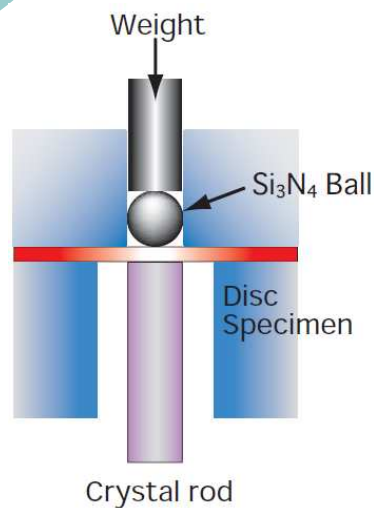


2010.8.31

1st Int. Conf. SSTT in Ostrava

Standardization of Test Method for Small Punch Creep Testing in Japan



WG Chairman: I. Nonaka (Tohoku Univ.)

WG Vice-chairman: A. Kanaya (Kyushu Elect. Pow. Co.)

WG Vice-chairman: S. Komazaki (Kagoshima. Univ.)

WG Vice-chairman: K. Kobayashi (Chiba Univ.)



Contents

1. Introduction

- * *Background*
- * *WG activity*

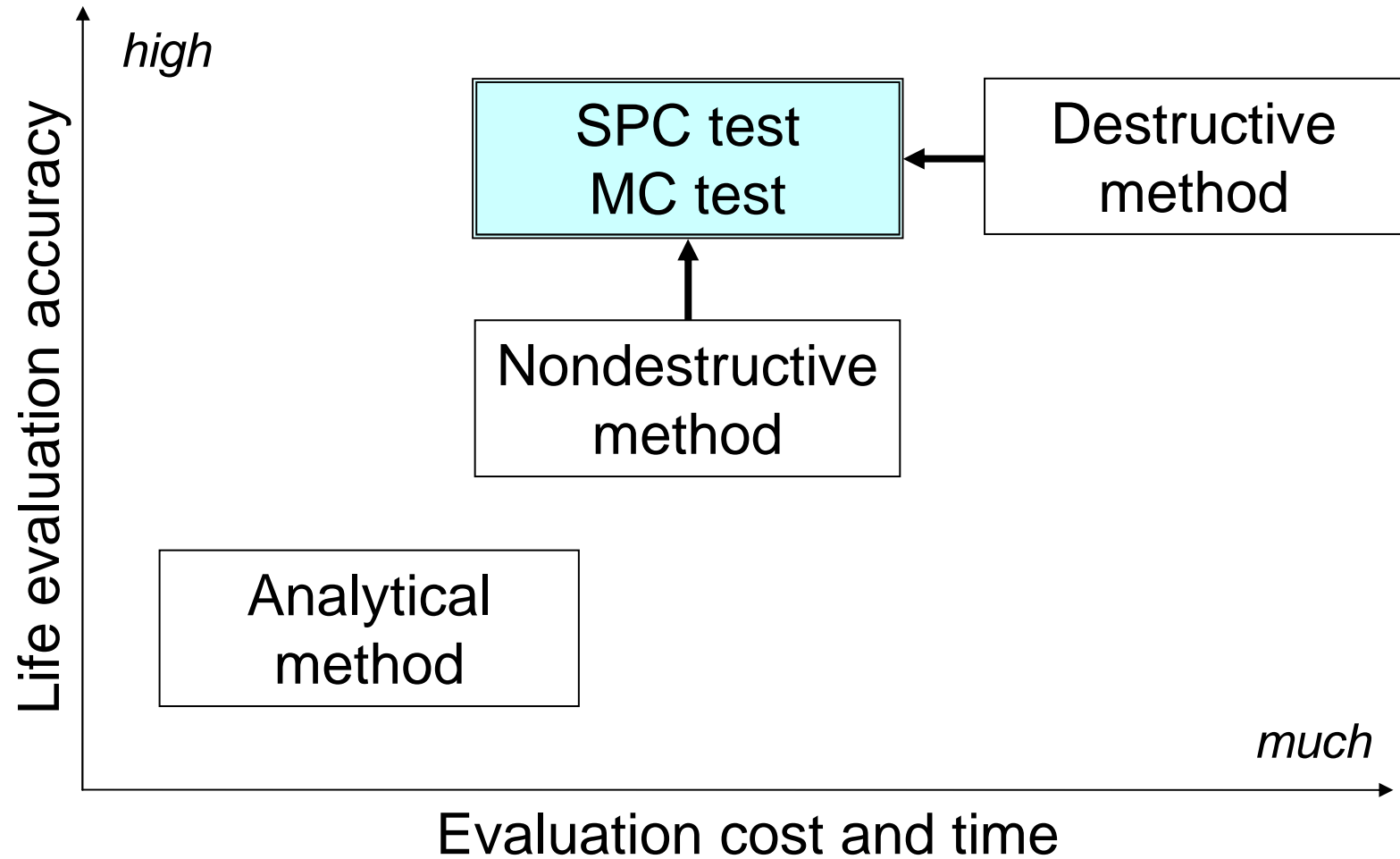
2. SPC Round-robin Test Results

- * *Test contents*
- * *Life dispersion test*
- * *Load/stress ratio test*
- * *Effect of ball diameter on rupture life*
- * *Deformation process test*

3. Outline of Test Standard Draft

1. Introduction

Residual life evaluation procedures



1. Introduction

WG participating organization

Academic organization 8	University 6
	Research institute 2
Industrial organization 13	Electric power co. 5
	Gas co. 1
	Fabricator 2
	Steel co. 1
	Test contractor 3
	Testing machine co. 1

2. SPC Round-robin Test Results

Test contents

Material: 2.25Cr-1Mo steel

Specimen diameter: 10mm, Specimen thickness: 0.5 ± 0.005 mm,

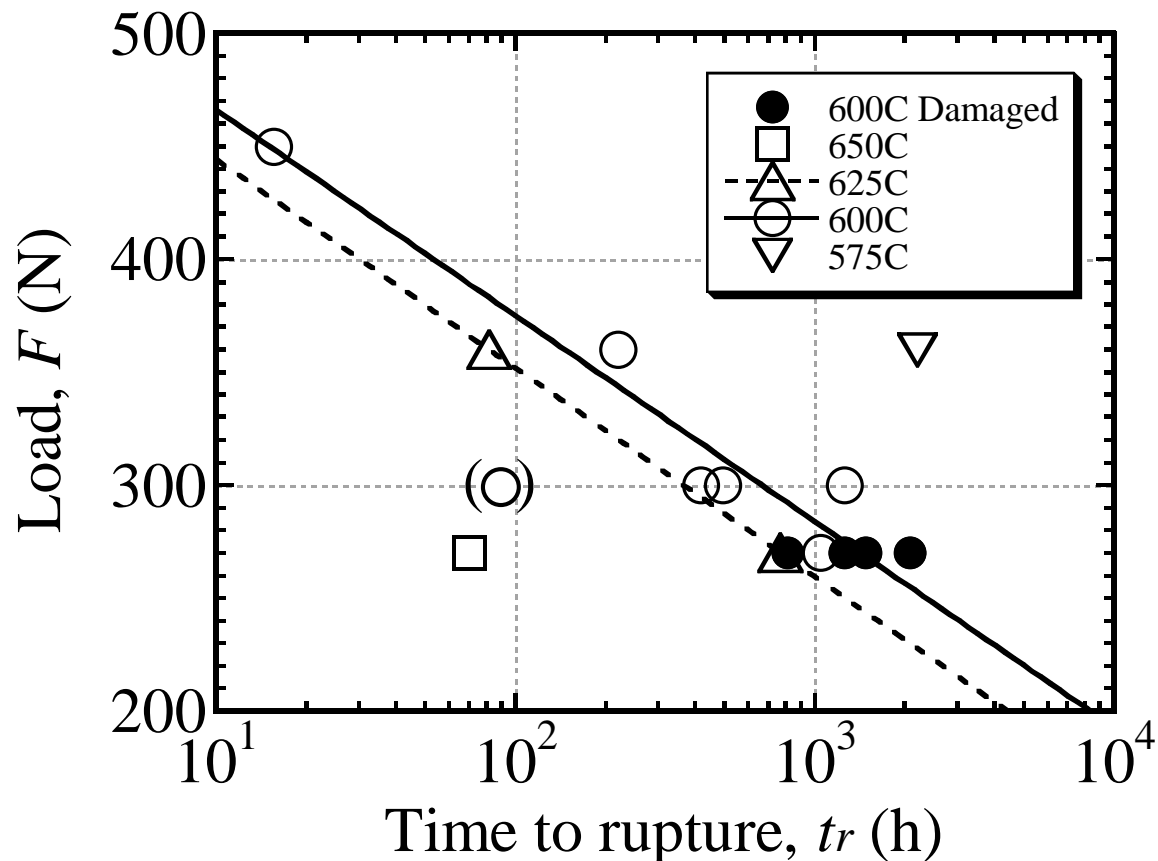
Ball diameter: 2.4mm(four organization), 2.0mm(one organization)

