Lecture 18

New Trends in Research

New Research is Featured in Journals

1. Engineering Fracture Mechanics, Elsevier
2. Fatigue and Fracture of Engineering Materials and Structures, John Wiley & Sons, Inc
3. International Journal of Fracture, Kluwer Academic Publishers
4. International Journal of Fatigue and Fracture of Engineering Materials and Structures, Blackwell
5. International Journal of Fatigue, Elsevier
6. Journal of Testing and Evaluation, ASTM

Topics in Journals

- Topics are too varied to put into categories
- Papers are contributed worldwide but recently many from Asia leads (China, India, Japan, Korea)
- Many papers are rejected, most require revision

New research is found on conferences and Symposia; Examples

- International Conference on Fracture, ICF
- ASTM National Symposium on Fatigue and Fracture Mechanics
- 15th International ASTM/ESIS Symposium on Fatigue and Fracture Mechanics (40th ASTM National Symposium on Fatigue and Fracture Mechanics)
- Dozens of conferences on various fatigue and fracture topics

International Conference on Fracture

- This conference has been held all over the world in at least 5 continents

- Example; ICF-6 New Delhi (India) 1984

International Conference on Fracture

- The leading conference on fracture mechanics is ICF, International Conference on Fracture
- This was first started in 1965 by Takeo Yokobori. ICF1 in Sendai, Japan in November 1965
- It is held every four years.
- Presently ICF-14 will be held in Rhodes, Greece, June 18-23, 2017

Recent Topics on Fatigue and Fracture

- ICF14 has 68 special topic sessions plus 4 honor or memory sessions
- Topics are too varied to list, look at the webpage for details, http://www.icf14.org/index.php/icf.html
- That many topics in 4 to 5 days means 10 or so simultaneously. This keeps attendance low in many sessions,

A few example topical sessions

- 1. Fatigue and fracture in aggressive environments: mechanisms and risk assessment
- 2. Fracture in material forming,
- 4. Mixed mode fracture,
- 7. Additive manufacturing
- 63. Fracture propagation and arrest of gas pipeline
- 67. Multiscale fracture of rock, concrete and aggregates
- 68. Optical techniques and its application to fracture mechanics

Special Section

Creep and Creep Cracking

Creep

- Time dependent deformation process occurring at elevated temperature
- At a constant stress, displacement occurs as a function of time
- At a constant displacement, stress relaxes

Creep Deformation CUrve

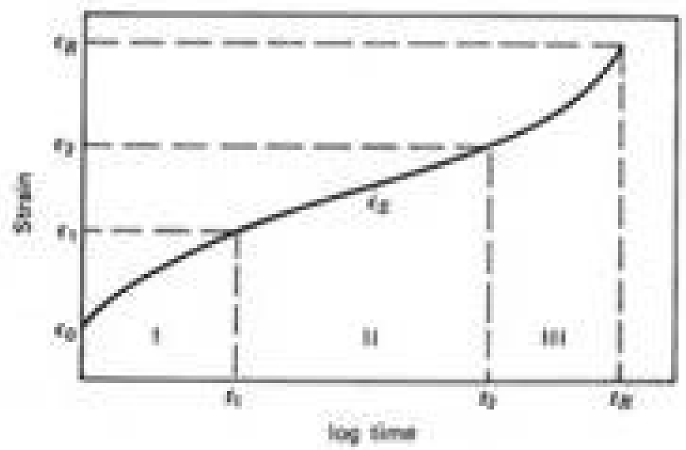


FIGURE 5.1 Typical creep curve showing three regions in strain–time–space.

Stage II or steady state creep

- Under steady state creep, the creep rate is constant at a fixed stress

- The relationship between stress and creep rate gives an analogy to plasticity

Creep Deformation at steady state

- Strain rate is constant under constant stress

- Strain rate relates to stress through a power law relationship

$$\dot{\varepsilon} = C\sigma^n, \quad where\ \dot{\varepsilon}\ is\ \frac{d\varepsilon}{dt}$$

