strained mild steel (C 0.18%) whose chemical composition is shown in Table 1. The specimens were subjected to tensile, torsional and their combined strain as shown in Table 2. The combined pre-strained specimens were stretched first and then twisted.

The dimensions of the three kinds of specimens are shown in Fig. 1, 2 and 3.

The experimental results are shown in Fig. 4. Although the fatigue strength of the 2% tensile pre-strained specimens decrease below that of the original materials, the others increase.

The conventional tensile strain ε, torsional strain γ are equivalently replaced by the Nadai's octahedral shear strain γ_{n1} and γ_{n2} using the equations[12)]

Table. 1 Chemical composition of material

Material	Symbol	Chemical composition (%)				
		C	*Si*	*Mn*	*P*	*S*
Mild Steel	JIS SR 24	0.18	0.21	0.54	0.030	0.021

Table. 2 The combinations of pre-strains for this experiment

$\varepsilon=0\%$ $\theta=0°/mm$	$\varepsilon=2\%$ $\theta=0°/mm$	$\varepsilon=10\%$ $\theta=0°/mm$	$\varepsilon=20\%$ $\theta=0°/mm$
$\varepsilon=0\%$ $\theta=3.6°/mm$	$\varepsilon=2\%$ $\theta=3.6°/mm$	$\varepsilon=10\%$ $\theta=3.6°/mm$	$\varepsilon=20\%$ $\theta=3.6°/mm$
$\varepsilon=0\%$ $\theta=7.2°/mm$	$\varepsilon=2\%$ $\theta=7.2°/mm$	$\varepsilon=10\%$ $\theta=7.2°/mm$	$\varepsilon=20\%$ $\theta=7.2°/mm$

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$$\gamma_{n1}=\sqrt{2}\,ln\,(1+\varepsilon)$$

$$\gamma_{n2}=\sqrt{\frac{2}{3}}ln\left\{1+\frac{\gamma^2}{2}+\gamma\left(1+\frac{\gamma^2}{4}\right)^{\frac{1}{2}}\right\}$$

while their combined strains are replaced by the sum* of γ_{n1} and γ_{n2}.

The relation between the equivalent pre-strain and fatigue strength are shown in Fig. 5, respect to the repeated cycles of stress $N=10^5$, 10^6 and 10^7.

As far as these experimental results are concerned, the effect of the pre-torsional strain on the fatigue is so much greater than that of the pre-tensile strain, and the fatigue strength of the combined pre-strained materials is slightly greater than that of the simply torsionaly pre-strained ones.

The appearance of the typical fatigue fracture is shown in Photo. 1~6. The fractures of the torsional pre-strained specimens look like a spiral form as shown in Photo. 3~6, while those of the tensile pre-strained specimens are perpendicular to the longitudinal axis as shown in Photo. 2, similaly to those of original material (Photo. 1).

The relation between the ultimate strength σ_B and the fatigue limit σ_{w0} are shown in Fig. 6. We see that σ_{w0} are nearly equal to the half of σ_B.

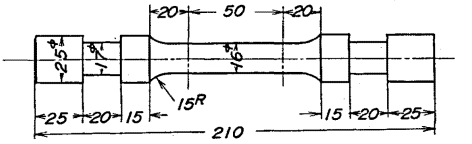

Fig. 1 Tension Specimen

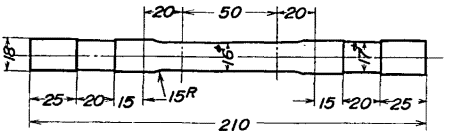

Fig. 2 Torsion Specimen

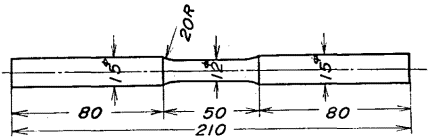

Fig. 3 Fatigue Specimen

* S. Fukui and the others showed the same expression in their report[3].

