第 126 回定例研究会　資料Ⅱ

疲労限度線図以下の応力による疲労破壊現象に及ぼす切欠き形状と侵入水素の影響

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Background

The integrity of equipments in hydrogen economy

Fatigue failure of material containing small defect is important.

(Two topics)

- **Fatigue fracture by stresses below fatigue limit**
- **Reduction of ΔK_{th} by hydrogen**

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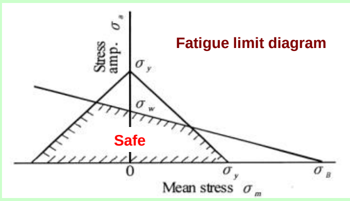
1st

Reduction of fatigue strength by under-stress

It is often assumed that fatigue fracture would not occur when all stress amplitudes are within fatigue limit diagram.



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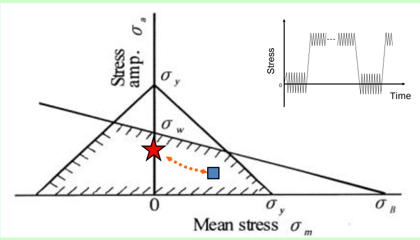
In some special loading history, fatigue fracture occurs in the case of notched specimen, even when all stresses are within fatigue limit diagram.



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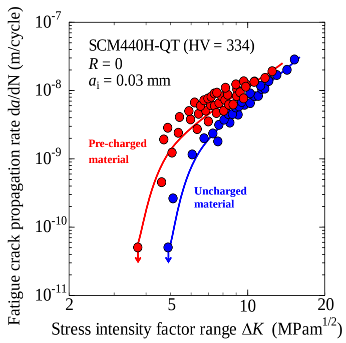
2nd

Absorbed hydrogen reduces fatigue strength



Y.Kondo et al, Trans. JSME Vol.74, No.746 (2008)

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Test material : SCM440H low alloy steel

Chemical composition of material (mass%)

Material	C	Si	Mn	P	S	Ni	Cr	Mo	Cu
SCM440H	0.42	0.22	0.8	0.02	0.02	0.03	1.04	0.16	0.02

Mechanical properties of material

Material	$\sigma_{0.2}$ (MPa)	σ_B (MPa)	δ (%)	Φ (%)	HV
SCM440H	911	1025	21.2	59.6	334

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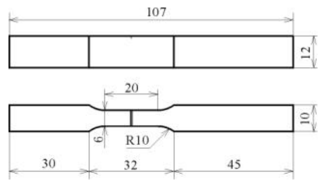
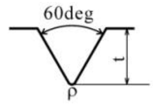
Small-notched specimen





Stress relieved in vacuum at 873K for 60 min after machining

Loading : Uniform bending
Frequency : 30Hz
Environment : In air, at room temp.

Notch shape

t	ρ
10μm	5μm
20μm	5μm
100μm	5μm
500μm	5μm
100μm	50μm
500μm	100μm
500μm	300μm

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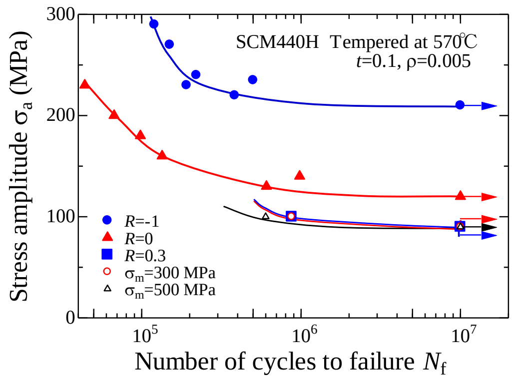
Fatigue fracture below fatigue limit

Sharp notch: (ρ = 5μm, *t* = 100μm)



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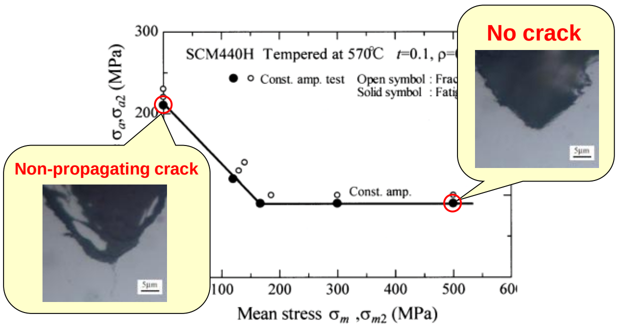
Non-propagating crack in constant amplitude test

Non-propagating crack was not formed at high mean stress under const.amp.