Creep Stress-life

- Creep life, t_f, depends on temperature and stress

- Temperature and time can be combined through a Larson-Miller parameter

$$T(C + \log t_f)$$

T is temperature

C is a constant, often 20 for metals

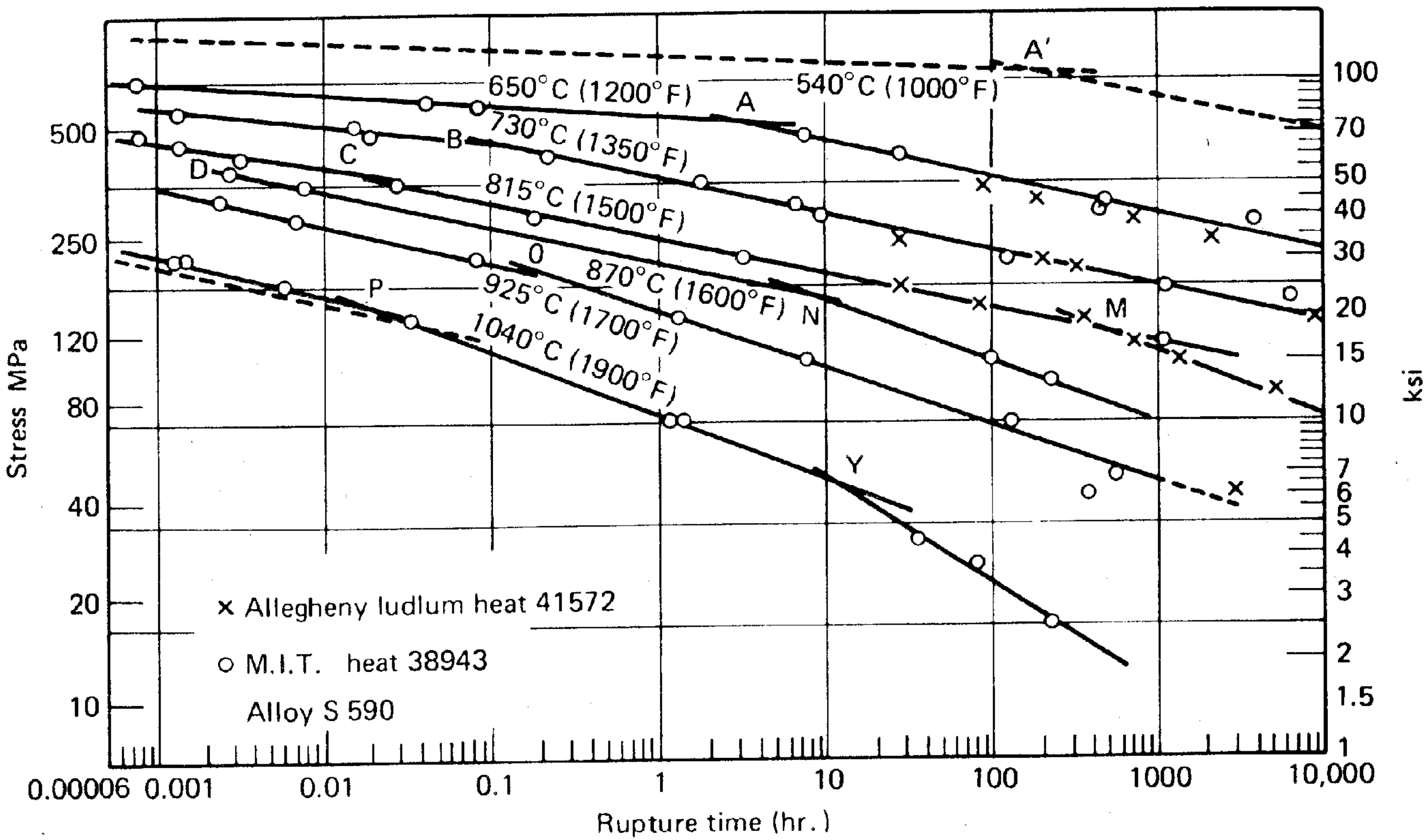


FIGURE 5.3 Stress–rupture life plot at several test temperatures for iron-based alloy