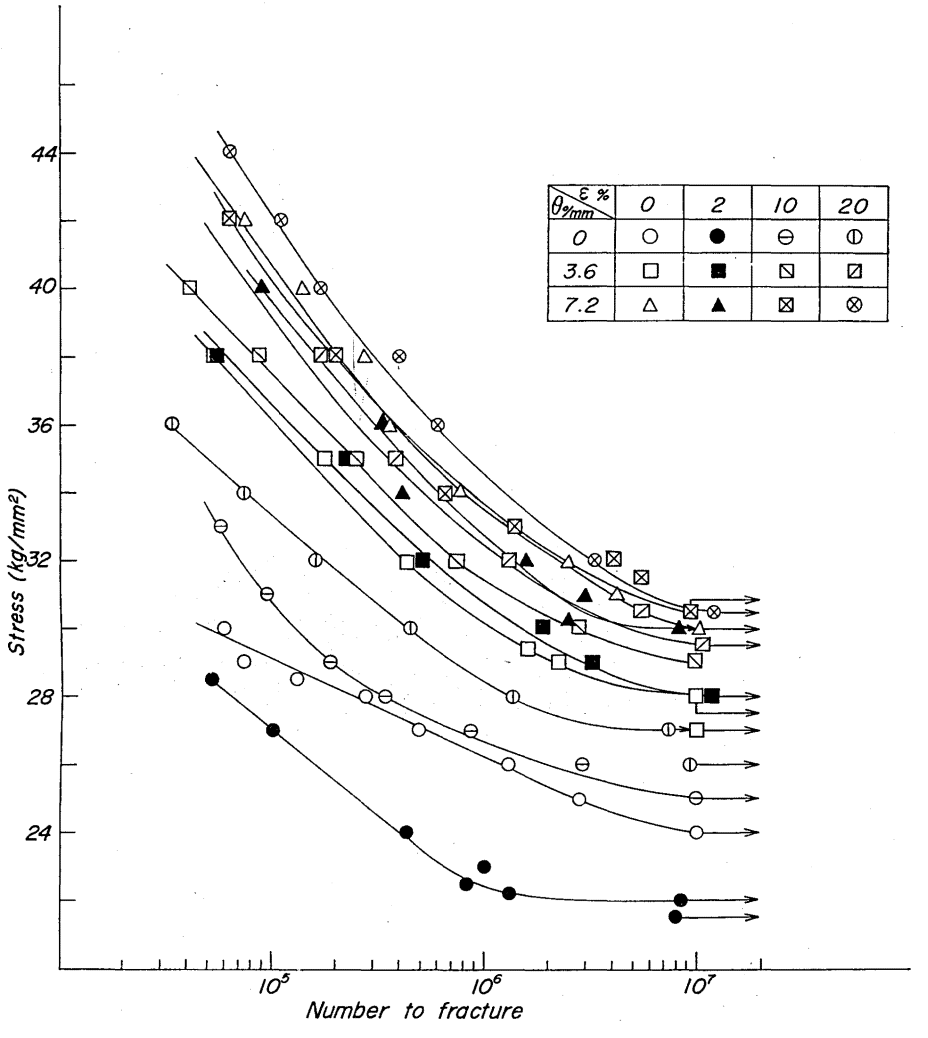

Fig. 4 S-N diagrams of original and pre-strained materials

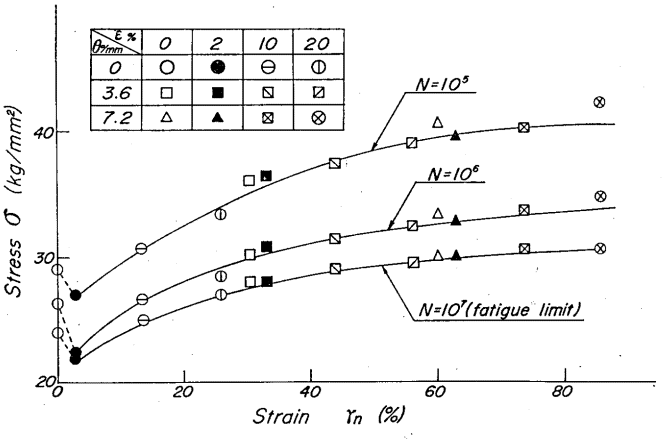

Fig. 5 Effect of the pre-strain, replaced by the Nadai's octahedral shear strain, on the fatigue strength under rotary bending.

