1st International Conference on SSTT

Determination of Mechanical Properties of Materials by Small Punch and Other Miniature Testing Techniques

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Effects of Configuration and Sizes of Test Rig and Specimen on Small Punch Creep Property

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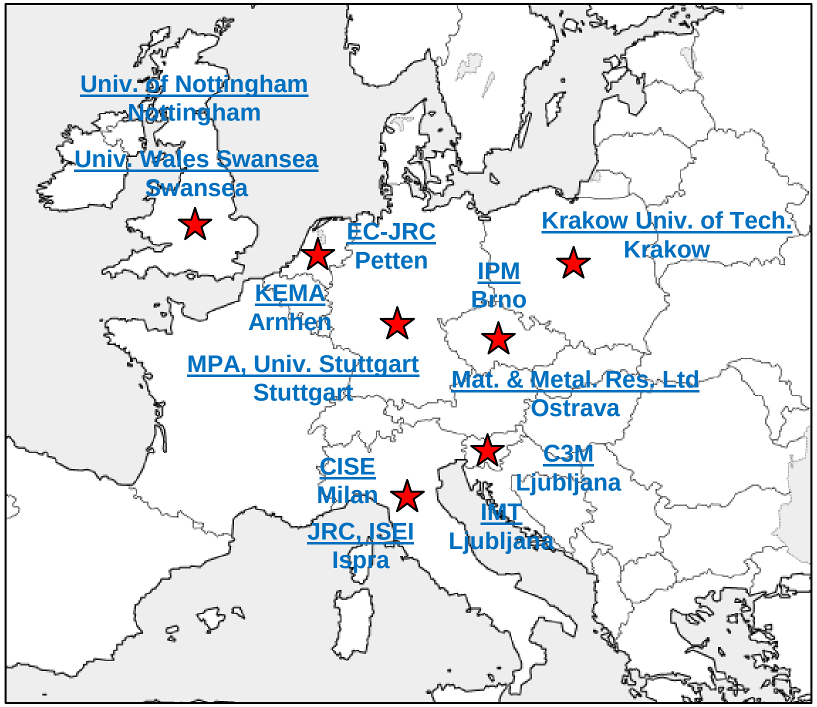
Small Punch Creep Test

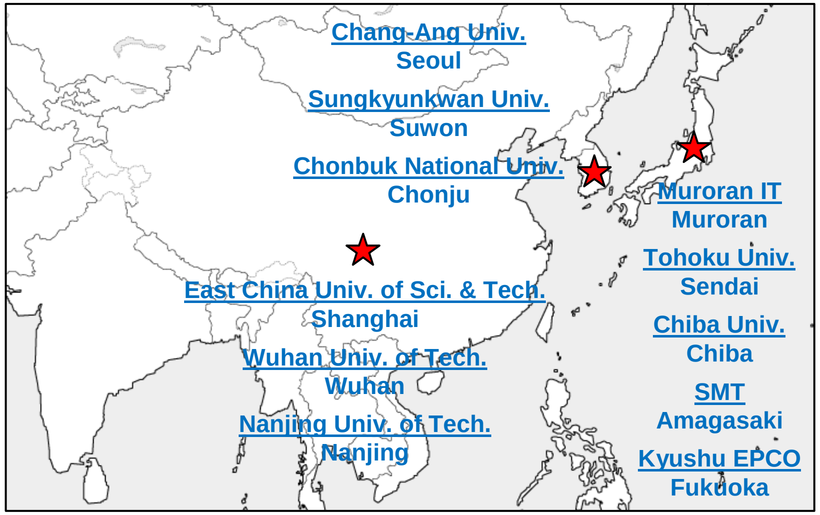
- ❖ **In the 90s, the small punch (SP) creep test using a miniature disc specimen was proposed in Europe.**

Pioneers in development of SP creep test

- ☐ **J.D. Parker et al. (UK)**
- ☐ **K. Milička & F. Dobeš (Czech)**

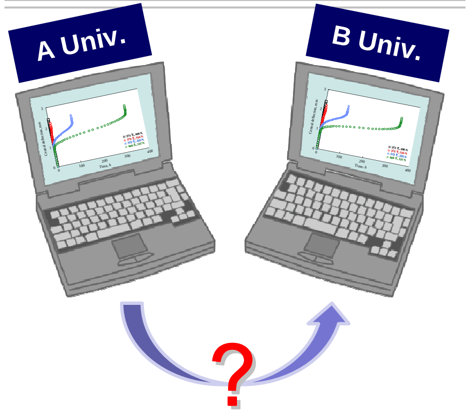
- ❖ **Many experimental works have been carried out in different European countries within the framework of the COPERNICS project (1994).**
- ❖ **The CEN has been recently working to develop “A Code of Practice for Small Punch Creep Testing”. (R. Hurst et al., 2006)**
- ❖ **In Japan, Komazaki et al. started the creep property measurement of high Cr ferritic steels (1997).**
- ❖ **There are many institutions which are interested in this technique in Asian countries (Japan, Korea, China).**





Small Punch Creep Test

- ❖ **The SP creep test has not yet been standardized and the geometry or dimension of the specimen, puncher (ball) and dies used are different depending on the university and industry.**
- ❖ **It is very difficult to compare directly the results obtained from the institutions using different test rig and specimen.**



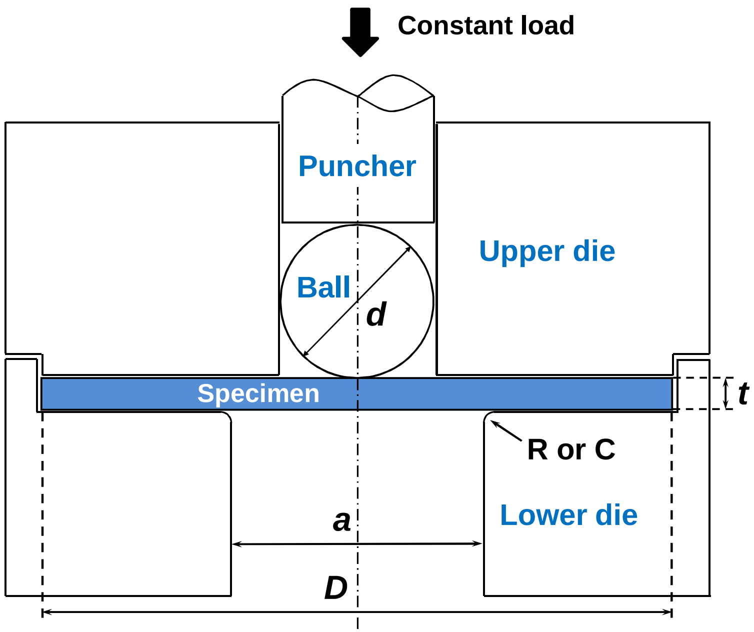


Fig. Specimen support configuration for SP creep test.