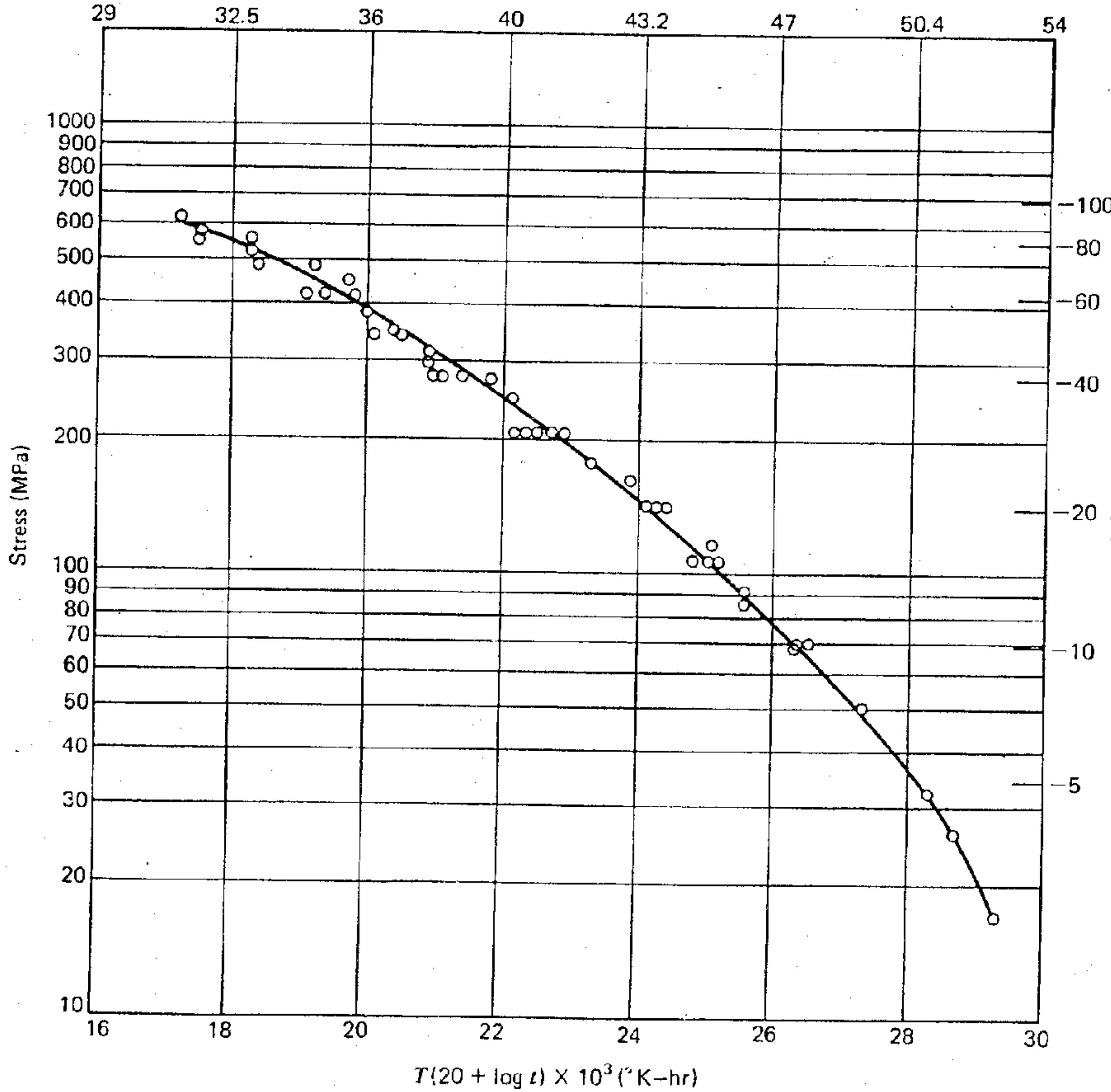


FIGURE 5.25 Larson-Miller plot showing S-590 iron-based alloy data presented in Fig. 5.3.

Creep Cracking

- Slow, stable crack extension under constant load, or increasing displacement and elevated temperature

- Creep cracking has an analogy to plasticity in steady-state, through the power law stress strain-rate relationship

Creep Cracking

1. C^* parameter

$$C^* = \int_\Gamma \left[W^*\, dy - T_i \frac{\partial \dot{u}_i}{\partial x}\, ds\right]$$

$$W = \int_0^{\dot{\varepsilon}} \sigma\, d\dot{\varepsilon}, \qquad \dot{u} = \frac{\partial u}{\partial t}$$