Die diameter: 4mm

Test name	Load(N)	Temp. (C)	Test No.
Life dispersion 1	270	600	1,4,5,7
Load/stress ratio	450	650,625	8-14
	360	600,575	
	270	550	
Deformation process	0-Failure	RT	18
Life dispersion 2	300	600	23-26

2. SPC Round-robin Test Results

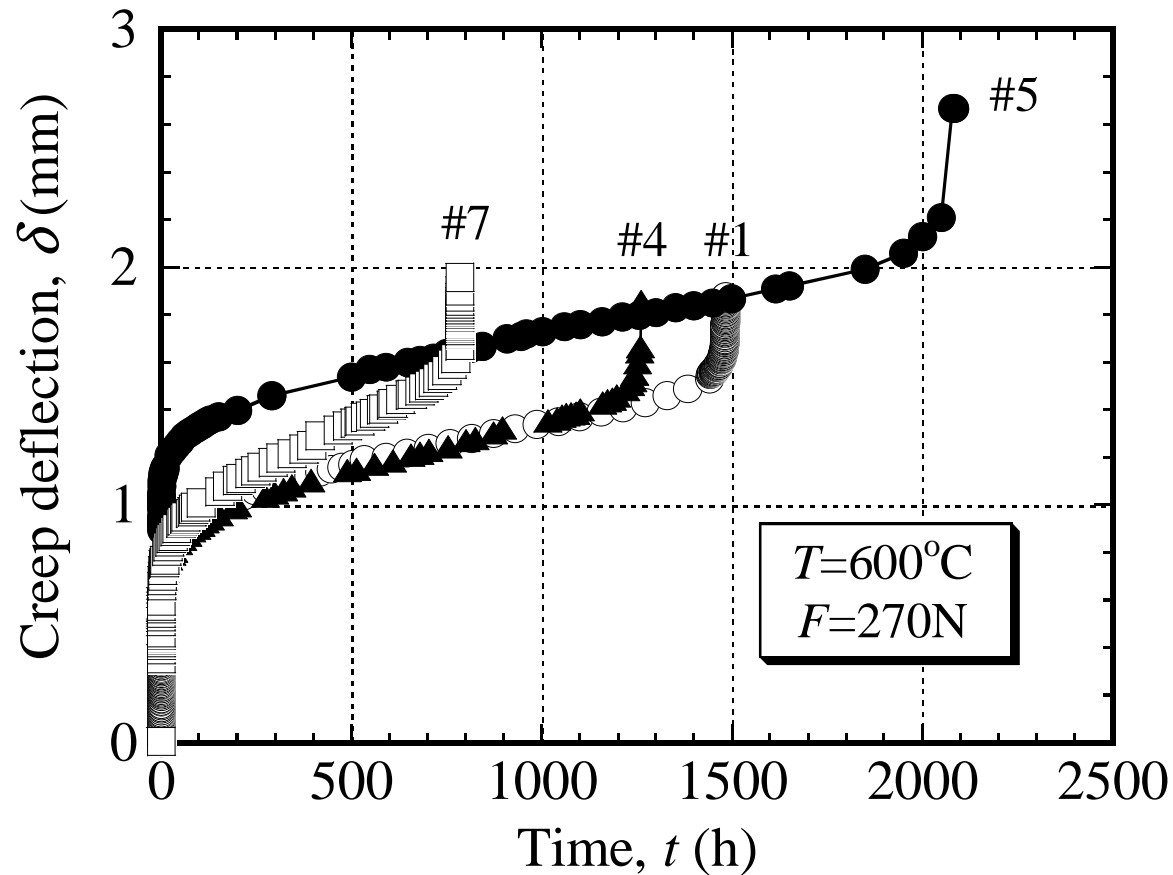
Life dispersion test



Relation between load and time to rupture in all tests.

2. SPC Round-robin Test Results

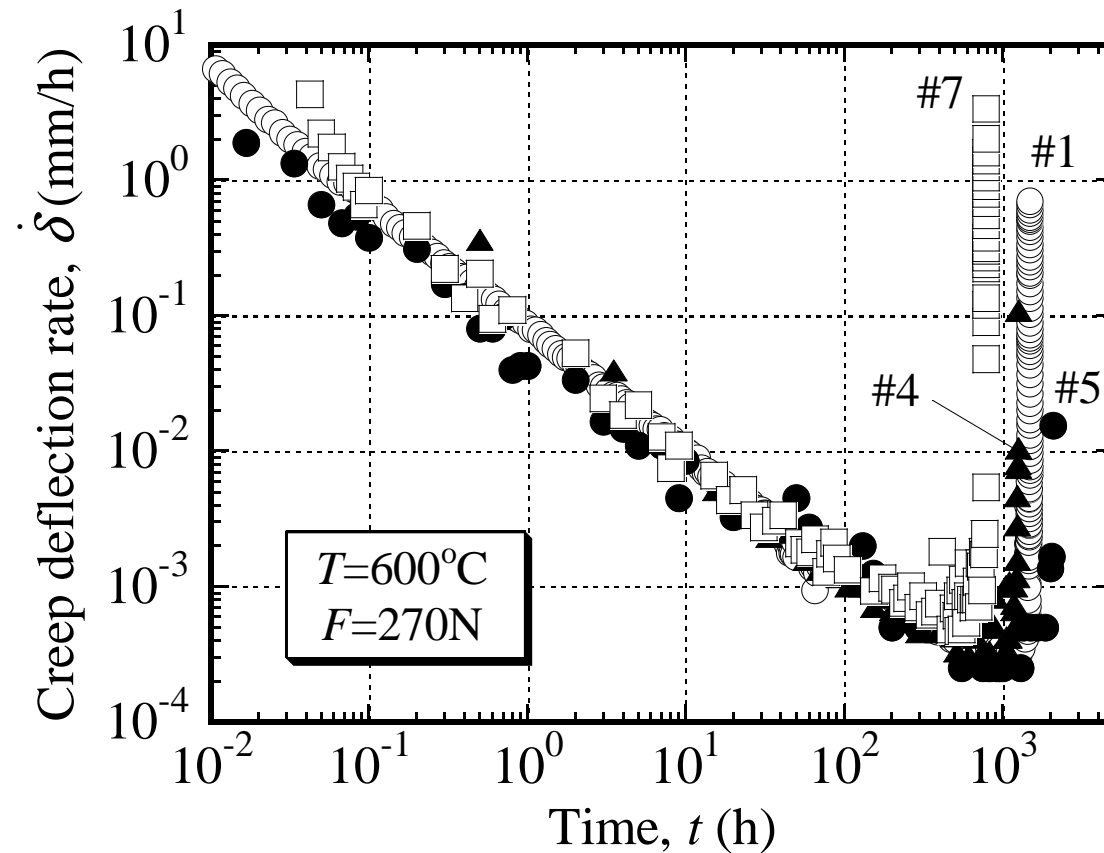
Life dispersion test



Creep deflection curves in the life dispersion test 1.