Table Examples of geometry and dimension of specimen, puncher and lower die used.

Specimen		Puncher		Lower die	
Geometry	Size (mm)	Geometry	Dia. (mm)	Inner dia. (mm)	Chamfer
Square	10×10×0.5	Ball	2.4	4.0	R=0.2
Square	10×10×0.5	Ball	2.4	4.0	Unknown
Disc	ϕ10×0.5	Ball	2.5	Unknown	
Disc	ϕ 10×0.5	Ball	2.0	4.0	R=1.0
Disc	ϕ 10×0.5	Hemisphere	2.4	5.0	Unknown
Disc	ϕ 8×0.5	Ball	2.5	4.0	C=0.2
Disc	ϕ 8×0.5	Hemisphere	2.0	4.0	Unknown
Disc	ϕ 7×0.5	Ball	2.4	4.0	Unknown

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Objective

- The effect of geometry or dimension of rig and specimen on SP creep property were investigated by FEA.
- The creep rupture data, which had been obtained under the various test conditions, were rearranged by the newly proposed σ_S.

What is the σ_S ?

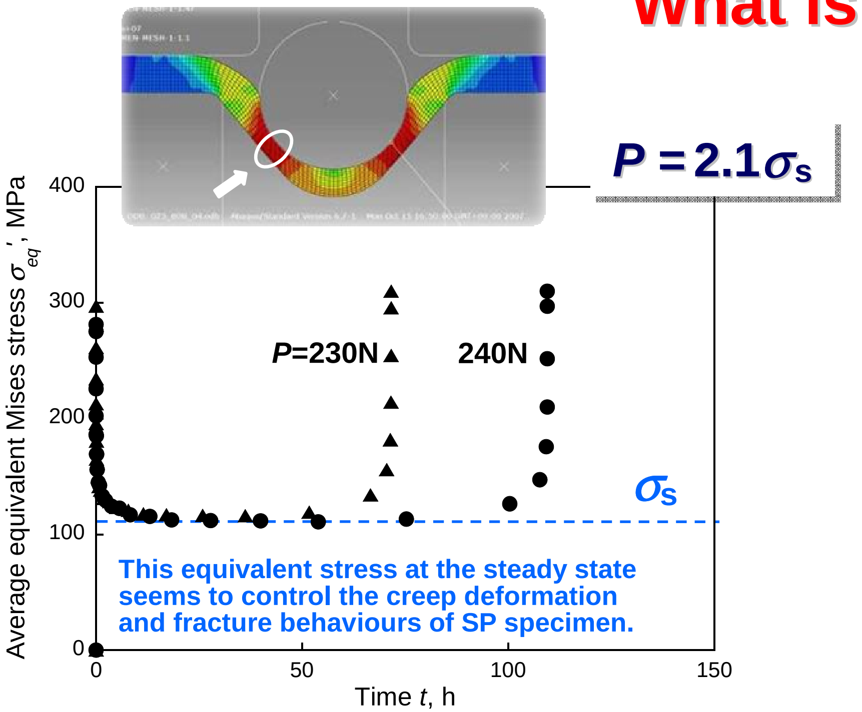

Fig. Average equivalent stress plotted as a function of testing time.

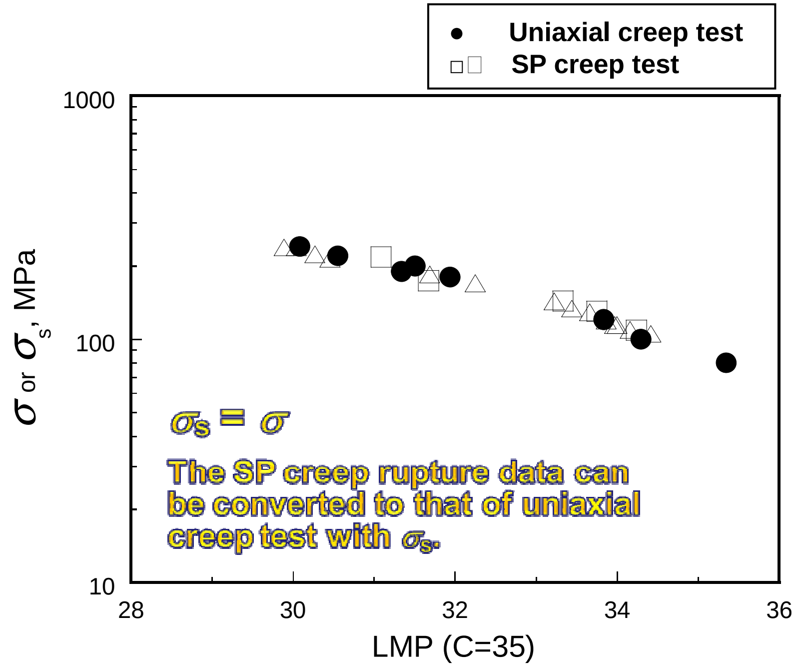

Fig. Results of uniaxial creep tests and SP creep tests. The load of SP creep test is converted to the σ_S.

Finite Element Analysis 1

Table　Conditions of finite element analysis.