2. C_t parameter

$$C_t = -\frac{1}{B} \frac{\partial U^*}{\partial a}$$

Determining C*

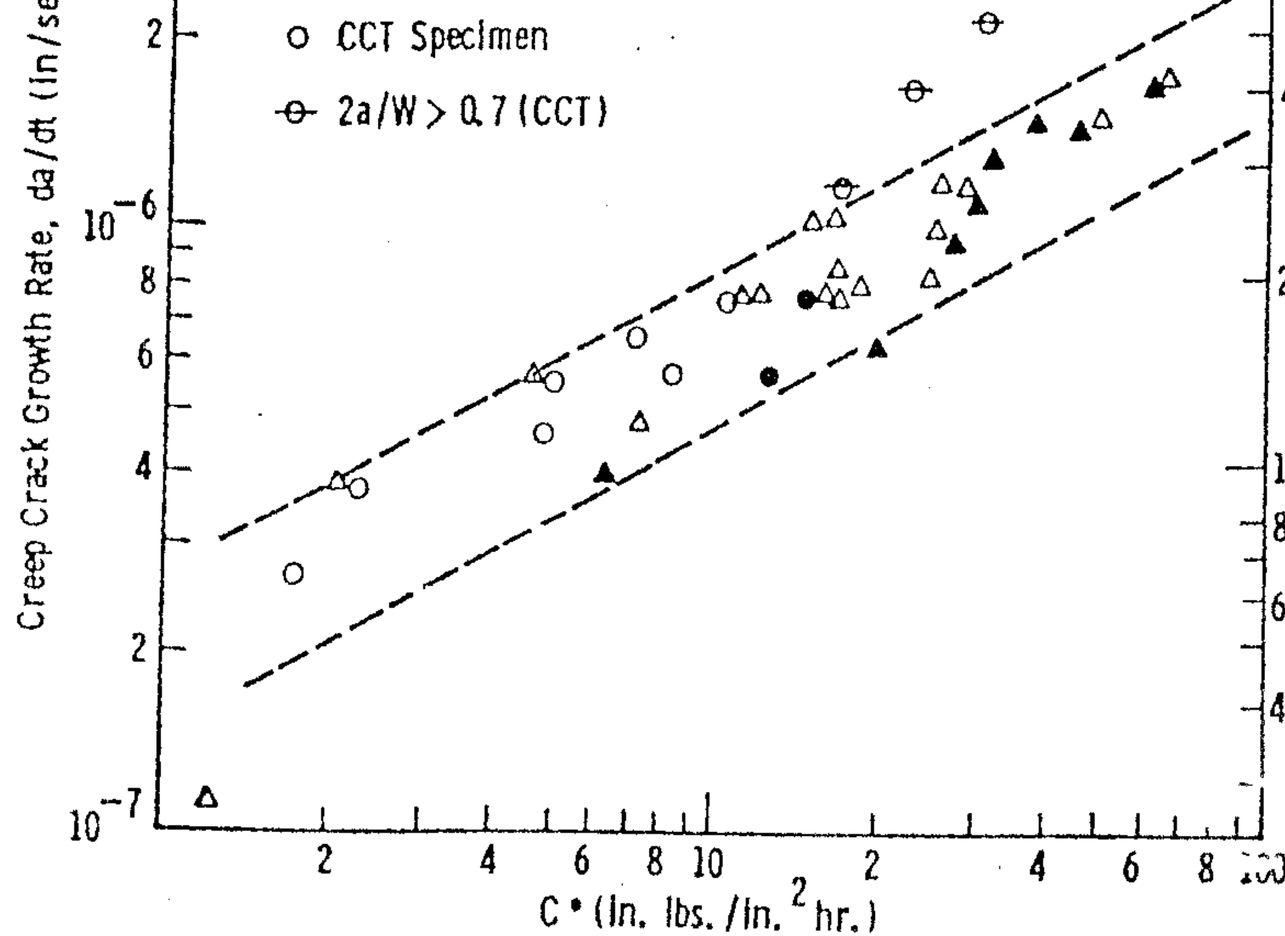
1. Since C* is the time dependent version of J, the EPRI Handbook can be used

2. The input parameters from the stress-strain law are substituted with the creep deformation law parameters

$$\dot{\varepsilon} = A\,\sigma^n$$

3. Then

$$C^* = A\,b\,h_1\left[\frac{P}{\Omega\,\eta\,Bb}\right]^{n+1}$$



Curve 714859-A

Fig. 161 — Creep crack growth rate of 304SS at 594°C (1100°F) as a function of C* for two specimen geometries.