2. SPC Round-robin Test Results

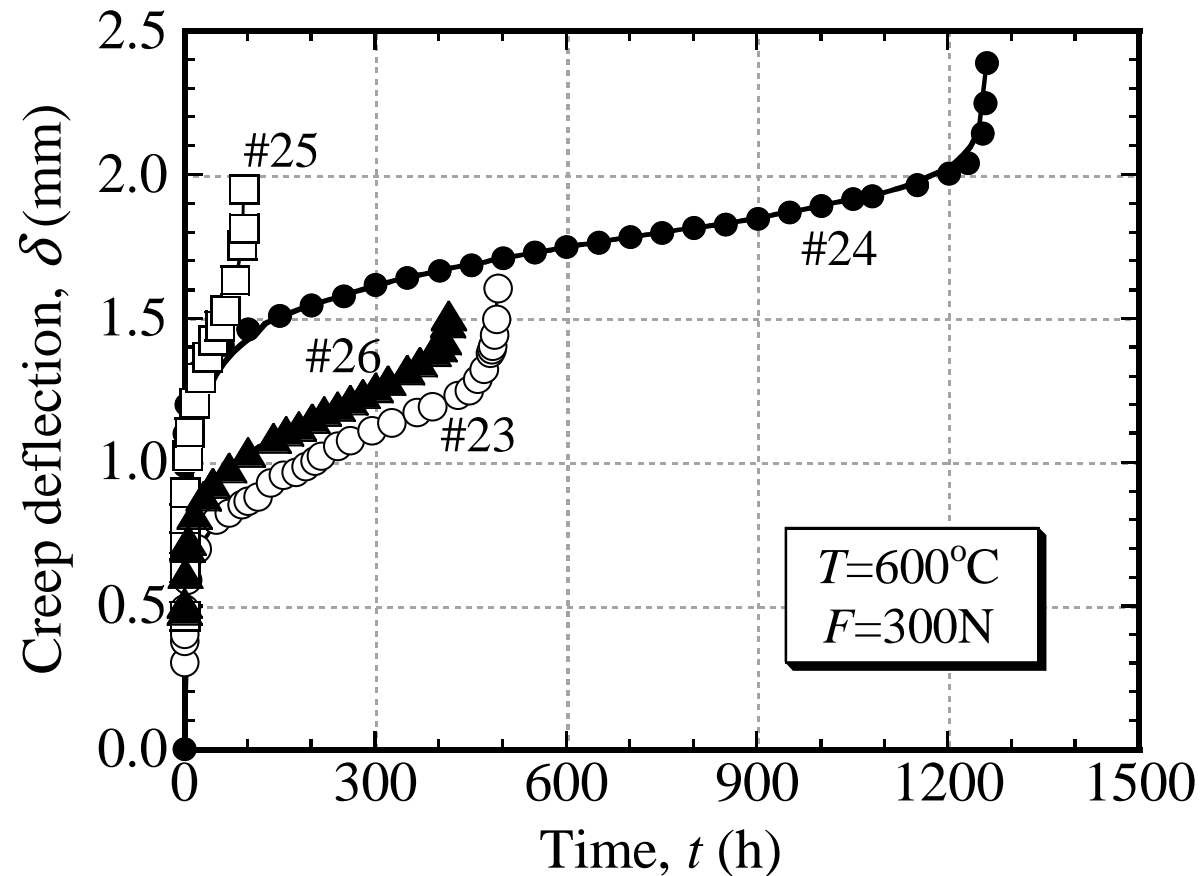
Life dispersion test



Relation between creep deflection rates and time in the life dispersion test 1.

2. SPC Round-robin Test Results

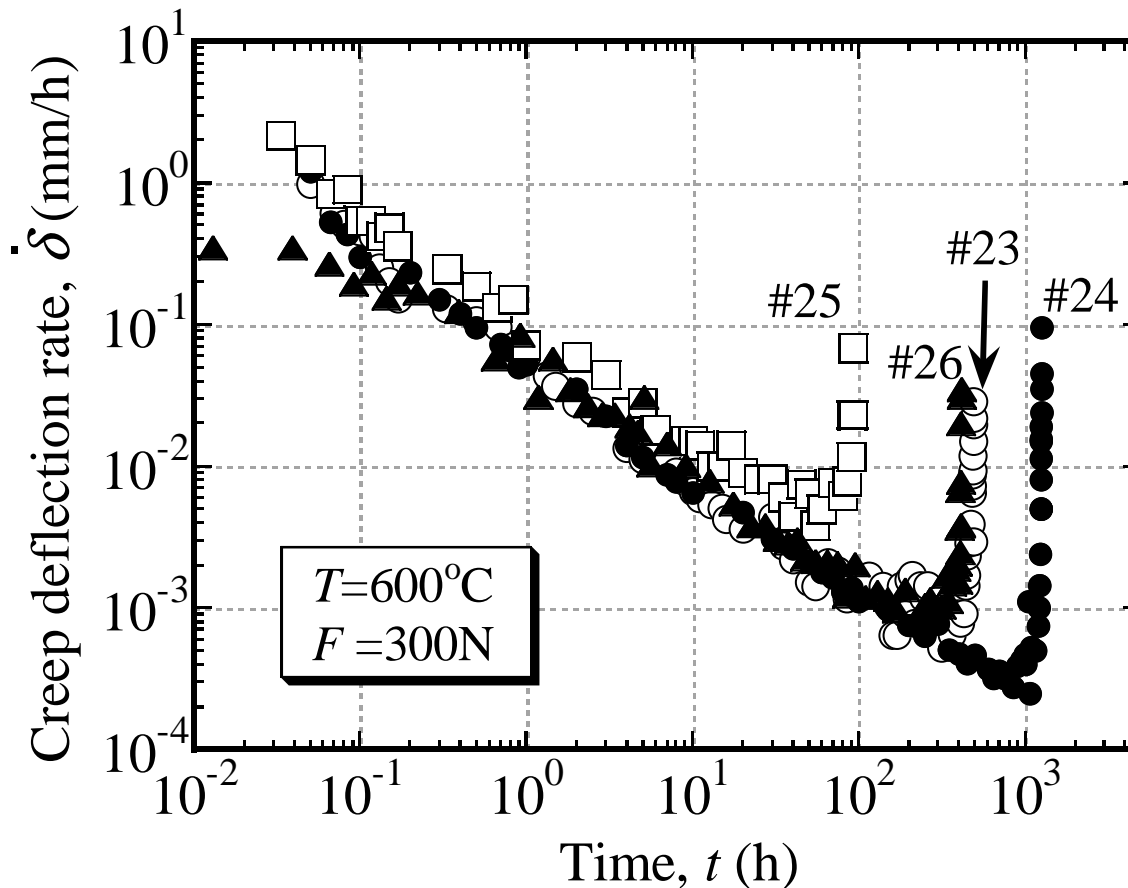
Life dispersion test



Creep deflection curves in the life dispersion test 2.

2. SPC Round-robin Test Results

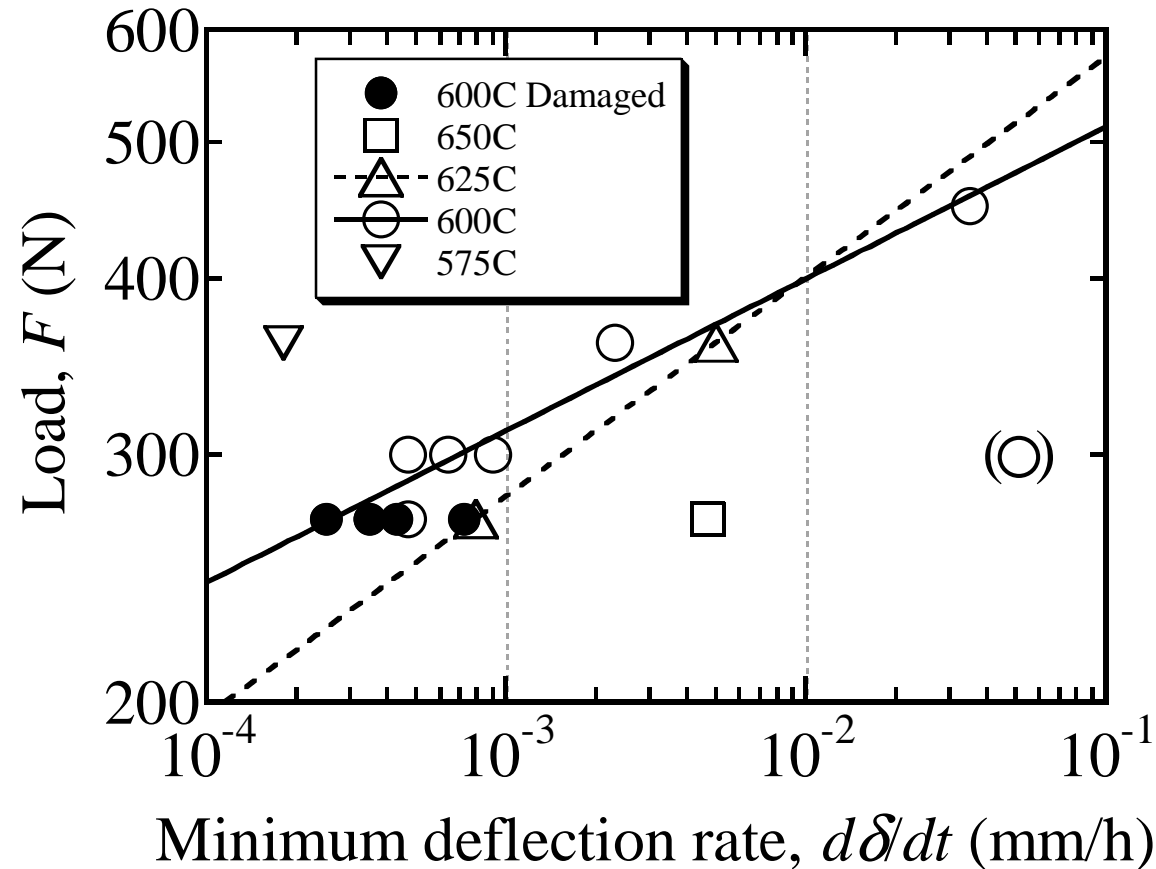
Life dispersion test



Relation between creep deflection rates and time in the life dispersion test 2.

