EFFECT OF PRE-STRAIN ON FATIGUE PROPERITES IN LOW AND HIGH CARBON STEELS

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ABSTRACT

In this work, Fatigue tests have been performed to investigate the fatigue damage process for two kinds of plain carbon steels, (low and high carbon steels) . The effect of pre-strain process on fatigue crack initiation and fatigue strength has been examined. The main results obtained are summarized as follows: (1) In the case of low carbon steel (0.15%C) , the fatigue limit of ε_p=0% (non-pre-strained specimen) is higher than or equal to those of ε_p=2% and ε_p=5% pre-strained specimens and lower than that of ε_p=8% pre-strained specimens. (2) In the case of high carbon steel (0.46%C), the fatigue limit of ε_p=0% (non-pre-strained specimen) is higher than those of ε_p=2%, 5% and 8% pre-strained specimens . (3) Though the fatigue limits of pre-strained specimens are lower than those of non-pre-strained specimen , the fatigue limits increase according to the increasing of pre-strain percentage for both of tested material.

1.INTRODUCTION

Most of plain carbon steels are practically used after plastic deformation caused by tensile or bending process . It will be consider that it is very important to investigate the effect of pre-

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from the crack of pearlite block and the plastic slip between ferrite grain and pearlite block which appeared after pre-straining process.

Finally, it seems to be clear that the fatigue crack initiation is highly affected by the weak field of plastic slip which appeared in pearlite block after pre-straining.

4.CONCLUSIONS

From this study, the following conclusions may be drawn :

1. In the case of tensile test, the plastic slip is generated in the boundary area between ferrite grain and pearlite block by total strain of 5% for material A (low carbon steel), and the cracks are observed in pearlite block by the total strain of 4.8% for material B (high carbon steel).
2. In the case of material A, the fatigue limit of pre-strained ε_p=2% is lower than that of ε_p=0%. On the other hand, the fatigue limit of pre-strained ε_p=5% is equal to that of ε_p=0%, and the fatigue limit of pre-strained ε_p=8% is higher than that of ε_p=0%.
3. In the case of material B, the fatigue limit of non-pre-strained ε_p=0% is higher than those of pre-strained ε_p=2.5% and 8%, respectively.
4. The fatigue limit of pre-strained specimen is lower than the non-pre-strained ones, and the fatigue limit increases due to the increasing of pre-strain for both of tested materials.

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strain process to fatigue properties. Unil now, researches about static tensile and fatigue test for non-pre-strained specimen have been reported, but the research for pre-strained specimen is limited [1-6]. Low and high carbon steels (0.15% C and 0.46%C) have been used in this work . In the case of low carbon steel, after tensile test, it has been observed that the plastic sliding is generated in the boundary area between ferrite grain and pearlite block by total strain of ε_p=5% without crack initiation. On contrary, for high carbon steel, after tensile test, cracks are initiated in pearlite block by total strain of ε_p=4.8% [7].

Therefore, it is interesting to investigate the influence of pre-strain on fatigue properties such as fatigue crack initiation, and to study the behaviour of plastic slip and micro-cracks which initiated by tensile test.

2.MATERIALS AND EXPERIMENTAL PROCEDURE

The chemical composition and mechanical properties of tested material are shown in tables (1) and (2), respectively. Furthermore, material grain size was unified by annealing at 900°C for 2 hrs (for 0.15%C carbon steel), and 990°C for 2 hrs (2 times) (for 0.46%C carbon steel) the mechanical properties were evaluated in the rolling direction.

The specimens from the material were cut out and were machined in the rolling direction concerning with the partial notch at the rolling surface as shown in Fig.(1).

The specimens were soaked at 600°C for 1hr, next cooling to room temperature for stress relief annealing, then the specimens were polished by mechanical polishing, finally were etched.