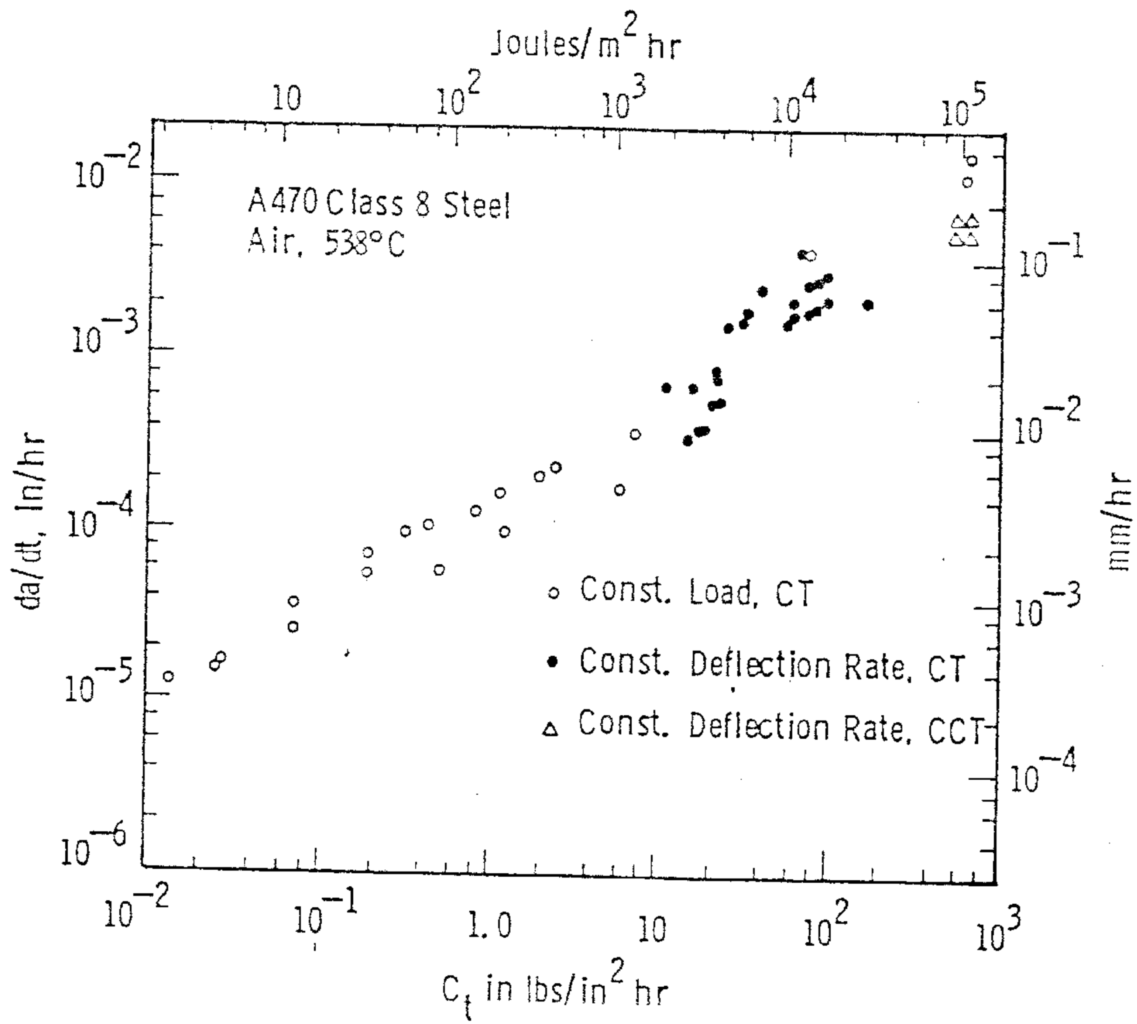


Fig. 5—Creep crack growth rate behavior of A470 class 8 steel