2. SPC Round-robin Test Results

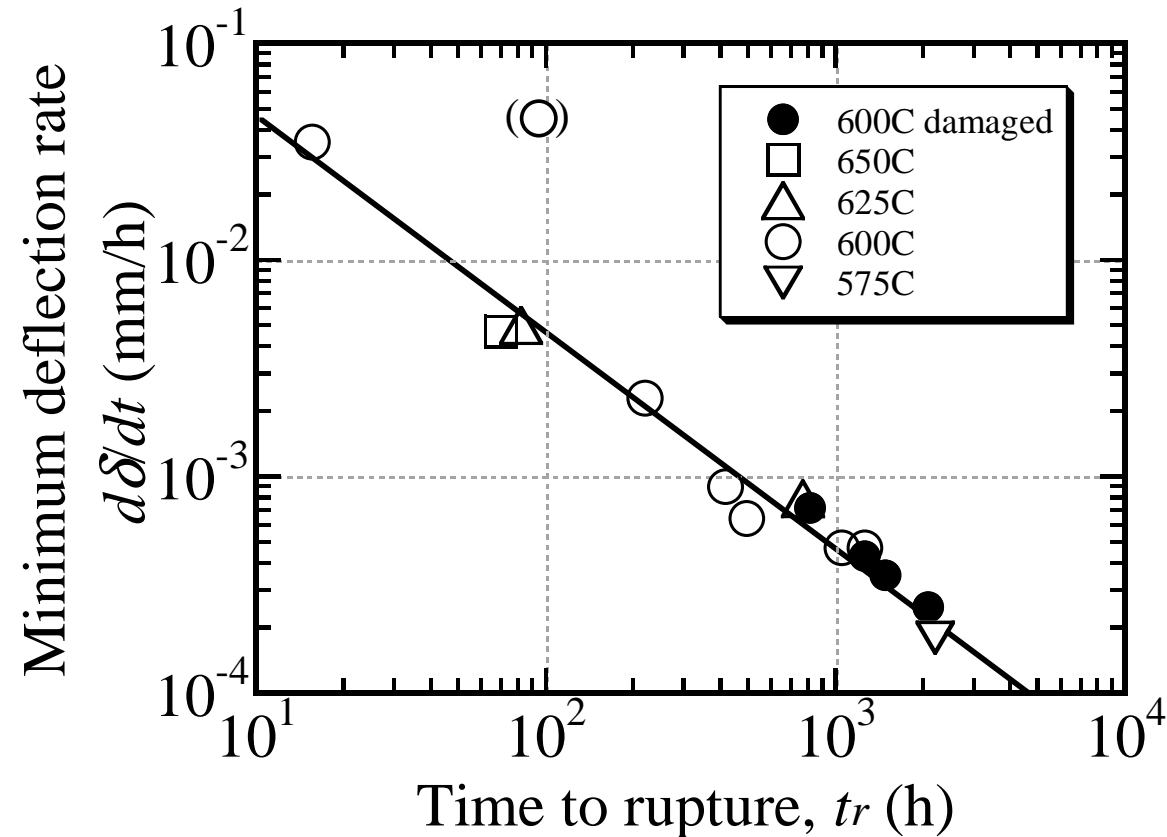
Life dispersion test



Relation between load and minimum deflection rate in all tests.

2. SPC Round-robin Test Results

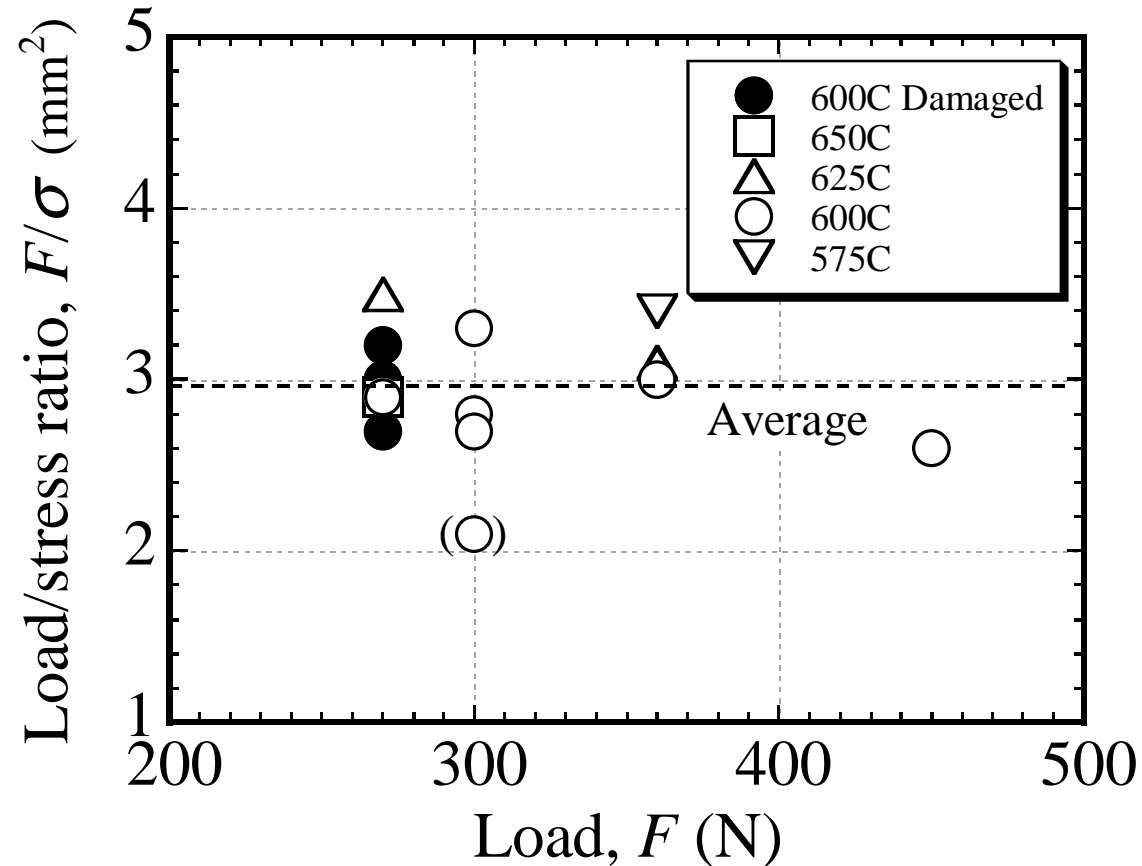
Life dispersion test



Relation between minimum deflection rates and time to rupture in all tests.

2. SPC Round-robin Test Results

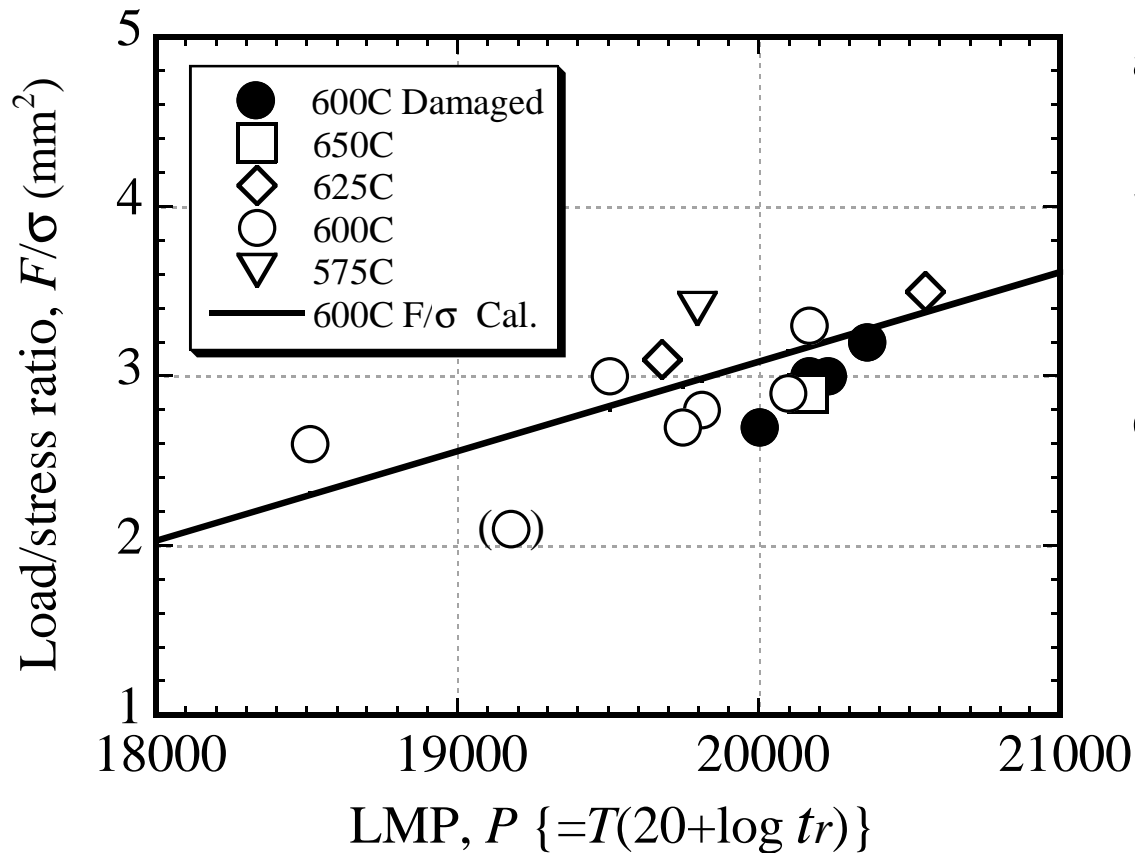
Load/stress ratio test



Relation between load/stress ratio and load in all tests.