Material	**F82H (8Cr-2W-VTa steel)**
Analysis model	2D-Axymentry
Elements	CAX4R 4-node, reduced-integration axisymmetric, solid element (0.05×0.05 mm)
Solver	ABAQUS Standard 6.8-2
Material properties @ 650□ (Uniaxial test results)	E=170 GPa ν = 0.31 $\sigma_{0.2}$= 219 MPa σ_B= 307 MPa Norton's law (ε_{min}=A・ σ^n) A=3.6×10^{-24}, n=8.2
Friction coefficient	μ =0.3
Load range	197-404 N

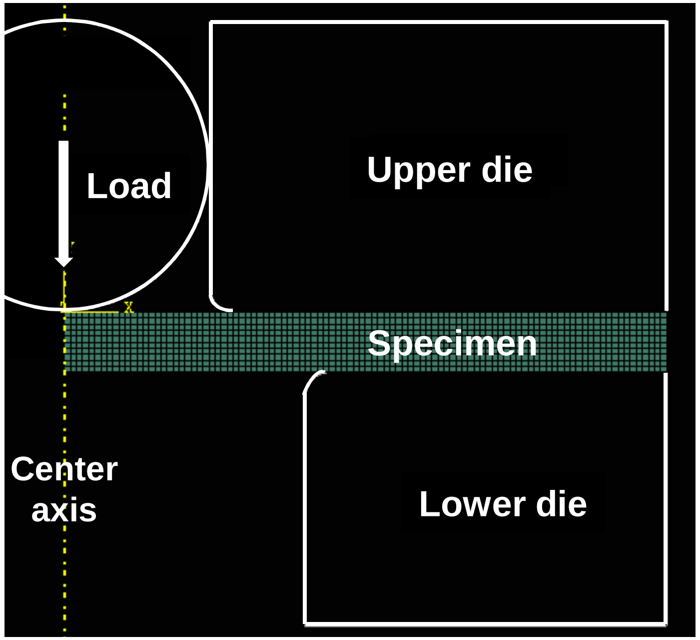

Fig. Finite element analysis model of SP creep tests.

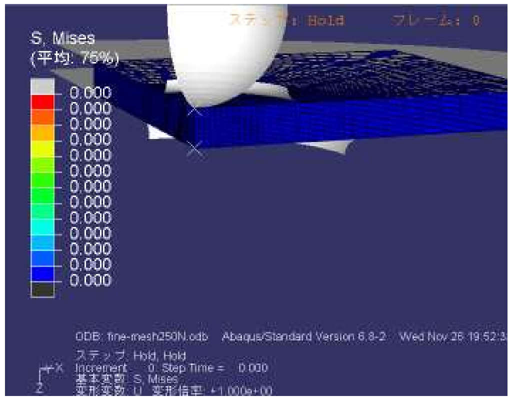

Fig. FEM 3D model (for reference).

Finite Element Analysis 2

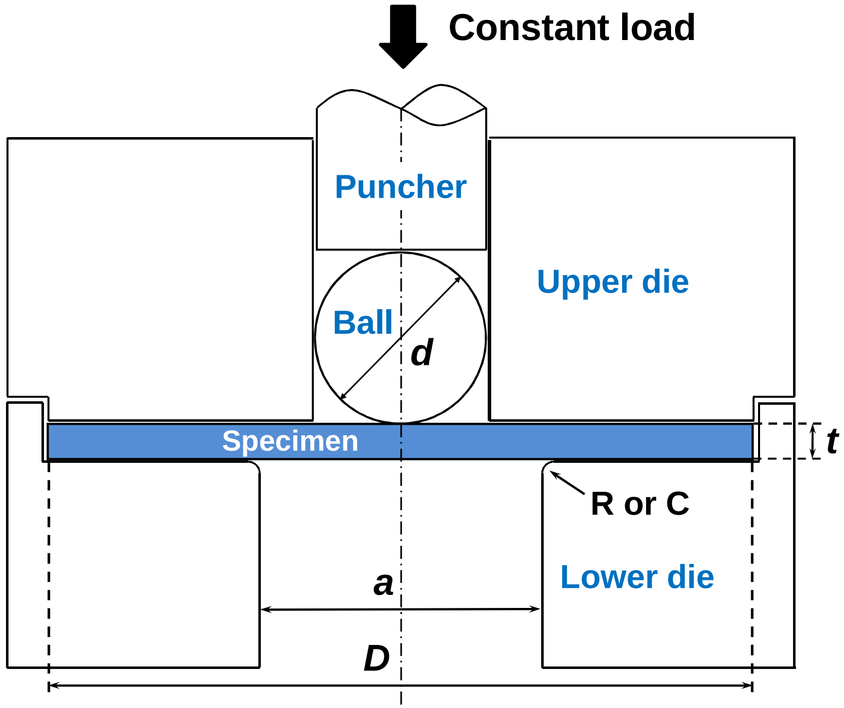

Fig. Specimen support configuration for SP creep test and configuration parameter used in FEM.

The underlined parts are dimension used in the actual experiment in our laboratory.

Specimen	
Diameter *D* (mm)	Thickness *t* (mm)
7.0, 10	0.45, 0.49 0.50 0.51, 0.55
Ball （Puncher）	
Geometry	Diameter *d* (mm)
Ball, Hemisphere	2.0, 2.4, 2.5
Lower die	
Inner diameter *a* (mm)	Chamfer dimension
3.8, 3.9, 4.0, 5.0	*R* =0.01, 0.2 *C* =0.2

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Effect of Specimen Diameter

- **_D_ =7.0, 10 mm**
- ***t* =0.50 mm**
- ***d* =2.4 mm**
- ***a* =4.0 mm**
- ***R* =0.2 mm**

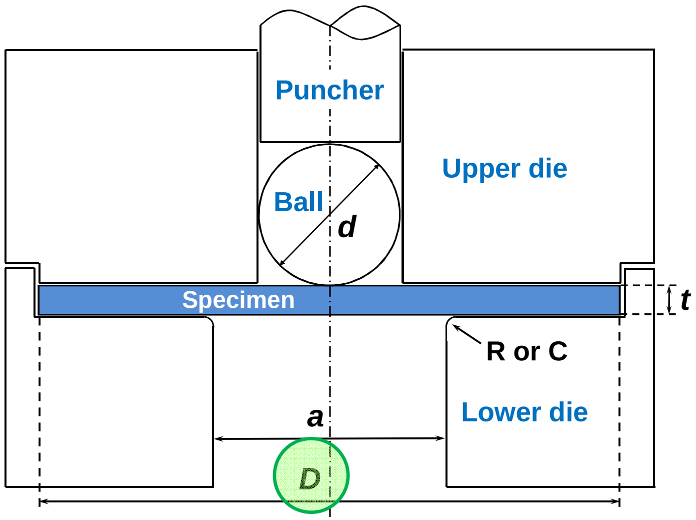


Fig. Specimen support configuration for SP creep test and configuration parameter used in FEM.