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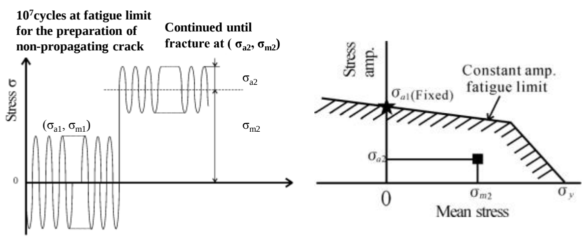
Two-step loading below fatigue limit



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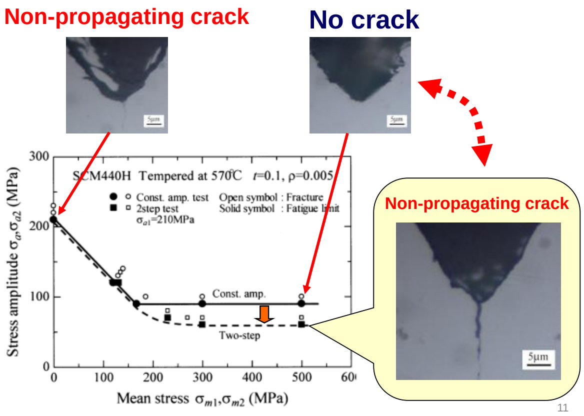
Difference between const. amp. and two-step loading



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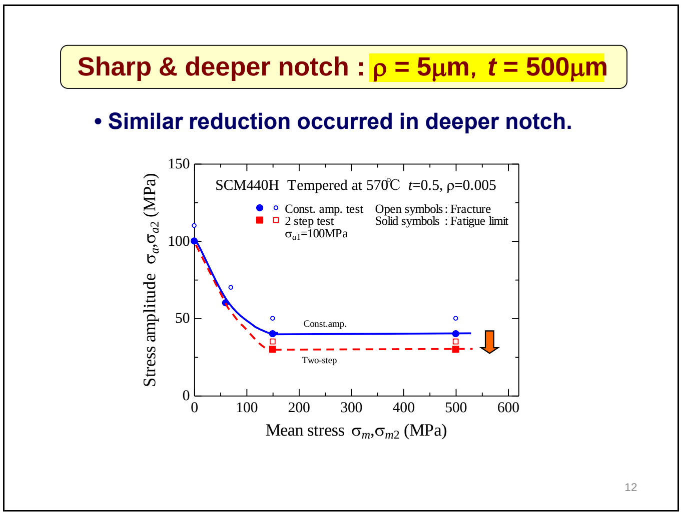
Sharp & deeper notch : ρ = 5μm, t = 500μm
• Similar reduction occurred in deeper notch.
SCM440H Tempered at 570℃ t=0.5, ρ=0.005
Const. amp. test
2 step test
Open symbols : Fracture
Solid symbols : Fatigue limit
Const.amp.
Two-step
Stress amplitude σa,σa2 (MPa)
Mean stress σm,σm2 (MPa)
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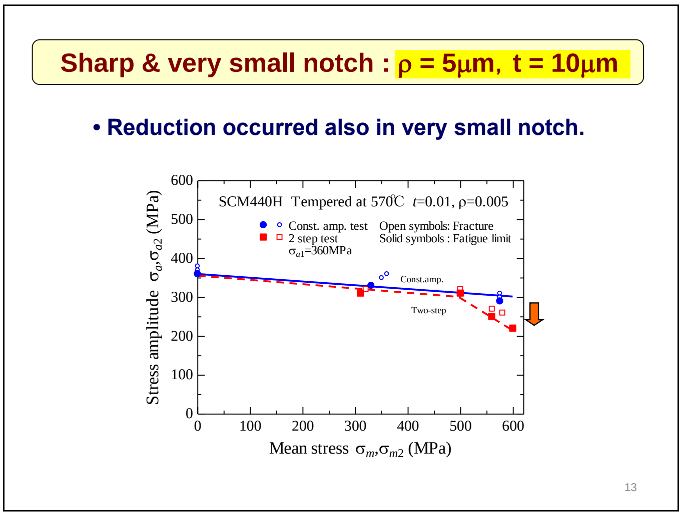
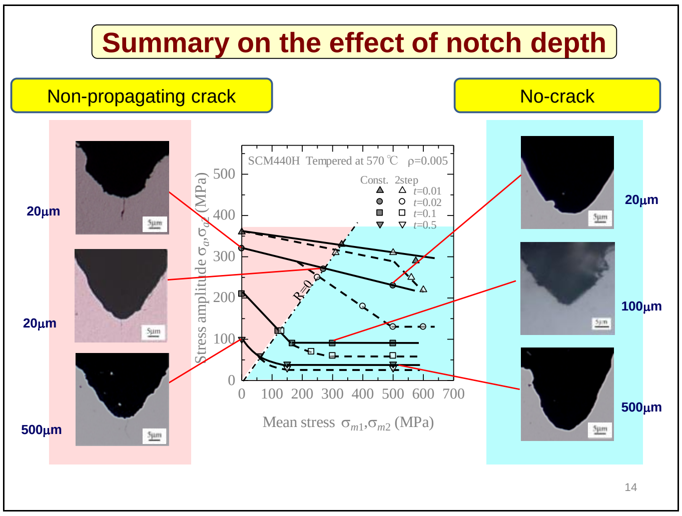