2. SPC Round-robin Test Results

Load/stress ratio test



at 600C

SPC

$$F=613.6t_r^{-0.110}$$

Uniaxial creep

$$\sigma=326.5t_r^{-0.184}$$

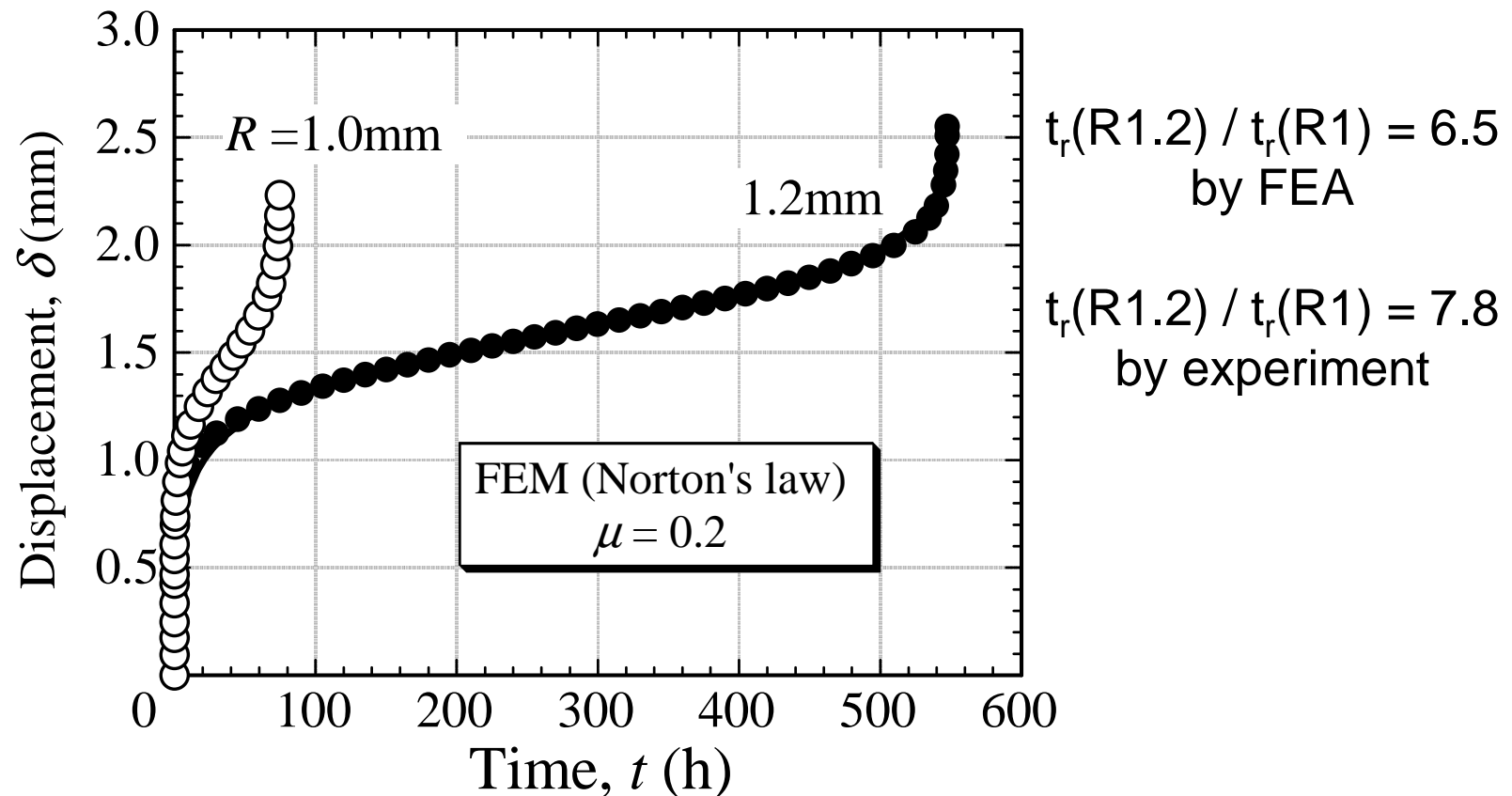


$$F/\sigma=1.88t_r^{0.074}$$

Relation between load/stress ratio and LMP in all tests.

2. SPC Round-robin Test Results

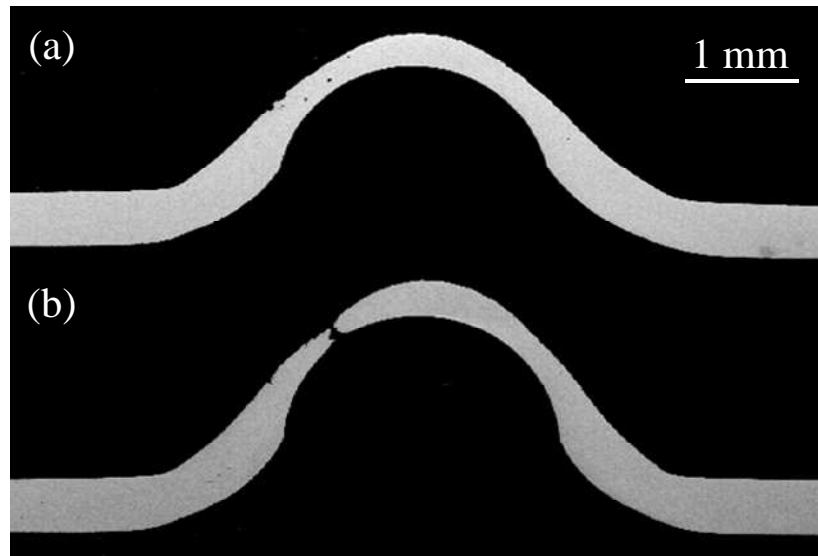
Effect of ball diameter on rupture life



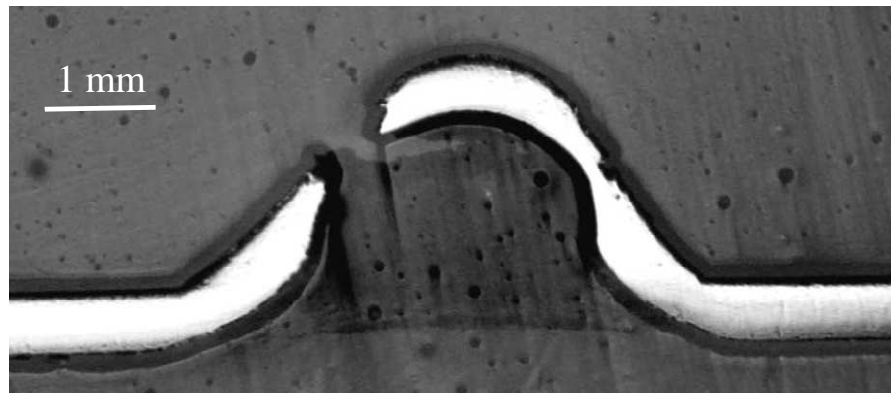
Difference of SPC curve analyzed by FEM when the radius of ball was changed.