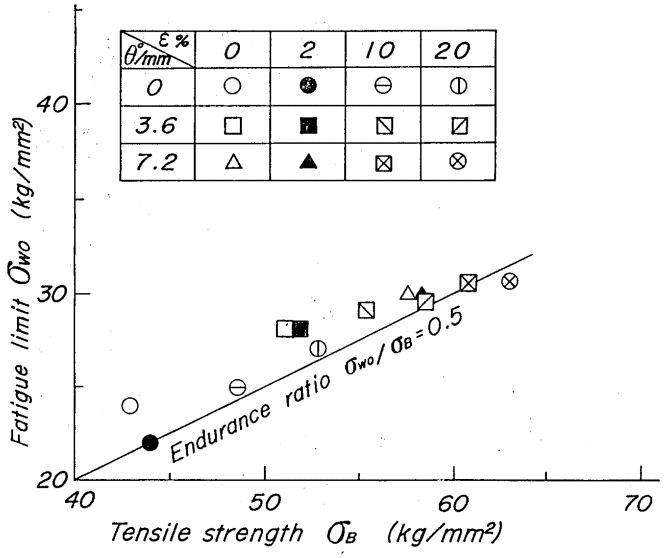

Fig. 6 Relation between rotary bending fatigue strength and tensile strength of pre-strained mild steel.