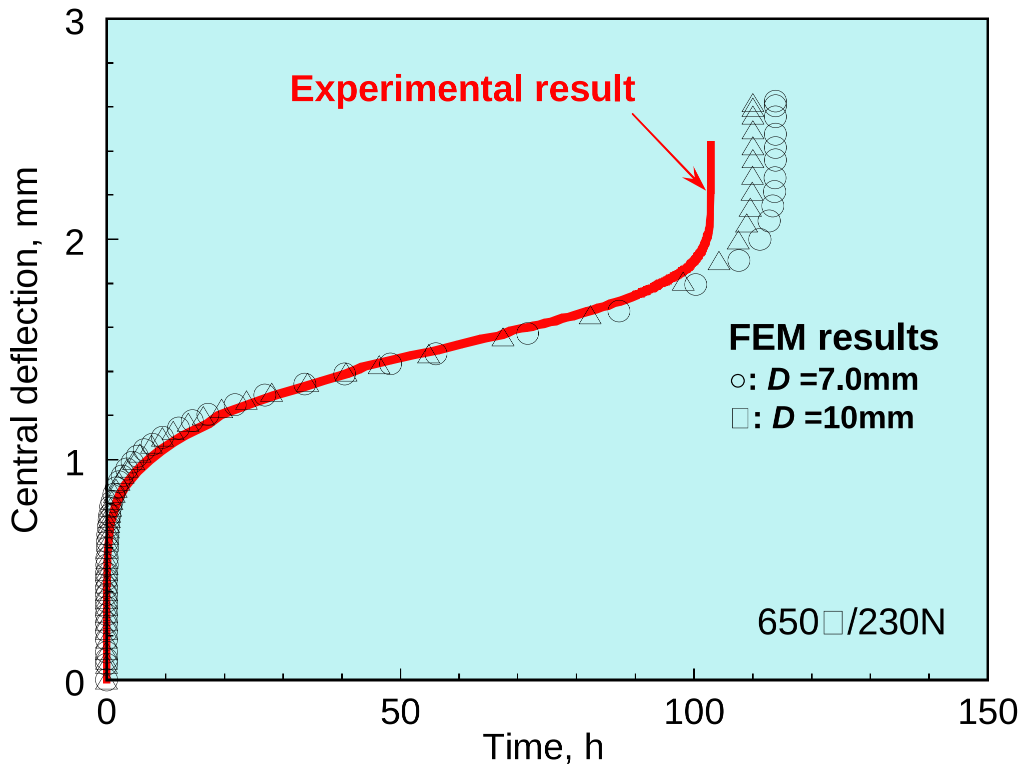


Fig. Central deflection –time curves obtained from the experiment and FEA with specimen diameter 7.0 and 10 mm.

- **The FEA result is in good agreement with the experimental result.**
  ➡ **The present FE model is appropriate for simulating the SP creep deformation.**
- **The specimen size (diameter, *D*) has no significant influence on the SP creep property.**

Effect of Specimen Thickness

- *D* =10 mm
- ☞ *t* =0.45, 0.49, 0.50, 0.51, 0.55 mm
- *d* =2.4 mm
- *a* =4.0 mm
- *R* =0.2 mm

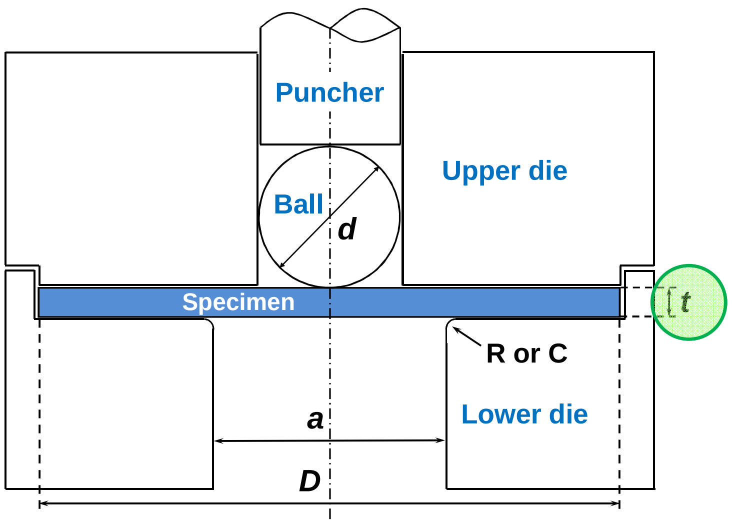


Fig. Specimen support configuration for SP creep test and configuration parameter used in FEM.

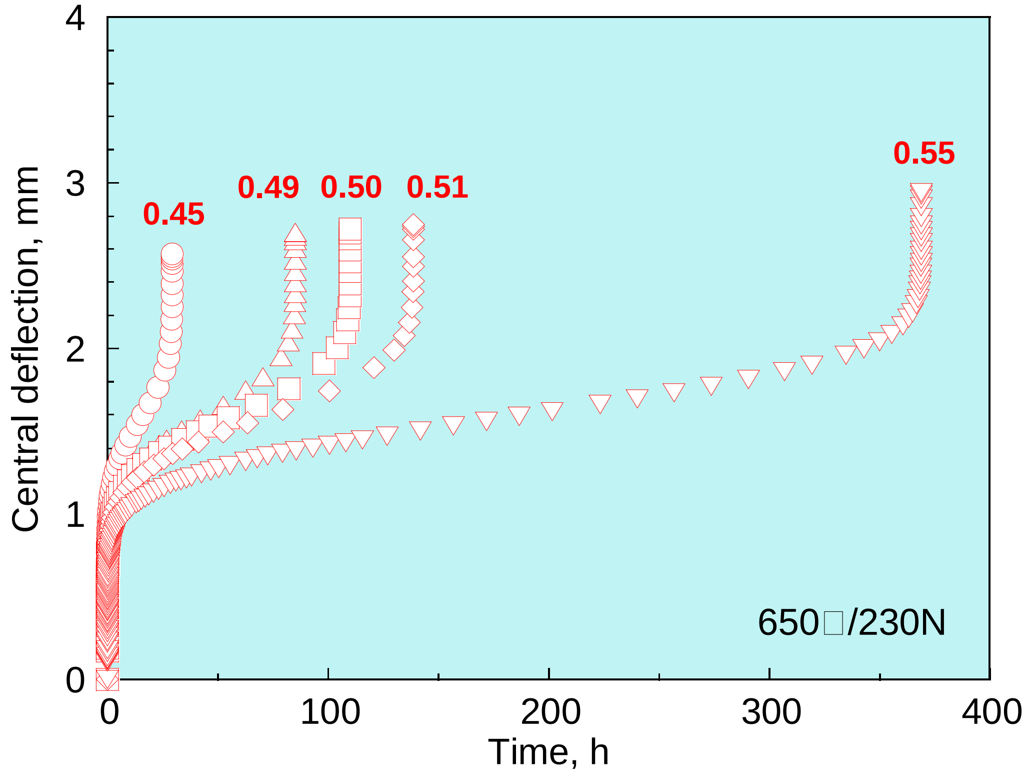


Fig. Central deflection –time curves obtained from the FEA with specimen thickness ranging from 0.45 to 0.55 mm.