2. SPC Round-robin Test Results

Deformation process test



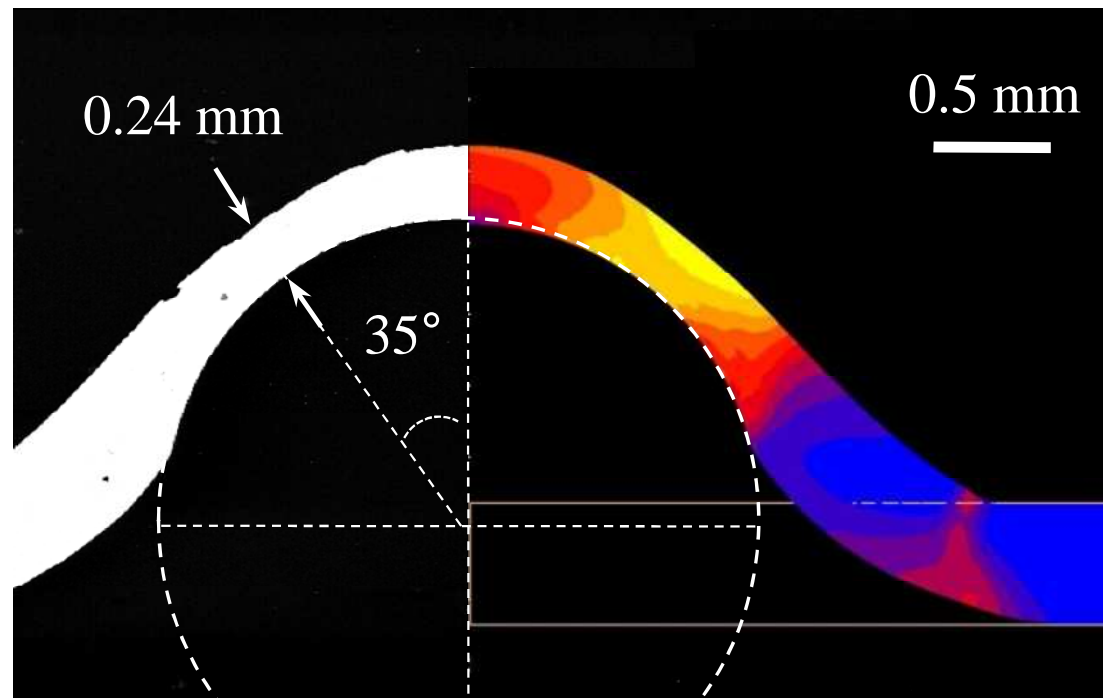
Cross sections of specimens subjected to SP test at room temperature. (a) Interrupted at max. load, (b) Fractured.



Cross section of specimen subjected to SPC test at 575C/360N ($t_r=2203h$).

2. SPC Round-robin Test Results

Deformation process test



Cross section of interrupted specimen and equivalent strain distribution by FEM analysis



3. Outline of Test Standard Draft

Text

1. Introduction

Objective / Outline / Scope / Quoted Standard

2. Definitions

3. Miniature Sample Removal Technologies

4. Test Apparatus

Loading System / Heating System / Test Environment /
Temperature Measurement System / Extensometer

5. Die, Ball and Puncher

Material and Configuration of Die / Material and
Configuration of Ball / Material and Configuration of Puncher

6. Specimen

Configuration and Tolerance / Manufacture Method



3. Outline of Test Standard Draft

Text (continued)

7. Test Procedure

Test Piece Clamping Procedure / Heating Procedure /
Loading Procedure / Temperature Control Procedure /
Environment Control Procedure / Displacement
Measurement Procedure / Test Interruption Procedure

8. Definition of Test Validity

9. Data Recording and Documentation

10. Evaluation Procedure of Test Results

Load to stress conversion procedure / Procedure of
Residual Life Evaluation for Components



3. Outline of Test Standard Draft

Description

1. Miniature Sample Removal Technologies
2. Test Apparatus, Jig and Specimen
3. Effect of Some Factors on Rupture Life
4. Derivation of Load/Stress Conversion Equation
5. Mathematical Relation of Load/Stress Conversion Equation
6. Relation of Load/Stress Ratio to Material Properties
7. Residual Life Evaluation Procedure for Components
8. FEM Analysis Procedure and Results

Appendix

1. Round-robin Test Results in WG
2. World Current Research for SPC Test



*Thank you very much
for your kind attention.*

Results until now

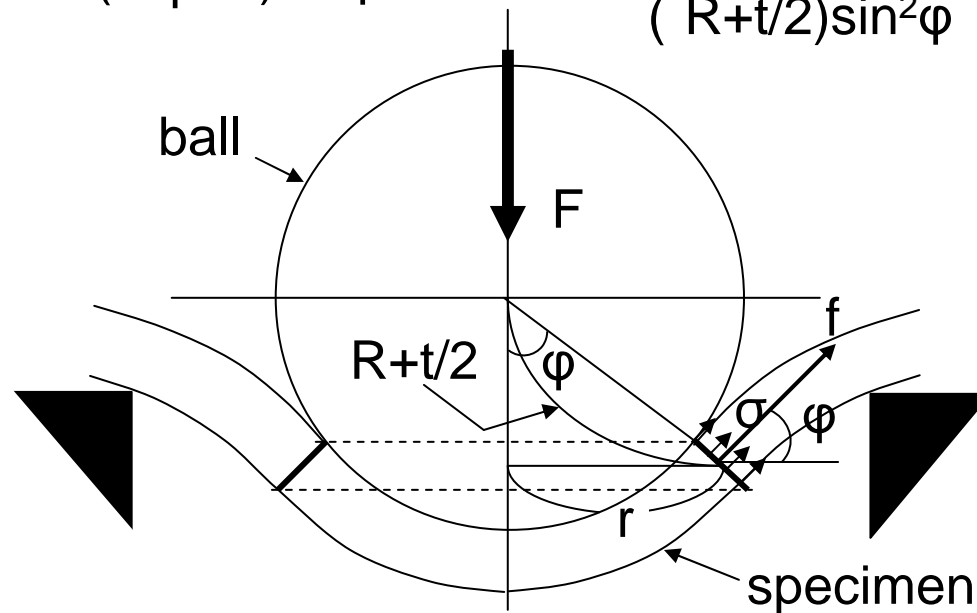
An example of load/stress conversion equation

$$f = 2\pi r t \quad r = (R + t/2) \sin \phi$$

$$f = 2\pi t \sigma$$

$$F = f \sin \phi = 2\pi t \sigma (R + t/2) \sin^2 \phi$$

$$\frac{F}{\sigma} = 2\pi t (R + t/2) \sin^2 \phi$$



F: load σ : stress

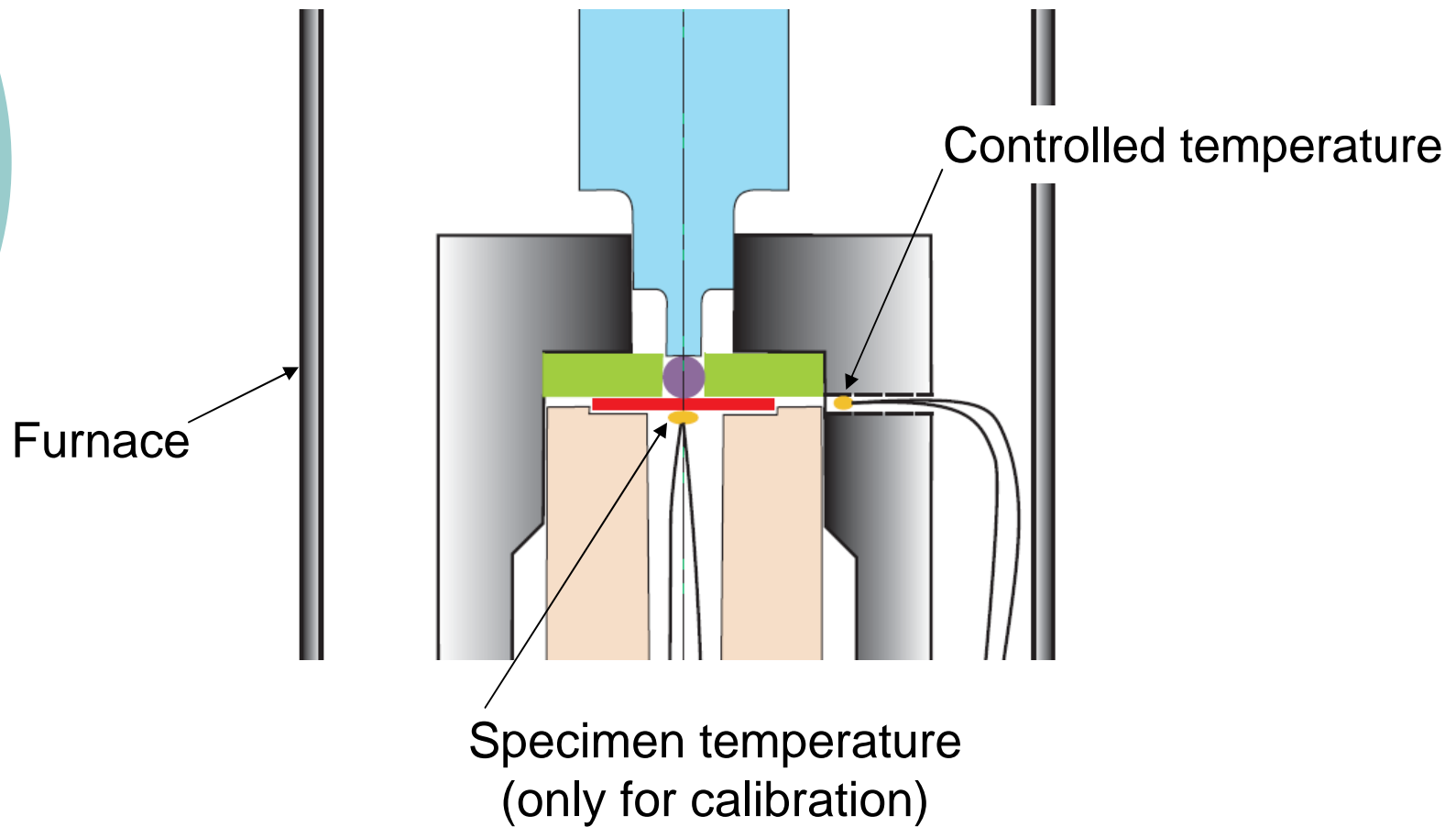
R: radius of ball t : specimen thickness