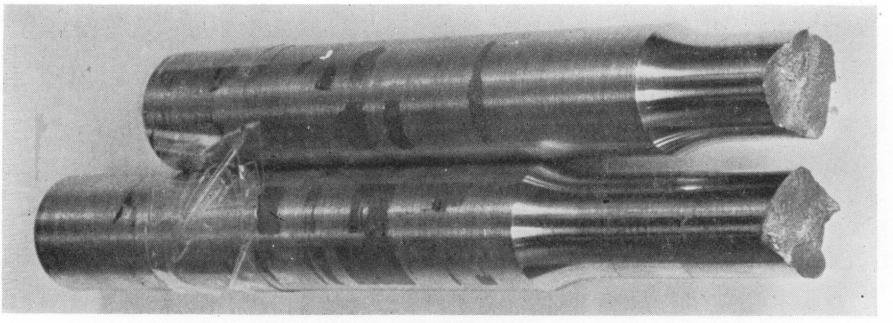

Photo. 1 Original material

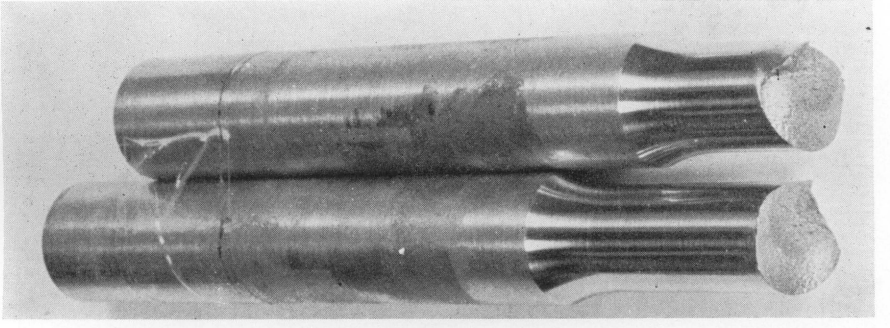

Photo. 2 Pre-strain $\varepsilon=2\%$, $\theta=0$ deg/mm

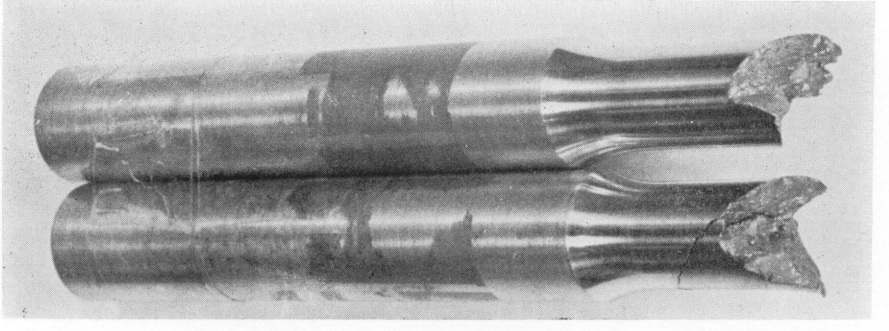

Photo. 3 Pre-strain $\varepsilon=2\%$, $\theta=7.2$ deg/mm

Photo. 1～6 Fatigue fractures of pre-strained materials (*Facing p. 42*)

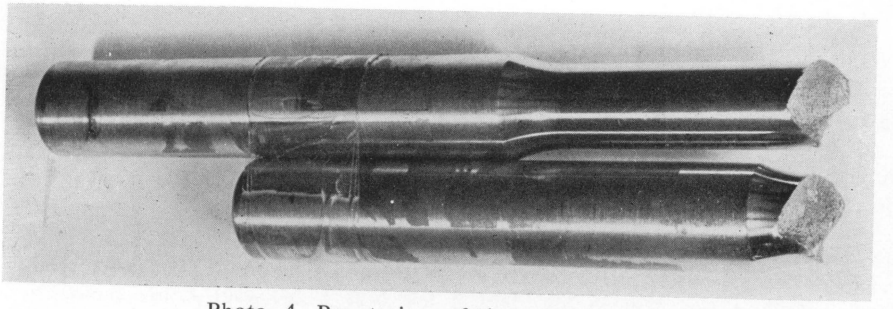

Photo. 4 Pre-strain $\varepsilon=0\%$, $\theta=3.6$ deg/mm

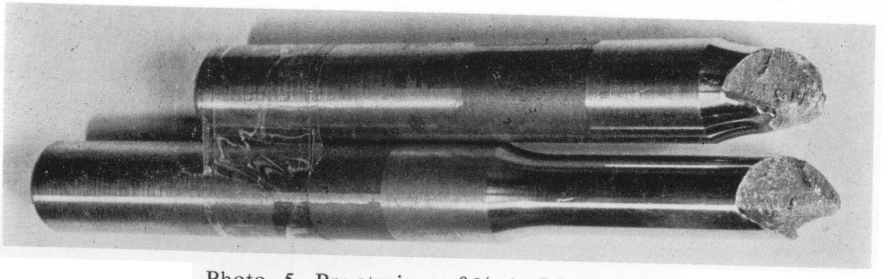

Photo. 5 Pre-strain $\varepsilon=0\%$, $\theta=7.2$ deg/mm

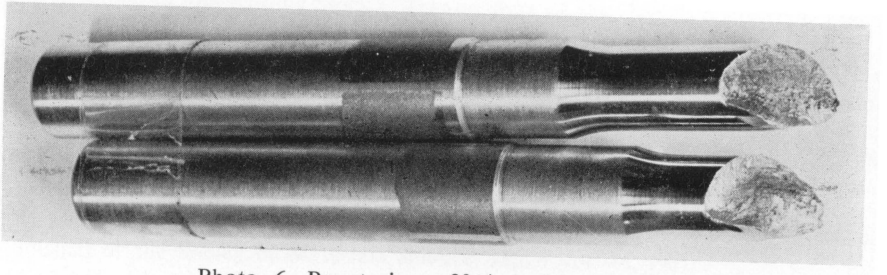

Photo. 6 Pre-strain $\varepsilon=20\%$, $\theta=7.2$ deg/mm

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