Sharp & very small notch : ρ = 5μm, t = 10μm
• Reduction occurred also in very small notch.
SCM440H Tempered at 570℃ t=0.01, ρ=0.005
Const. amp. test
2 step test
Open symbols: Fracture
Solid symbols : Fatigue limit
Const.amp.
Two-step
Stress amplitude σa,σa2 (MPa)
Mean stress σm,σm2 (MPa)
13


Summary on the effect of notch depth
Non-propagating crack
No-crack
20μm
20μm
500μm
20μm
100μm
500μm
SCM440H Tempered at 570 ℃ ρ=0.005
Const. 2step
t=0.01
t=0.02
t=0.1
t=0.5
Stress amplitude σa,σa2 (MPa)
Mean stress σm1,σm2 (MPa)
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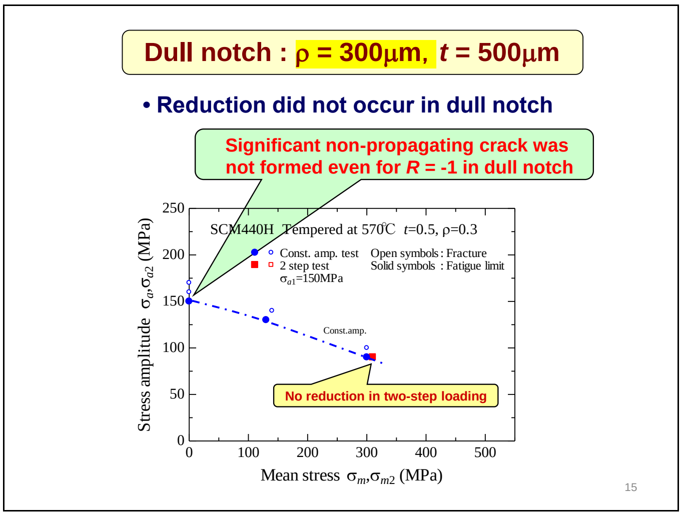
Dull notch : ρ = 300μm, t = 500μm
• Reduction did not occur in dull notch
Significant non-propagating crack was not formed even for R = -1 in dull notch
SCM440H Tempered at 570℃ t=0.5, ρ=0.3
Const. amp. test
2 step test
Open symbols : Fracture
Solid symbols : Fatigue limit
Const.amp.
No reduction in two-step loading
Stress amplitude σa,σa2 (MPa)
Mean stress σm,σm2 (MPa)
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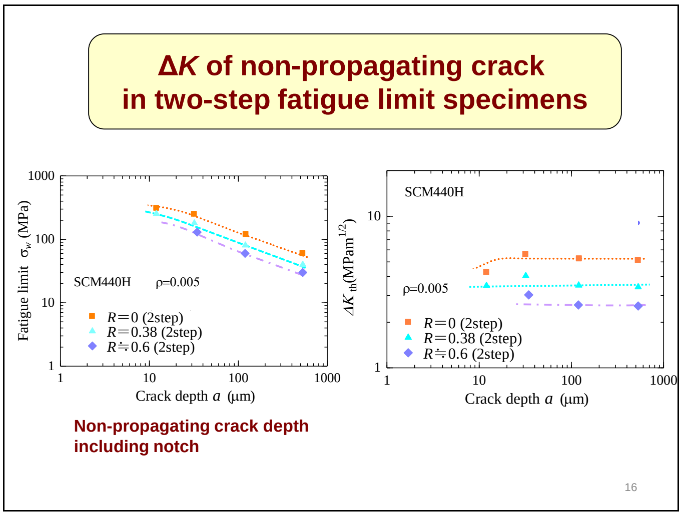
ΔK of non-propagating crack
in two-step fatigue limit specimens
SCM440H ρ=0.005
R=0 (2step)
R=0.38 (2step)
R≒0.6 (2step)
Fatigue limit σw (MPa)
Crack depth a (μm)
ΔKth(MPam1/2)
Non-propagating crack depth including notch
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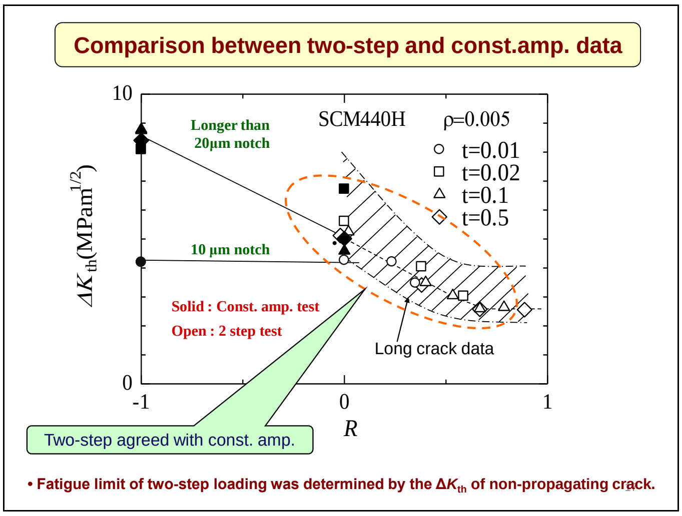
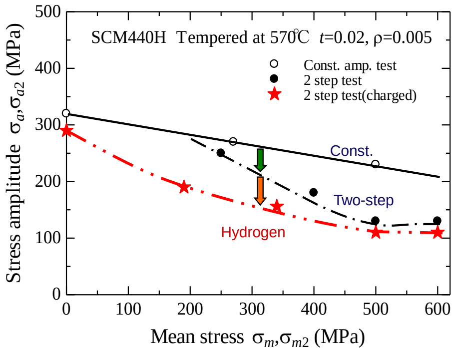