Load/stress conversion equation

<p>Membrane stress theory</p> $\frac{F}{\sigma} = 2\pi \left(R + \frac{t}{2} \right) \sin^2 \theta \quad [1]$ $\frac{F}{\sigma} = \frac{2\pi R \sin \phi \cdot \tan \phi}{\sqrt{1 + \tan^2 \phi}} \quad [2]$ $\frac{F}{\sigma} = 2\pi R \sin^2 \phi \quad [3]$	<p>Deep drawing process</p> $\frac{F}{\sigma} = K\pi d^{2/3} \left(\frac{a}{d} - \chi \right) \quad [6]$ <p>Constant load vs. constant stress</p> $\frac{F}{\sigma} = Lt^2 \left[\frac{(n+1)\epsilon}{(1+\epsilon)^{n+1} - 1} \right]^{1/n} \quad [7]$
<p>Regression by experimental data</p> $\frac{F}{\sigma} = \frac{CRt^2}{a/2} E \quad [4]$ $\frac{F}{\sigma} = 3.33K_{sp} \left(\frac{a}{2} \right)^{-0.2} R^{1.2} t \quad [5]$	<p>UAC test vs. SPC test</p> $\frac{F}{\sigma} = \left[\frac{A_C}{A_S} F^{n_c - n_s} \exp \left(\frac{Q_C - Q_S}{RT} \right) \right]^{1/n_c} \quad [8]$