The pre-strain was given to specimen using a universal testing machine. The fatigue tested specimens were machined from the pre-strained specimens to the shape and dimensions as shown in Fig.(1). On contrary, fatigue test was carried out at room temperature using rotating bending fatigue testing machine at speed of 2880 R.PM. Fatigue micro-cracks were observed by successive taken replica method on the circumferencial direction of the specimen surface. The taken replicas of the specimens were examined using metallurgical microscope and scanning electron microscope, SEM (Jeol Ts-20 Japan).

Table (1) : Chemical composition %wt

Material	C	Si	Mn	P	S	Al
A	0.15	0.22	0.55	0.034	0.025	----
B	0.46	0.20	0.73	0.029	0.017	0.018

Table (2) : Mechanical properties

Material	Mechanical properties			Heat treatment
	σ_u MPa	σ_y MPa	ψ %	
A	440	283	70.8	900°C 2hrs → A.C.
B	632	360	53.8	990°C 2hrs →F.C.(2 times)

σ_u : Tensile strength σ_y :Yield strength

ψ : Reduction of area

A.C : Air cooling F.C :Furnace cooling

3.RESULTS AND DISCUSSION

The stress-strain curves of both tested materials are shown in Fig.(2). The changes of surface state during static tensile test process for both materials 0.15%C (material A) and 0.46%C (material B) are shown in Fig. (3). The plastic slip is generated in the boundary area between ferrite grain and pearlite block by total strain of 5% for material A, while the cracks generating are observed in the pearlite block by total strain of 4.8% for material B.

The changes of surface state of the pre-strained specimen are significant at about ε_p=5%. It is reasonable to choose this level pre-strain to investigate the effect of pre-strain process to the fatigue properties. In addition, pre-strained ε_p=2% and ε_p=8% specimens are also employed in order to represent the lower and higher pre-strain cases.

The S-N curves of both materials A and B are shown in Figs. (4) and (5). From the curves, it is concluded that, the fatigue limits of material A (0.15%C) reached by $1x10^7$ cycles at pre-strain ε_p=0, 2, 5 and 8% are 205, 200, 205 and 220 MP_a, while the fatigue limits of material B (0.46%C) reached by 1×10^7 cycles at ε_p=0, 2, 5 and 8% are 250, 215, 235 and 245 MP_a, respectively.

The comparison of the fatigue limits of pre-strained specimens to the non-pre-strained one is shown in Fig. (6). It is remarked that, (1) for material A, the fatigue limit of ε_p=2% pre-strained specimen is lower than that of the non-prestrained specimen (ε_p=0%)by 2.4%, while the fatigue limit of ε_p=5% is equal to the fatigue limit of ε_p=0 (non-prestrained specimen), and on contrary, the fatigue limit of ε_p=8% is higher than that of the [ε_p=0%] by 7.3% , (2) for material B (0.46%C), the fatigue limit of the non-pre-strained specimen is higher than that of the pre-strained specimens, especially for material B, the fatigue limit of ε_p=2% is lower than that of ε_p=0% by 35 MP_a. Though the fatigue limit of pre-strained specimens are lower than that of the non-pre-strained one, the fatigue limit of pre-strained specimens increases due to the increasing of pre-strain for both kinds of material.

The improvement of fatigue limit have been reported in a previous researches [1-4]. But in this study, the fatigue limit of pre-strained specimen for high carbon steel, such as material B (0.46%C) become worse than that of non-pre-strained. This can be attributed to the crack initiation and plastic slip which appeared after static tension (pre-strain).

Fatigue micro-cracks have been observed by successive application of taken replica technique on the circumferencial direction of the specimens for material A and material B, as shown in Figs. (7), and (8). Further details of the fatigue cracks initiation in Fig. (8) are shown in Figs. (9) and (10) by SEM observation.