- The time to rupture and the fracture deflection increase as the specimen thickness increases.
  - ➡ **It is very important to control the specimen thickness as precisely as possible to collect the data with high reproducibility.**

Effect of Ball Diameter

- D =10 mm
- t =0.50 mm
- ☞ <u>d =2.0, 2.4, 2.5 mm ball or hemisphere</u>
- a =4.0 mm
- R =0.2 mm

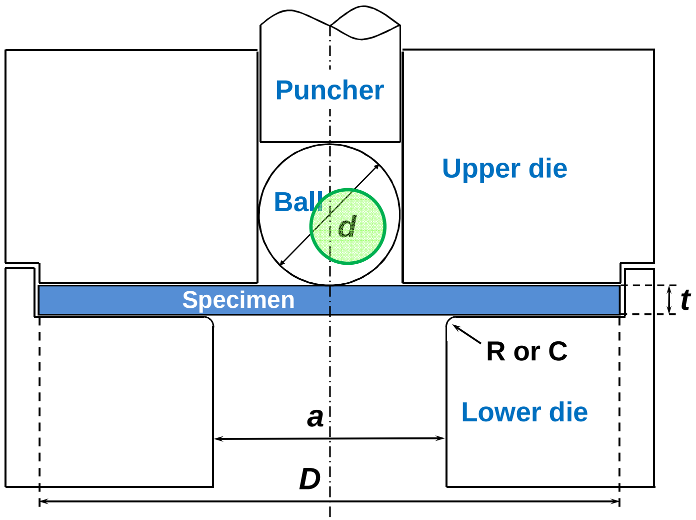


Fig. Specimen support configuration for SP creep test and configuration parameter used in FEM.

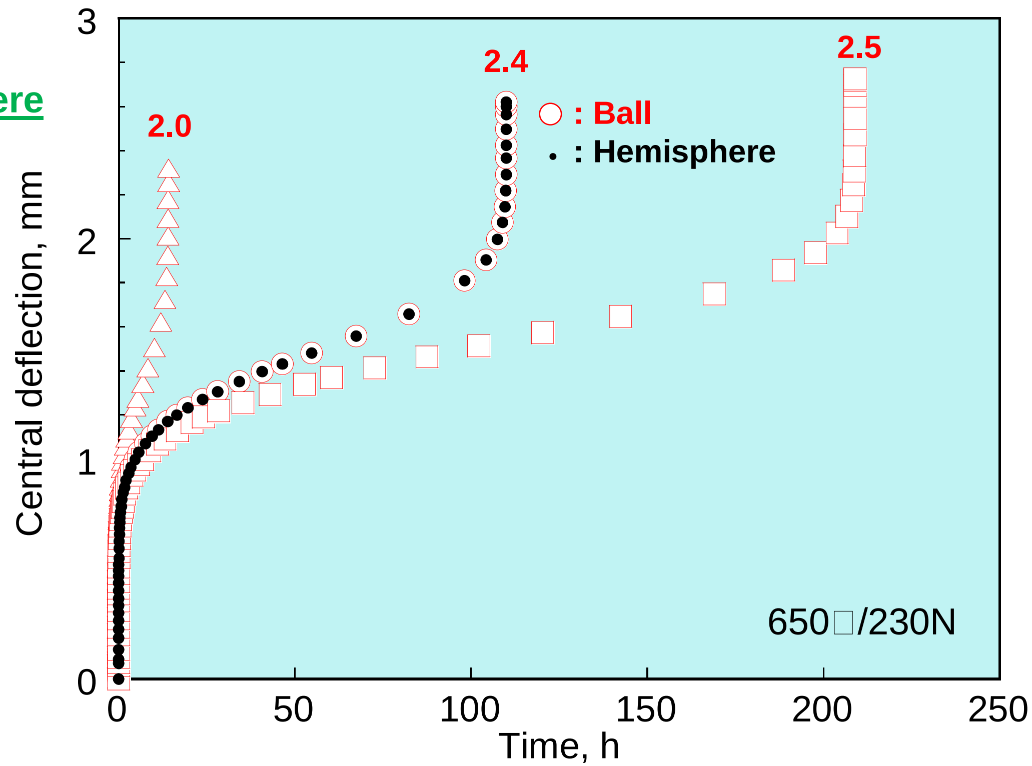


Fig. Central deflection –time curves obtained from the FEA with ball or puncher diameter 2.0, 2.4 and 2.5 mm.

- ❖ **The geometry of puncher (ball or hemisphere) does not have an influence on the SP creep property at all.**
- ❖ **The time to rupture and fracture deflection decrease as the ball diameter decreases.**