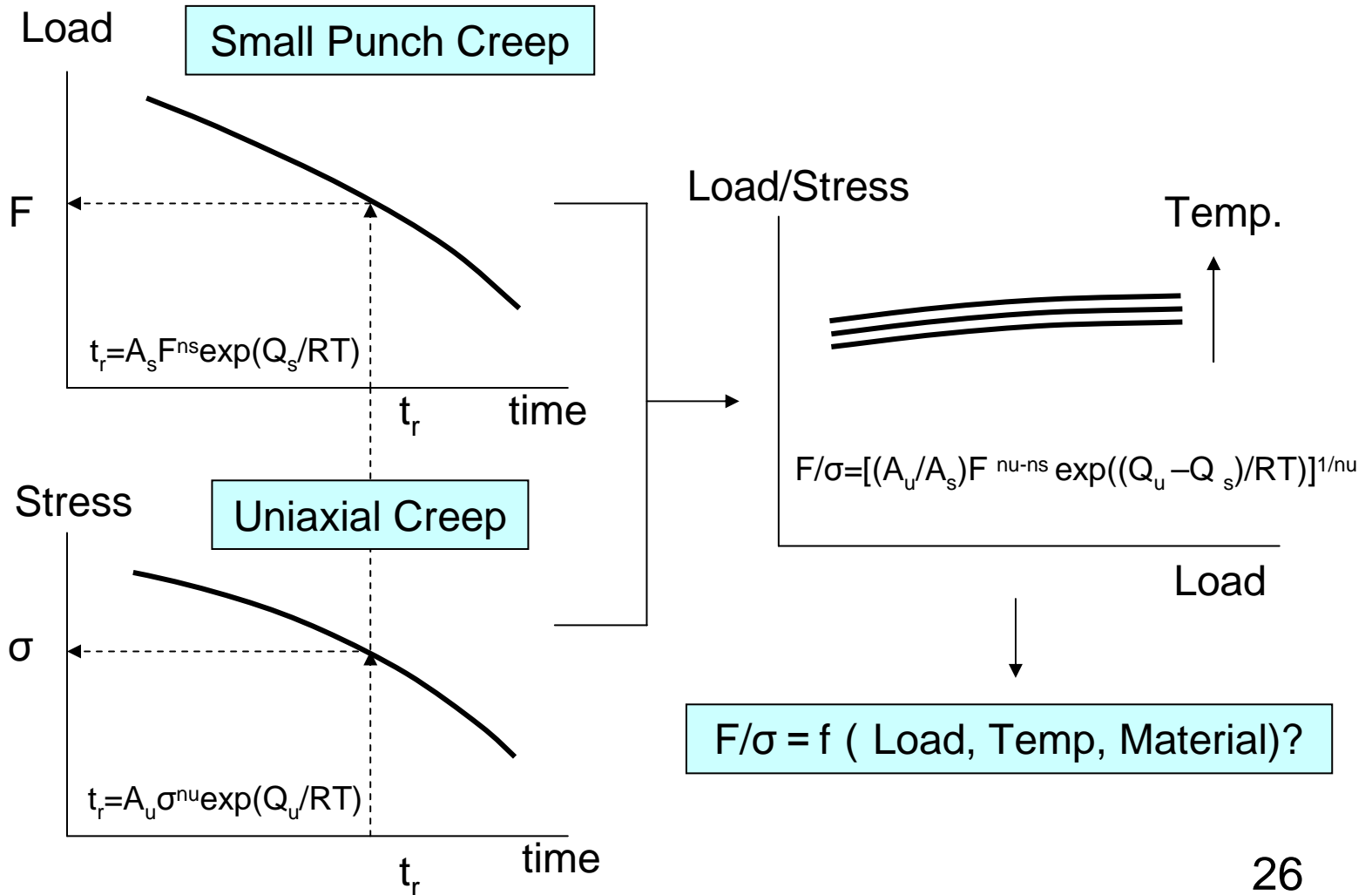
Further WG activity

Temperature calibration procedure



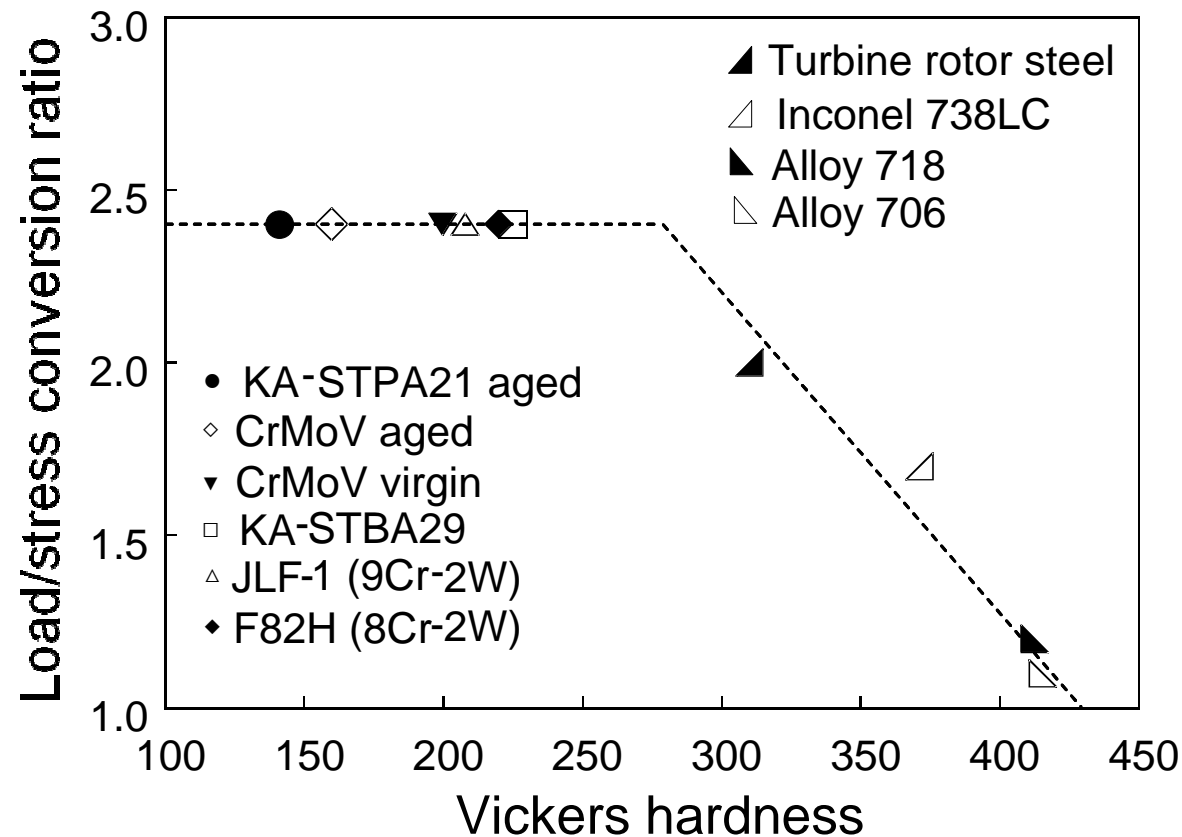
Results until now

Definition of load/stress ratio



Results until now

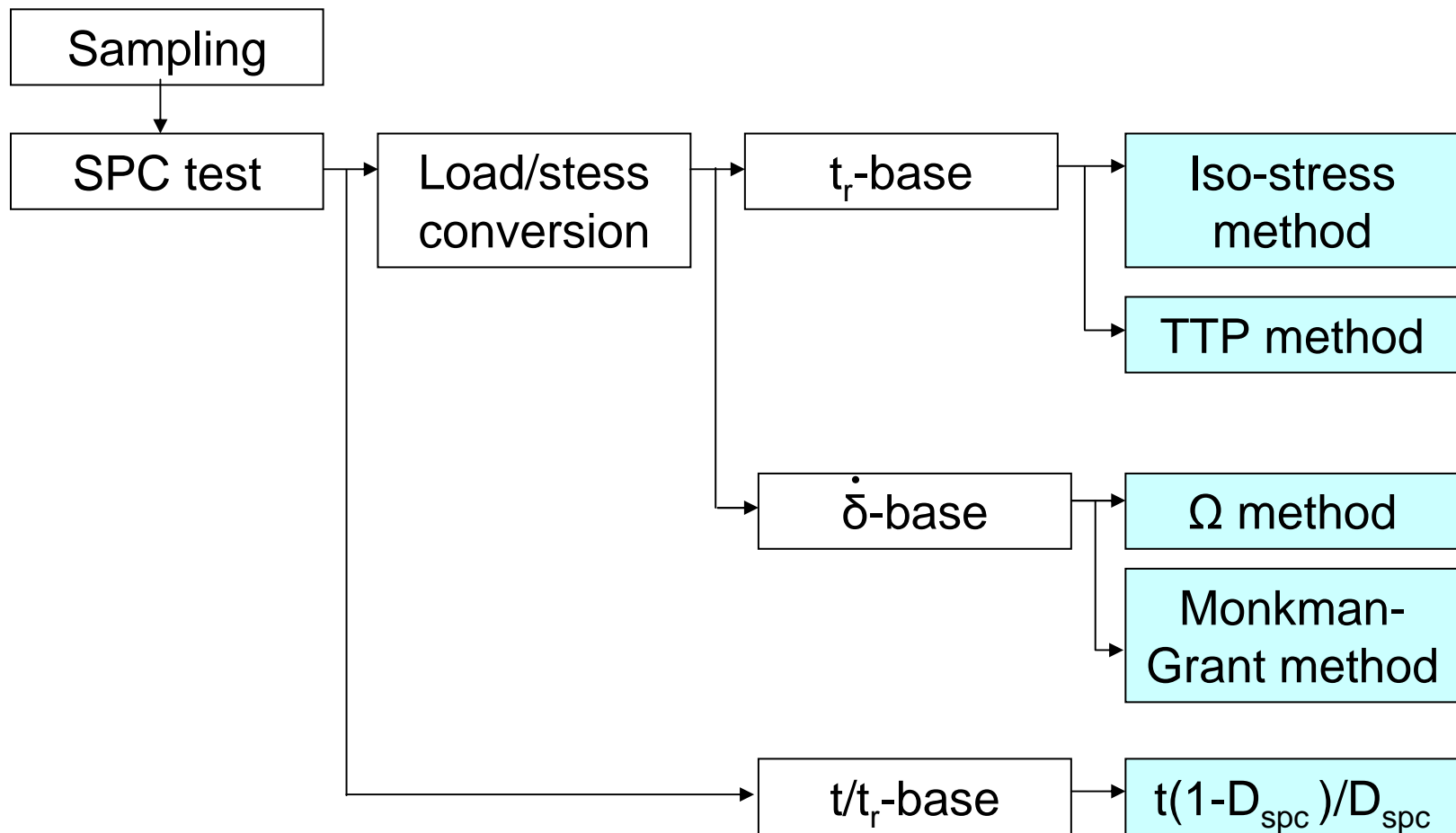
Relation load/stress ratio vs. hardness



S. Komazaki et al, Proc. of Int. Symp. on Advances in Stainless Steels 2007, April 9-11, 2007, Chennai, India.

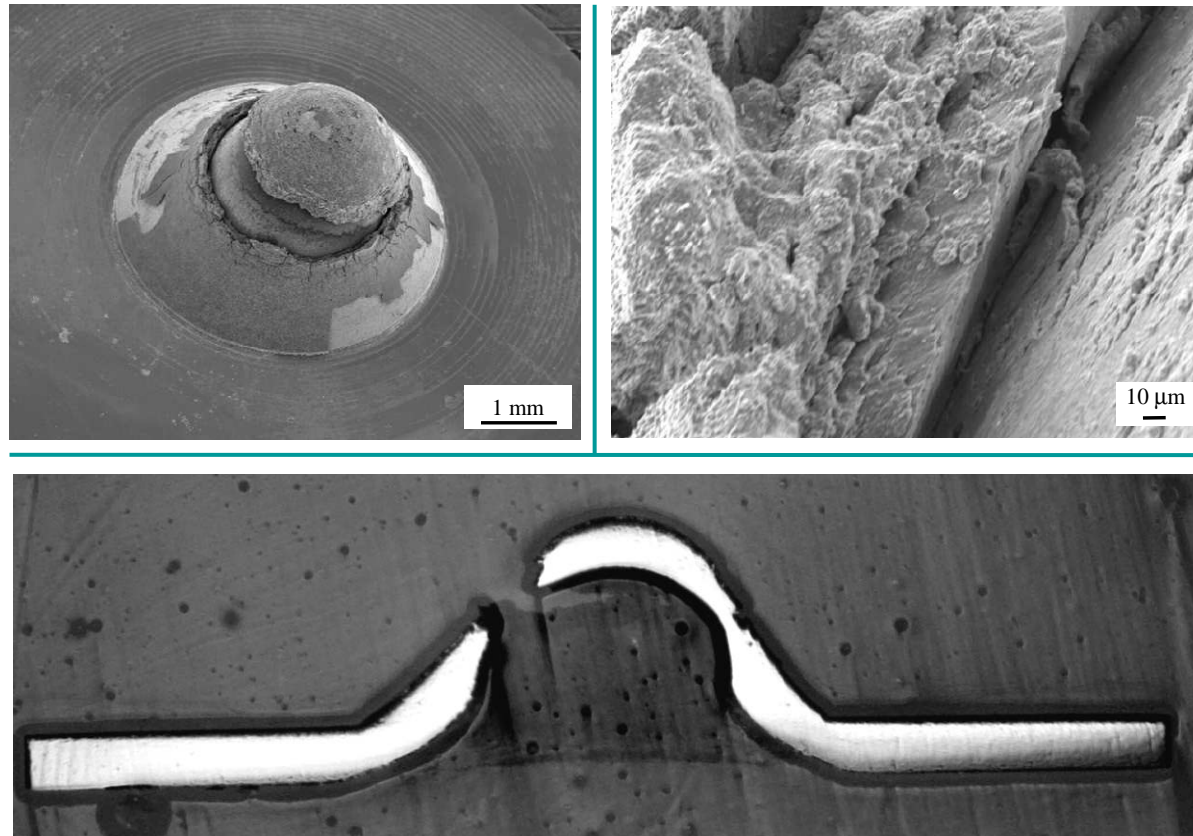
Results until now

Residual life evaluation methods



Results until now

Round-robin test results



(Test No.13: 575C, 360N, $t_r=2204h$)