For material A (0.15%C) Fig (7), the cracks in ε_p=2% specimen initiate from the plastic slip of ferrite transcrystalline and intercrystalline which appeared after pre-straining process. The cracks in ε_p=5 and 8% specimens initiate from the plastic slip between ferrite grain and pearlite block which appeared after pre-straining process. For material B (0.46%C) [Figs. (8), (9) and (10)], the cracks in ε_p=2% specimen initiate from the plastic slip between ferrite grain and pearlite block which appeared after pre-straining process. Further the cracks of ε_p=5% and 8% specimens initiate

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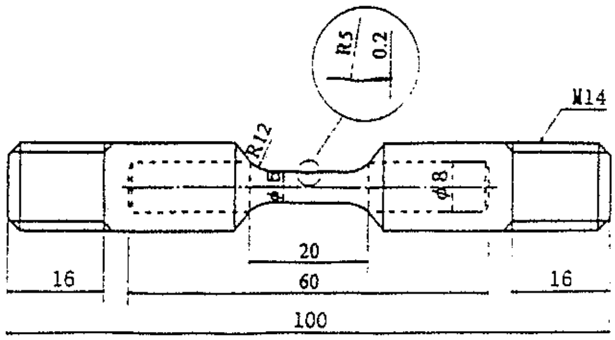


Fig. 1 Shape and dimensions of specimen. mm.

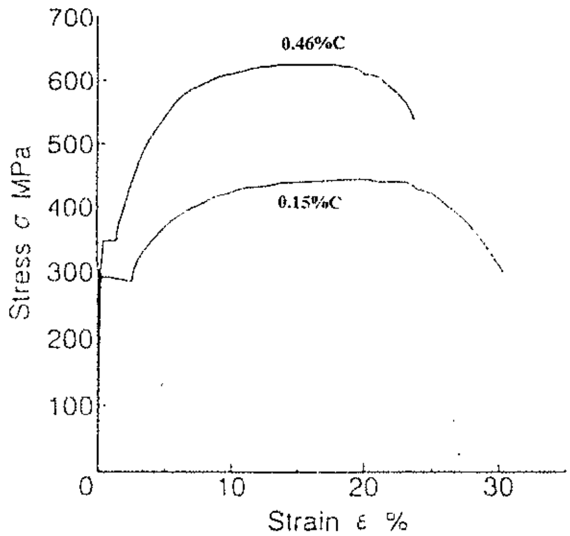
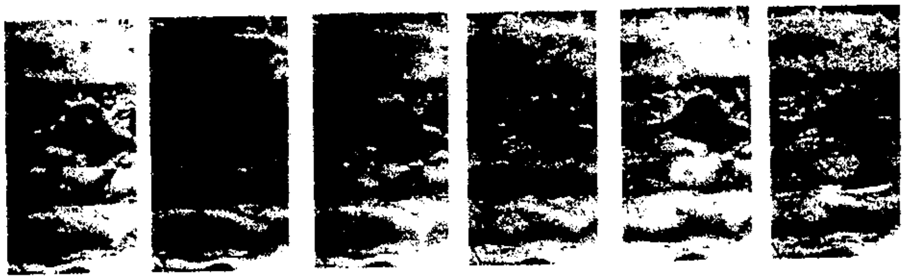
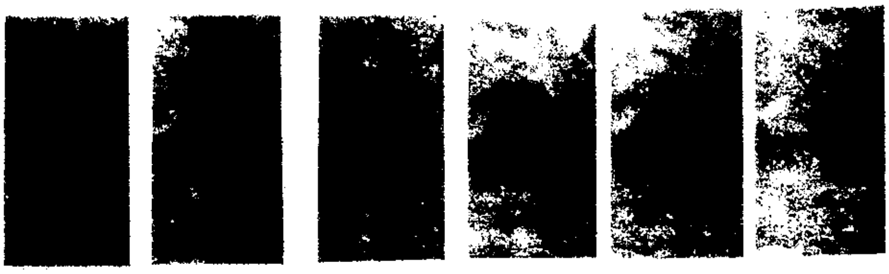


Fig. 2 Stress-strain curves.