Comparison between two-step and const.amp. data
SCM440H ρ=0.005
t=0.01
t=0.02
t=0.1
t=0.5
Longer than 20μm notch
10 μm notch
Solid : Const. amp. test
Open : 2 step test
Long crack data
ΔKth(MPam1/2)
R
Two-step agreed with const. amp.
• Fatigue limit of two-step loading was determined by the ΔKth of non-propagating crack.

Effect of absorbed hydrogen on fatigue limit

• **Another reduction was caused by absorbed hydrogen.**



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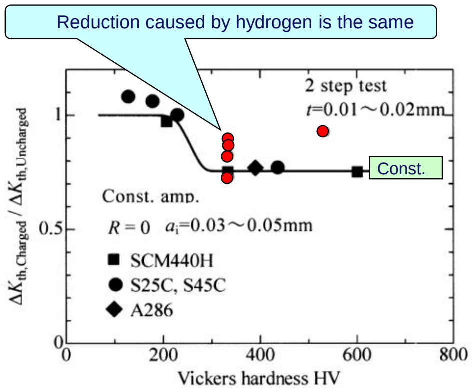
Comparison between const. amp. and two-step loading



Conclusion

Fatigue fracture below fatigue limit was examined using two-step loading pattern.

(1) Fatigue fracture below fatigue limit occurred even in 10μm deep notch.

(2) In two-step load, a non-propagating crack is formed by the first step stress (R=-1). Thus-formed crack functioned as a pre-crack for the second step stress with high mean stress. It propagated under stresses well below fatigue limit.

(3) Fatigue fracture below fatigue limit was triggered when the ΔK of non-propagating crack for the second step stress exceeded the ΔK_{th} of constant amplitude.

(4) Absorbed hydrogen caused additional reduction of fatigue limit in two-step loading.

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