Effect of Ball Diameter

Ball *d* =2.0 mm	Ball *d* =2.4 mm	Hemisphere *d* =2.4 mm

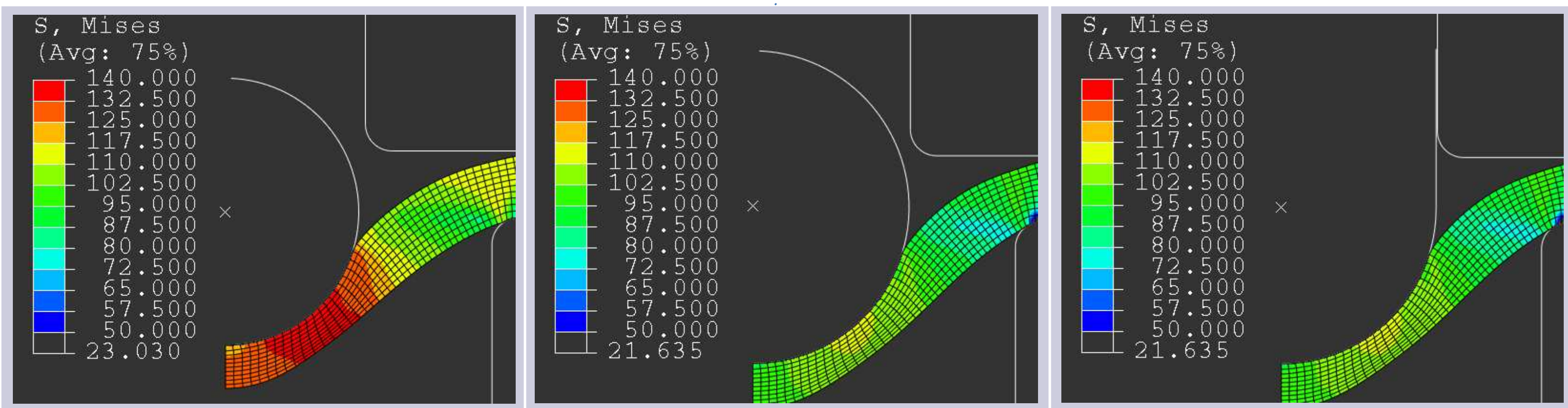
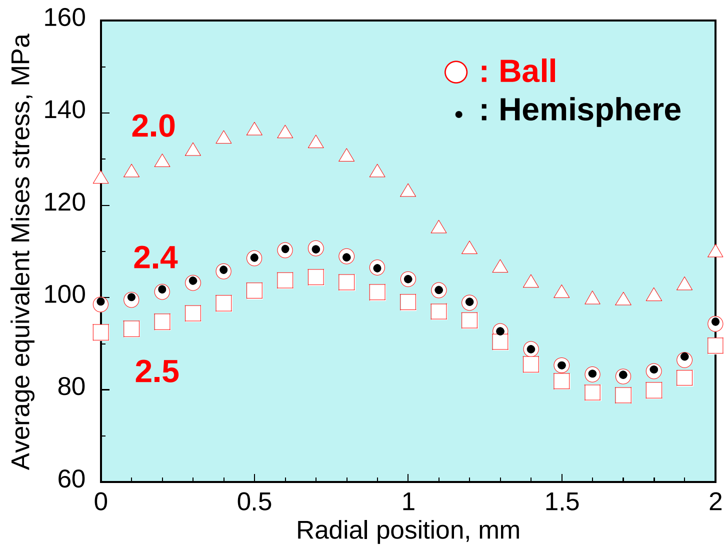


Fig. Deformed SP creep specimens and equivalent Mises stress contours when the diameter is 2.0 and 2.4 mm (life fraction: 50%, 650□/230N).

Fig. Average equivalent Mises stress plotted as a function of distance from center of specimen (life fraction: 50%, 650□/230N).



❖ **The overall equivalent stress increases with decreasing ball diameter.**

Effect of Inner Diameter

- *D* =10 mm
- *t* =0.50 mm
- *d* =2.4
- ☞ *a* =3.8, 3.9, 4.0, 5.0 mm
- *R* =0.2 mm

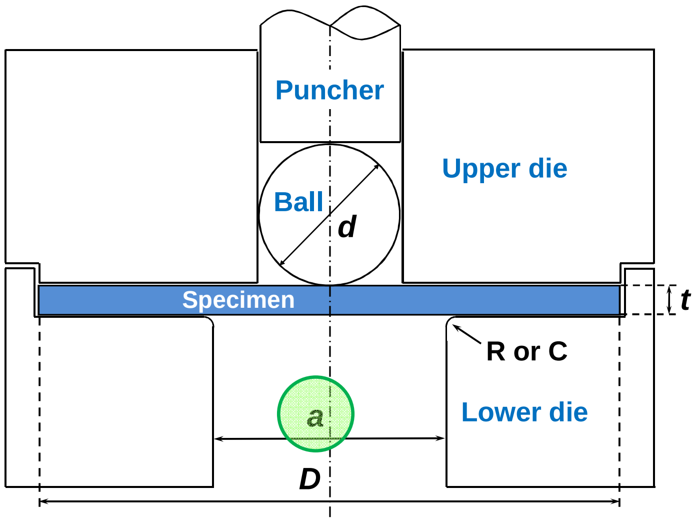


Fig. Specimen support configuration for SP creep test and configuration parameter used in FEM.

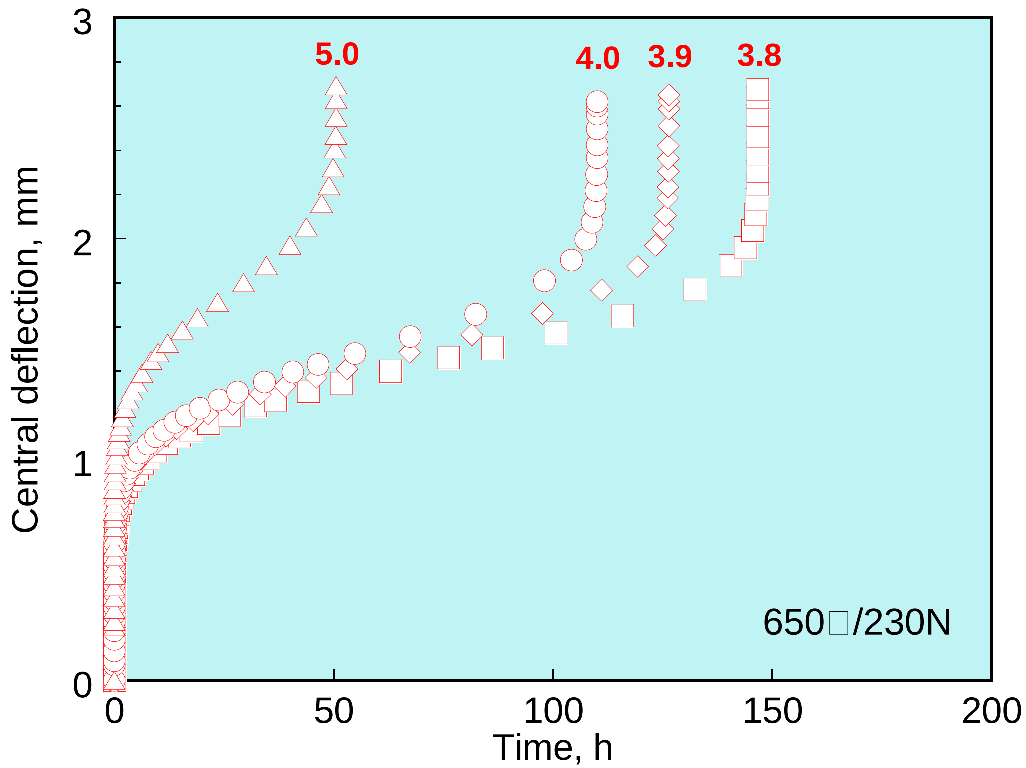


Fig. Central deflection –time curves obtained from the FEA with inner diameter ranging from 3.8 to 5.0 mm.