ε p=0%　2%　3.4%　4.8%　6.3%　9.1%

(a) 0.15%C



ε p=0%　2%　3.4%　4.8%　6.3%　9.1%

(b) 0.46%C

30μm

Axial direction

Fig. 3 Changes of surface state during pre-strain process.

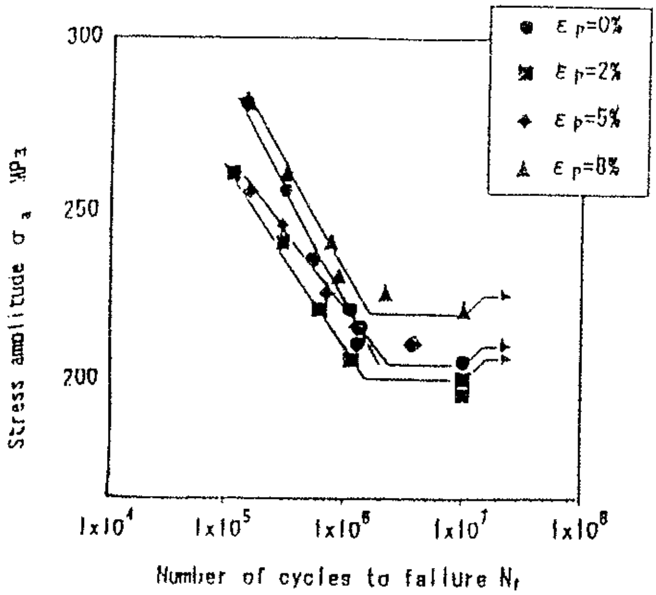


Fig. 4 S-N curves of material A (0.15%C).

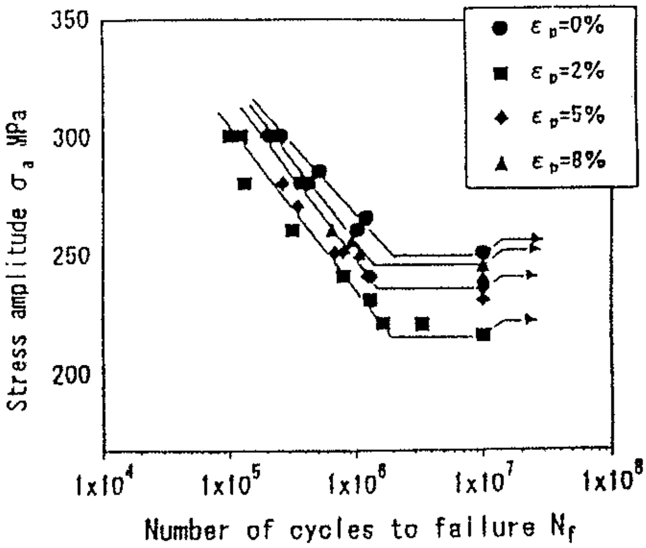


Fig. 5 S-N curves of material B(0.46%C).

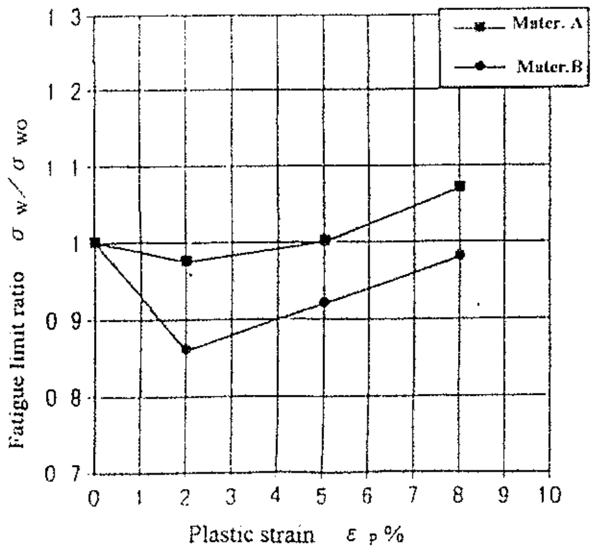


Fig. 6 Relation between σ_w/σ_{wo} and ε_p%.