at 538°C in air

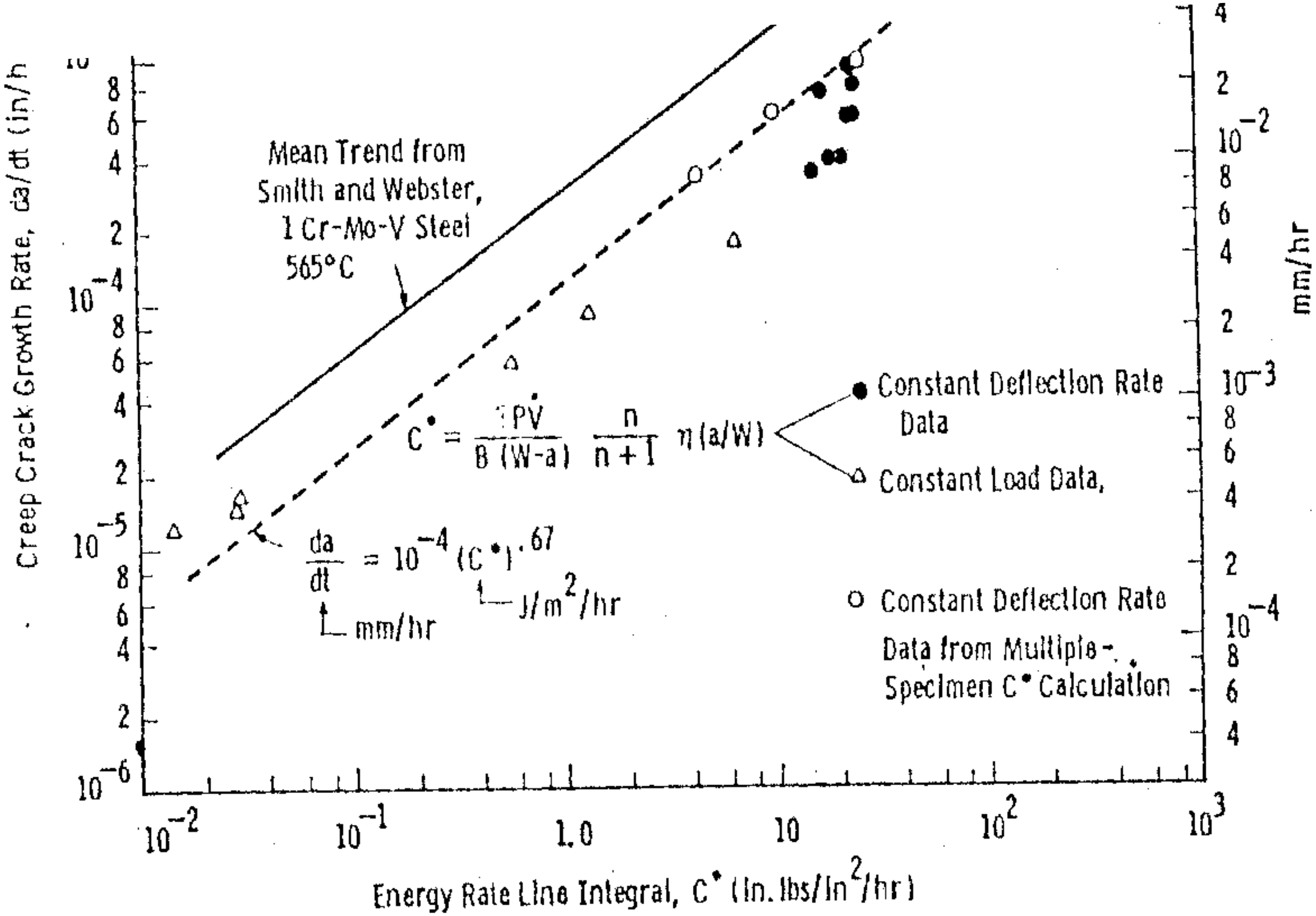
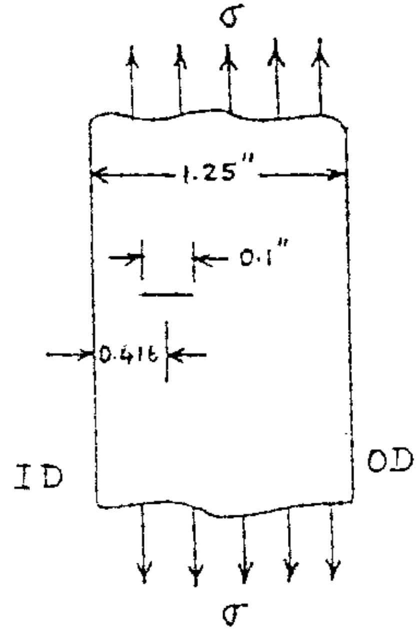