❖ **The time to rupture decreases as the inner diameter of lower die increases.**

Effect of Chamfer Dimension

- *D* =10 mm
- *t* =0.50 mm
- *d* =2.4
- 4.0 mm
- ☞ *R* =0.01, 0.2, 1.0 mm, *C* =0.2

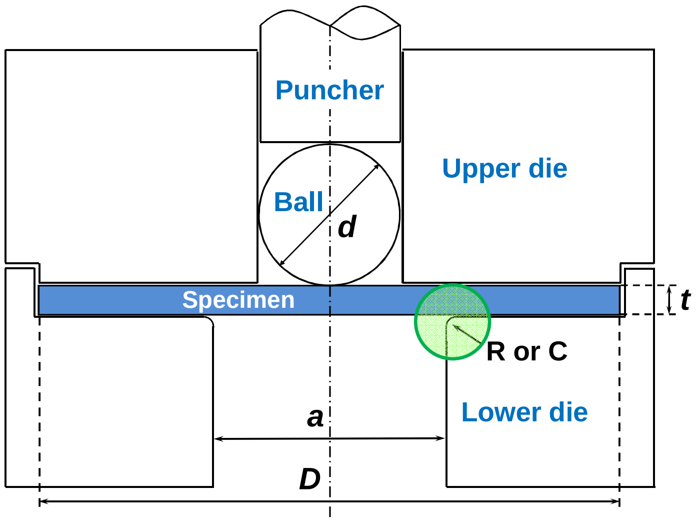


Fig. Specimen support configuration for SP creep test and configuration parameter used in FEM.

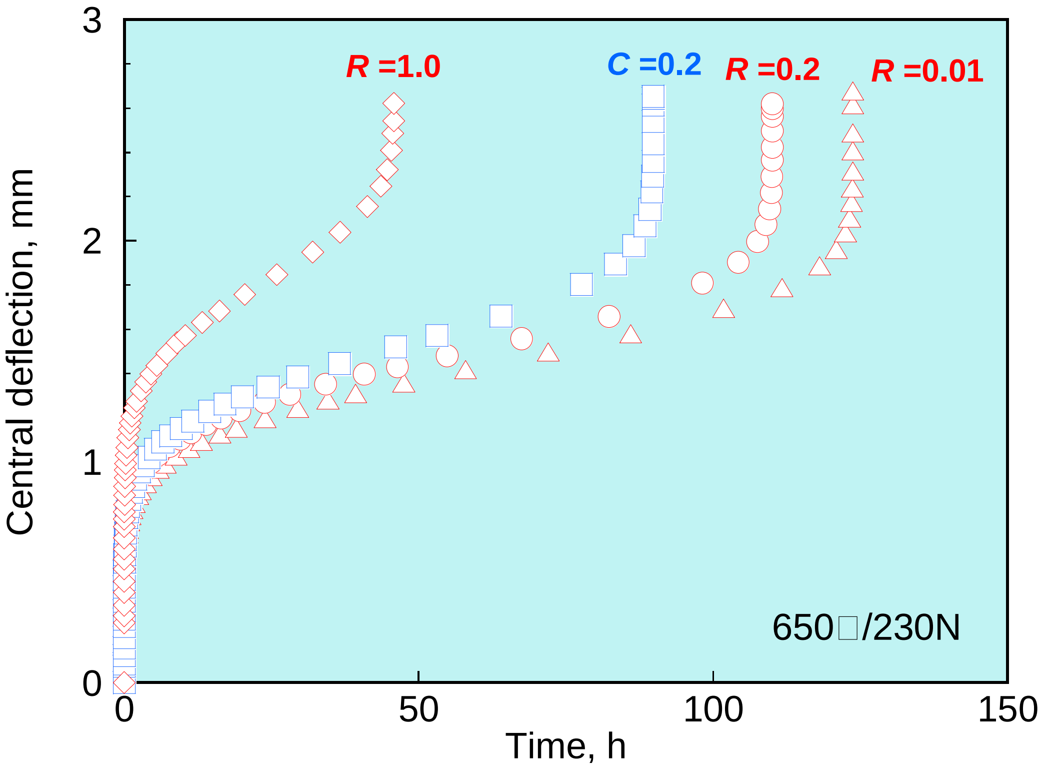


Fig. Central deflection –time curves obtained from the FEA with "R chamfer" 0.01, 0.2 and 1.0 mm and "C chamfer" 0.2 mm.

- ❖ **The time to rupture of the shoulder with "C chamfer" is slightly shorter than that with "R chamfer".**
- ❖ **The time to rupture decreases as the radius of chamfer increases.**