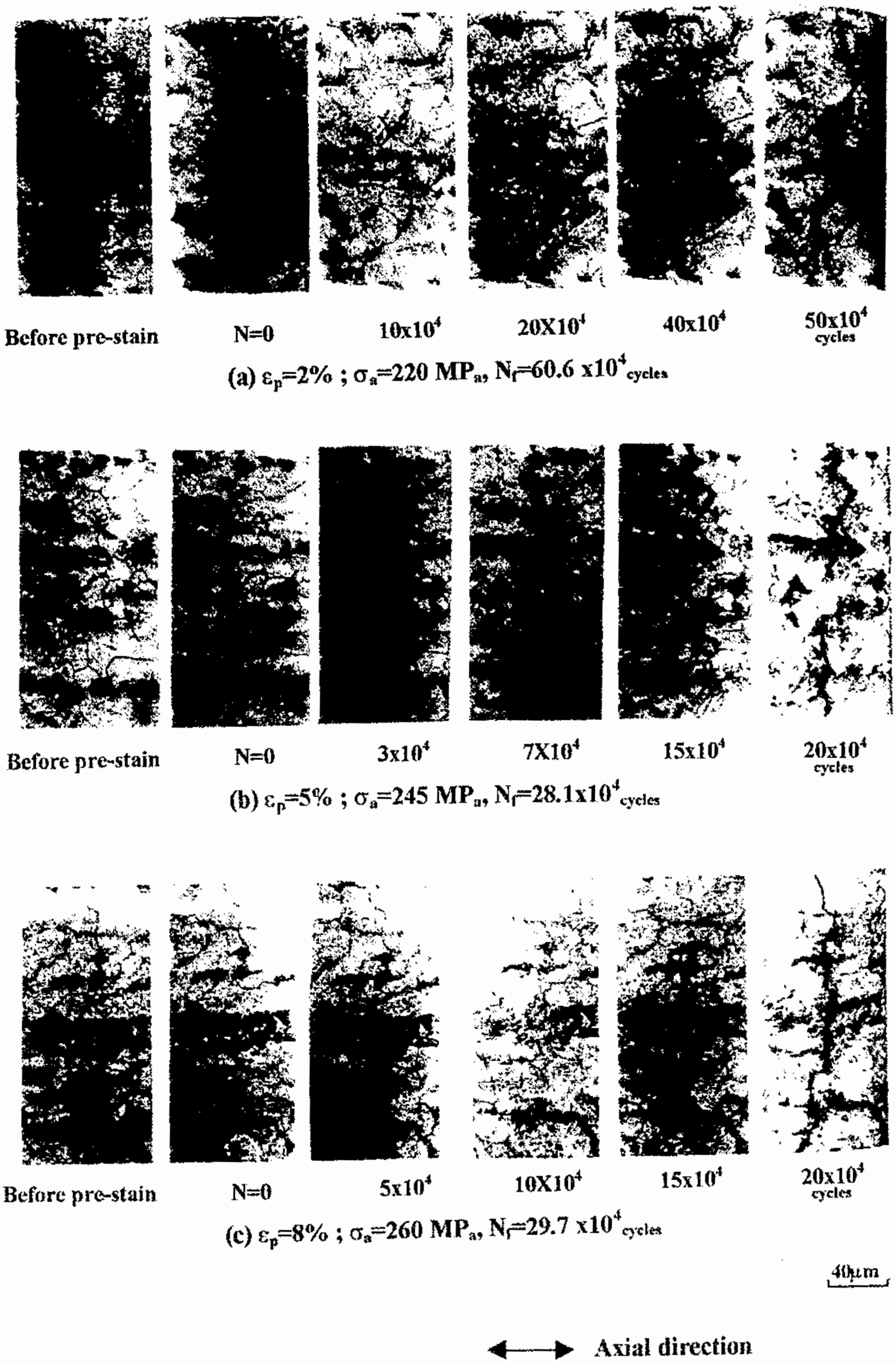


Fig. 7 Successive observation of fatigue crack initiation of pre-strained specimen (material A:0.15%C).