Fig. 162 - Creep growth rate as a function of C* for A470 Class 8 steel

Curve 73138.

Example creep cracking life problem

- A crack exists in the wall of a pipe
- The pipe has two ends
  - A hot end has creep damage
  - A cold end has no creep damage
- Estimate life



initial flaw size = 0.1"

Hoop stress = $\sigma = pr/t$

p = pressure = 600 psi

r = radius of the pipe = 15"

t = wall thickness = 1.25"

σ = 7.2 ksi

Operating temperature = 1000 F, Material : 1.25 Cr - 0.5 Mo Steel

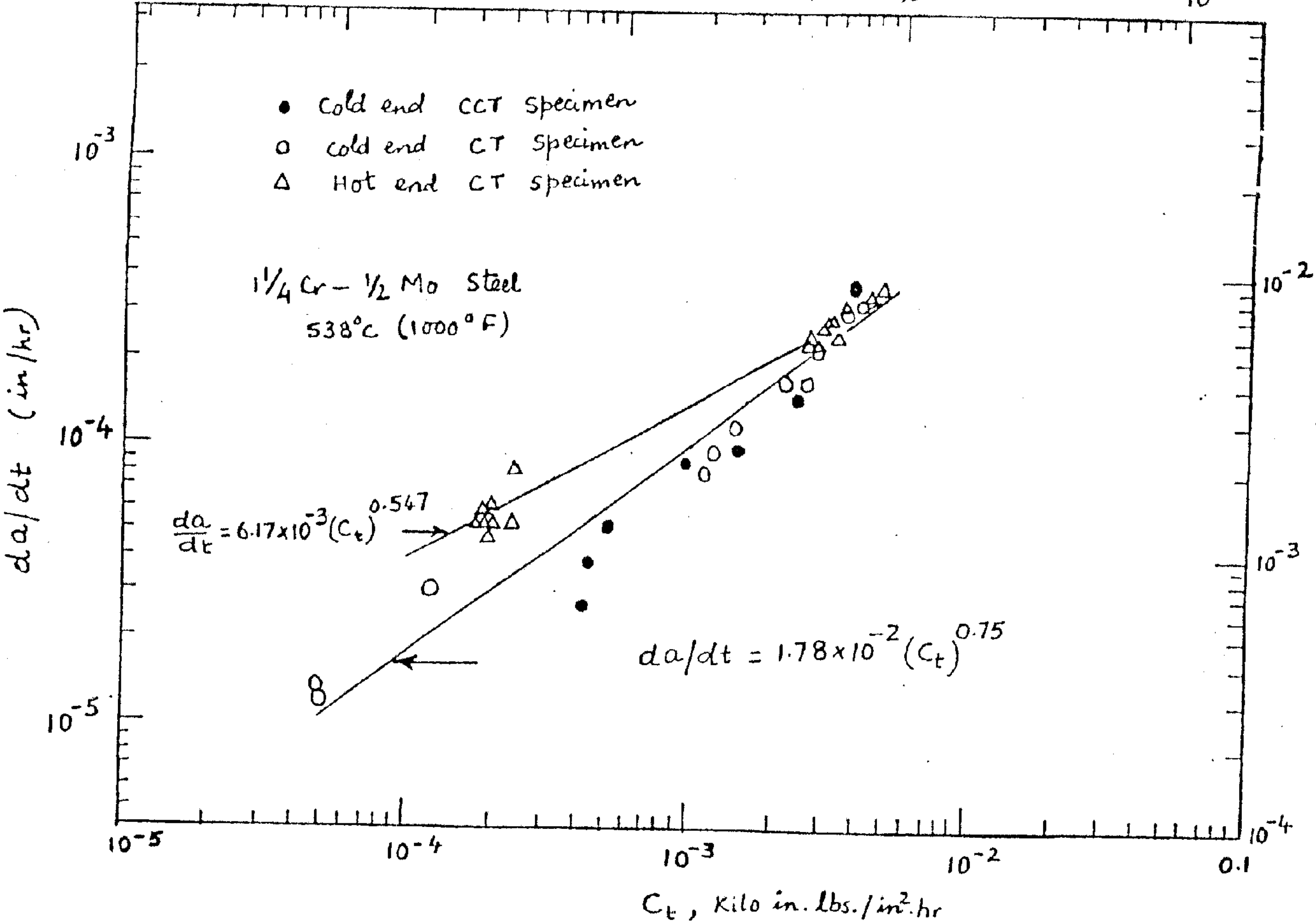
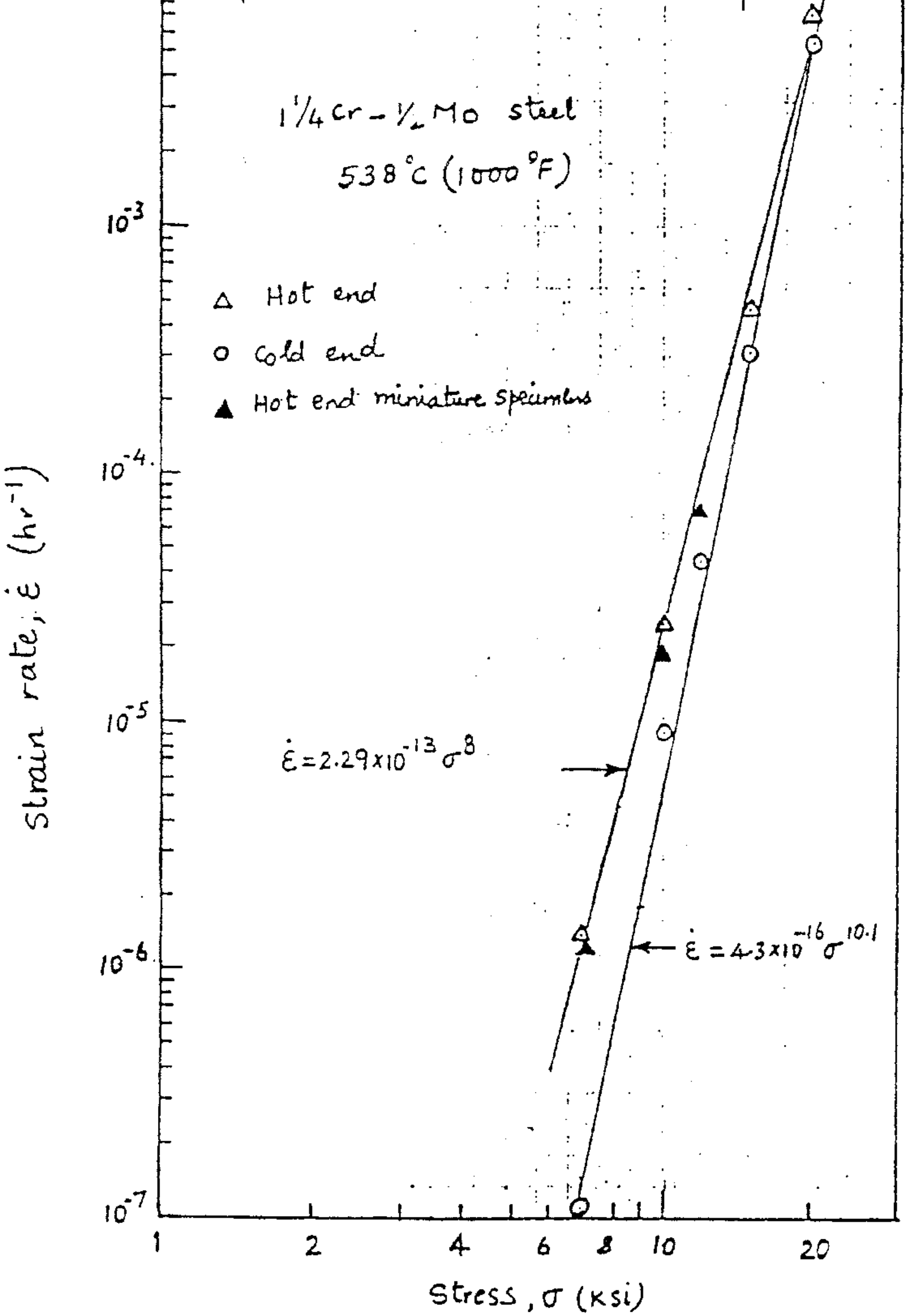