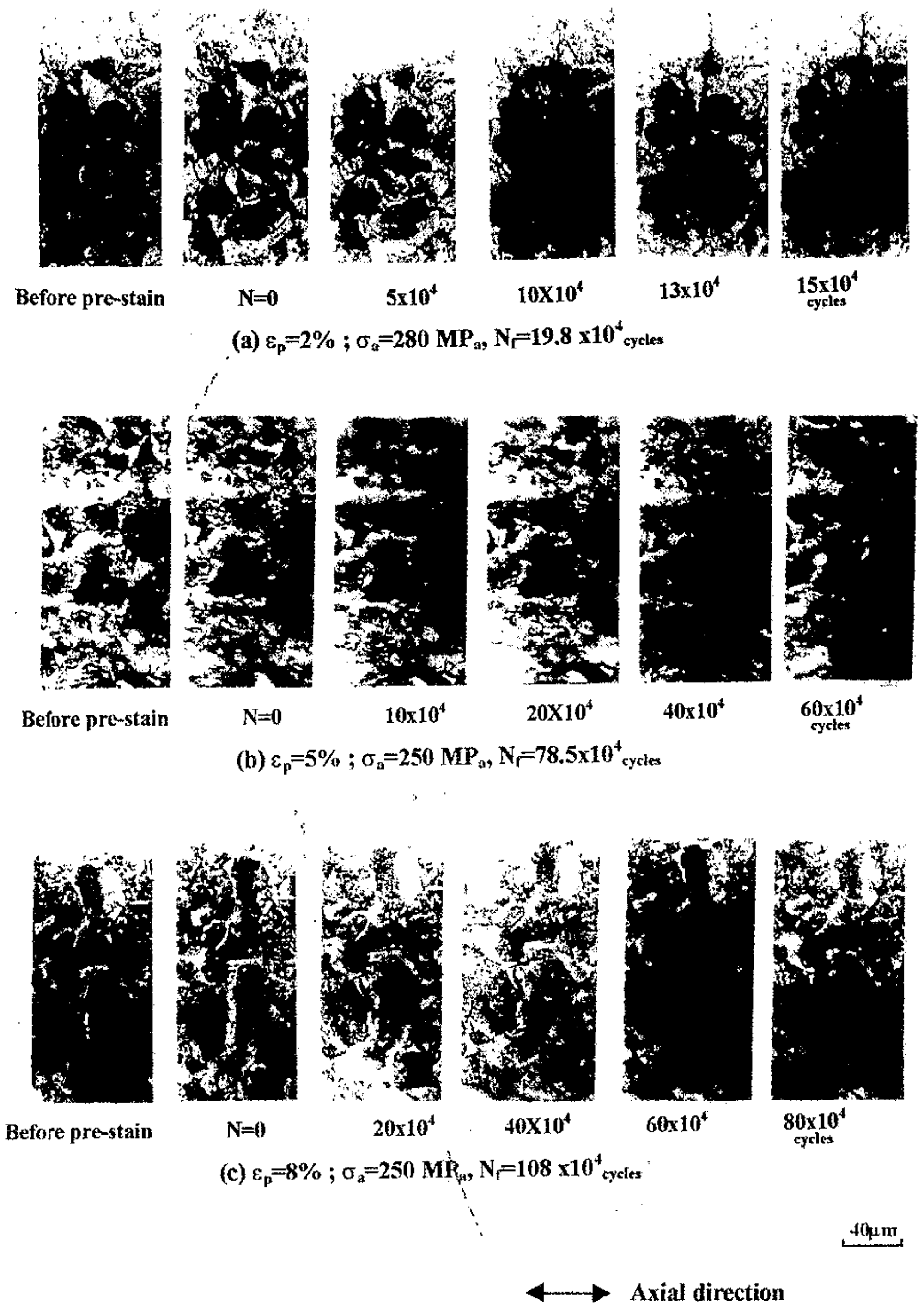


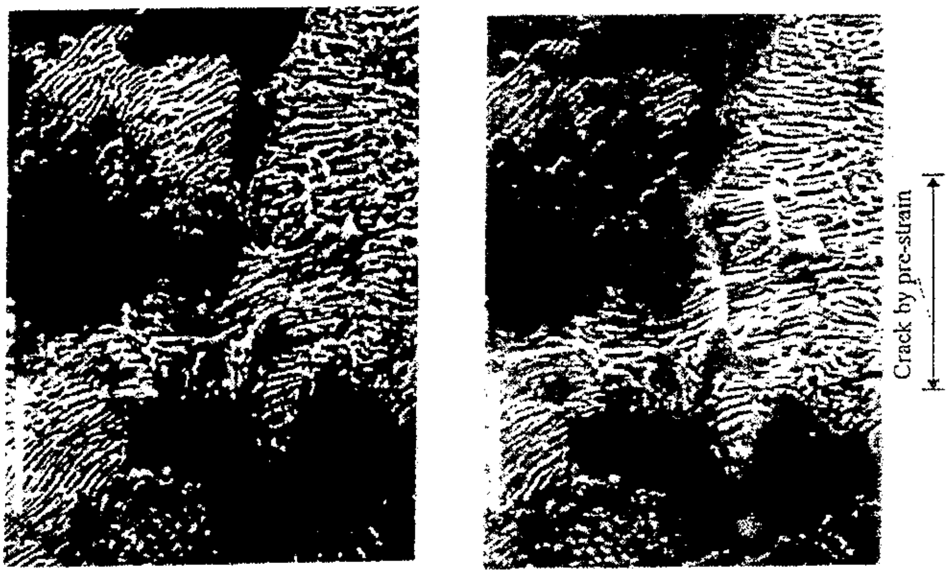
Fig. 8 Successive observation of fatigue crack initiation of pre-strained specimen (material B:0.46%C).

Before pre-strain ($\varepsilon_p = 0$) After pre-strain ($\varepsilon_p = 2\%$)

$\varepsilon_p = 2\%$, $\sigma_a = 280$ MPa, $N_f = 19.8 \times 10^4$ cycles 10μm

⟷ Axial direction

Fig. 9 Successive observation of fatigue crack initiation of pre-strained specimen using SEM (material B:0.46%C).



Before pre-strain ($\varepsilon_p = 0$) After pre-strain ($\varepsilon_p = 5\%$)

$\varepsilon_p = 5\%$, $\sigma_a = 250$MPa, $N_f = 78.5 \times 10^4$ cycles 10μm

⟷ Axial direction

Fig. 10 Successive observation of fatigue crack initiation of pre-strained specimen using SEM (material B:0.46%C).

تأثير الانفعال المسبق على خصائص الكلال لكل من الصلب المنخفض والعالي الكربون

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ملخص البحث:

يهدف هذا البحث إلى دراسة تأثير انفعال الشد المسبق على خصائص الكلال لكل من الصلب المنخفض والعالي الكربون. وتم في البحث إعداد عينات اختبار الكلال بعد تعرضها لانفعال شد مسبق. كذلك اشتمل البحث على إجراء اختبارات الكلال الانحنائية الدوارة. واشتمل البحث على استخدام الـ Replication tecnique لملاحظة منشأ شرخ الكلال Fatigue crack initiation باستخدام كل من الميكروسكوب الضوئي والميكروسكوب الماسح الإلكتروني .SEM.

ولقد خلص البحث إلى أن قيمة حد الكلال Fatigue limit للعينات التي تم تعريضها لانفعال شد مسبق تكون أقل من قيمتها عما في حالة عدم تعرضها، وإلى أن حد الكلال يتزايد بتزايد الانفعال المسبق لكلا النوعين من الصلب.