Fig. 1 – Creep crack growth behavior of a 1.25 Cr – 0.5 Mo steel at 1000 F



1¼ Cr - ½ Mo steel
538°C (1000°F)
△ Hot end
○ Cold end
▲ Hot end miniature specimens
$\dot{\varepsilon} = 2.29 \times 10^{-13} \sigma^{8}$
$\dot{\varepsilon} = 4.3 \times 10^{-16} \sigma^{10.1}$
Strain rate, $\dot{\varepsilon}$ (hr^{-1})
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
1
2
4
6
8
10
20
Stress, σ (ksi)

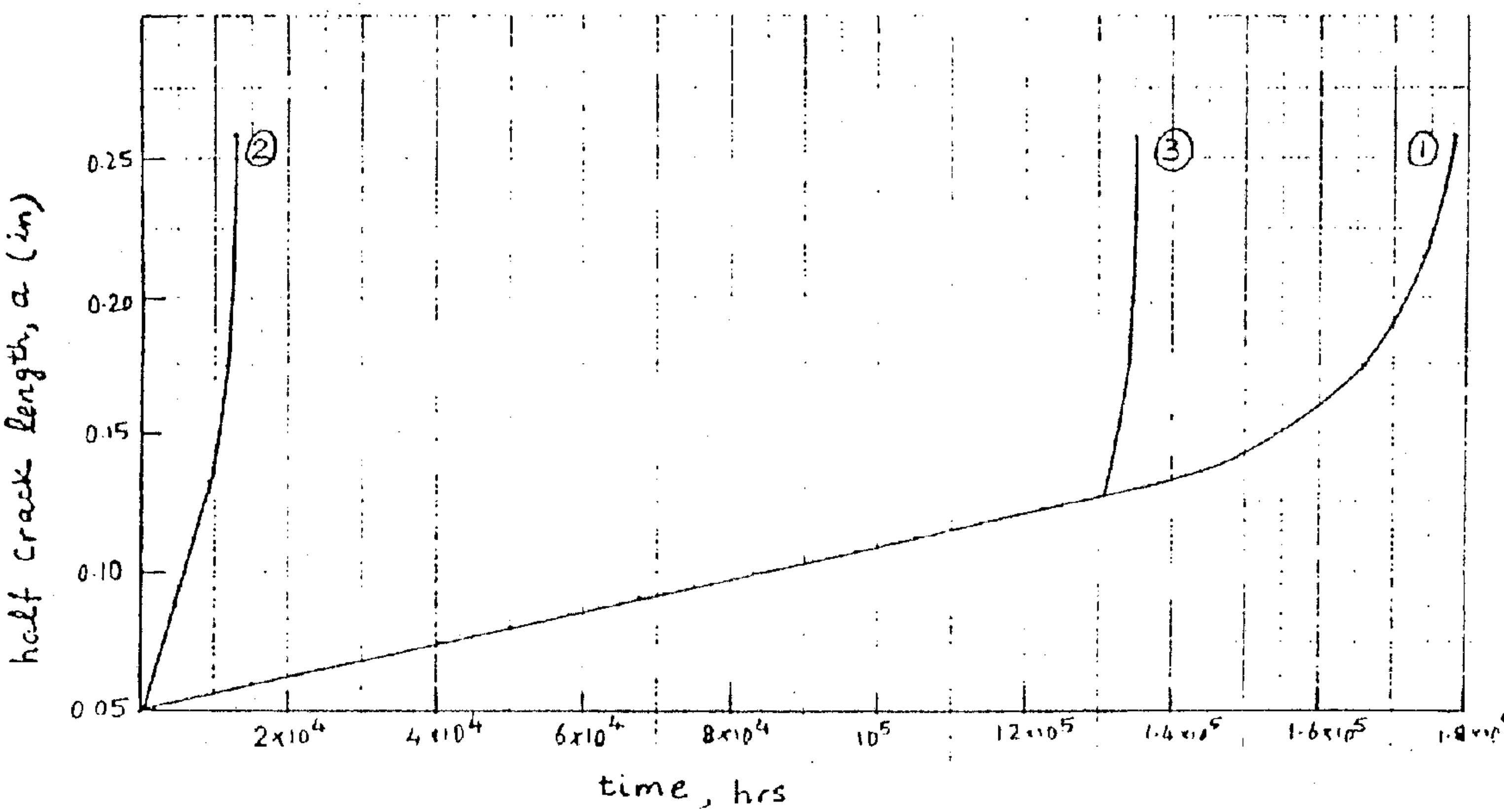


Fig. 4 - Predicted crack length as a function of time for the steam pipe. Curve 1 is based on cold end ex - service header properties, curve 2 is based on hot end ex - service header properties, and curve 3 is based on cold end properties for the first fifteen years of service and hot end properties thereafter.

Creep Crack Growth Standard

- **ASTM E1457 - 07e1 Standard Test Method for Measurement of Creep Crack Growth Times in Metals**

Creep-Fatigue Standard

- **ASTM 2714-13 - Standard Test Method for Creep-Fatigue**

This is the latest creep standard