Effects of Configuration Parameters

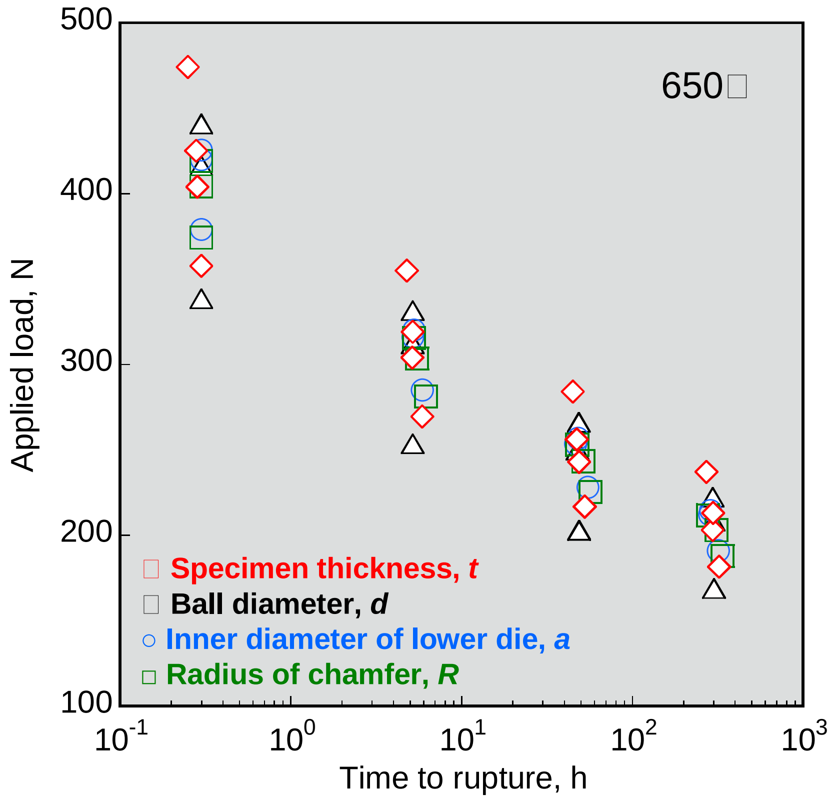


Fig. Summary of rupture test results obtained from FEA under various configuration parameters.

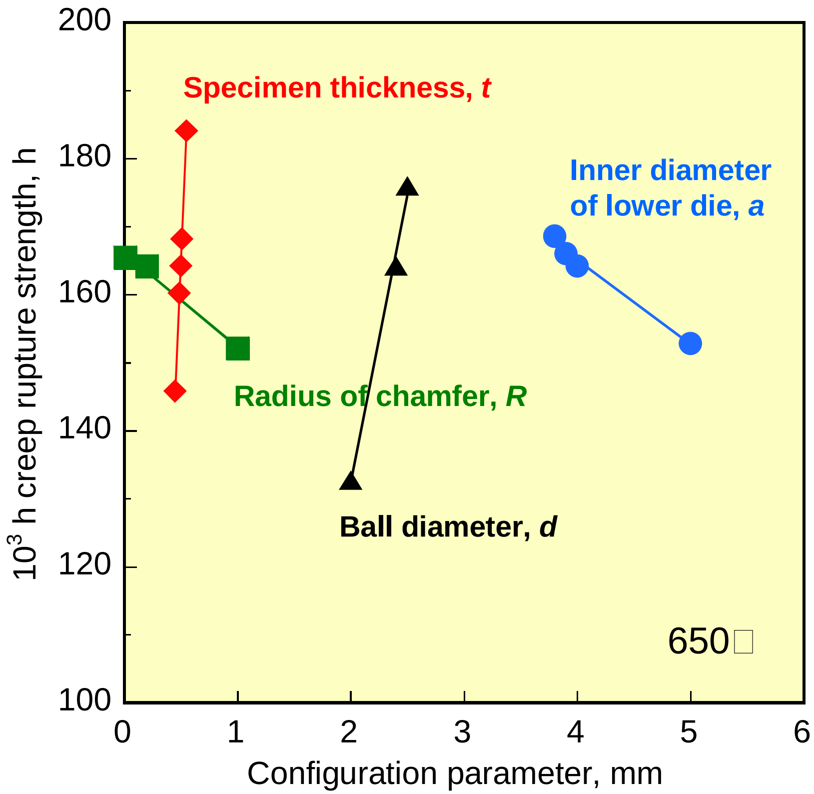
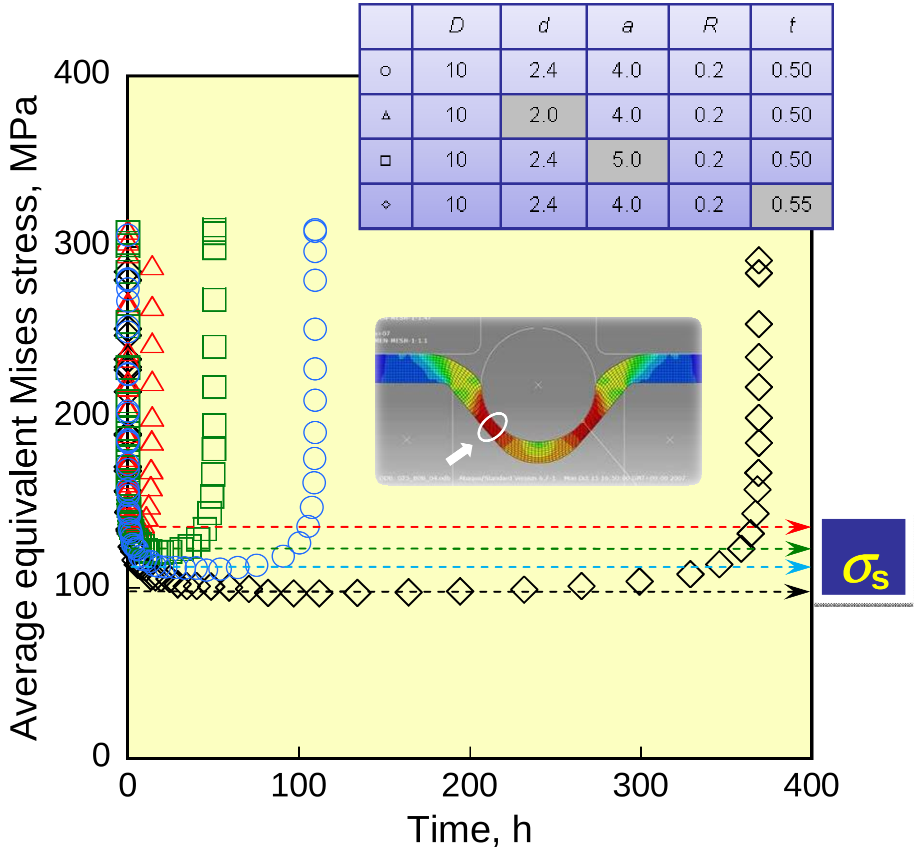


Fig. 10^3 h SP creep rupture strength plotted as a function of configuration parameter.

- **The rupture time is different depending on the geometry or dimension of rig and specimen, even when the applied load is same!**

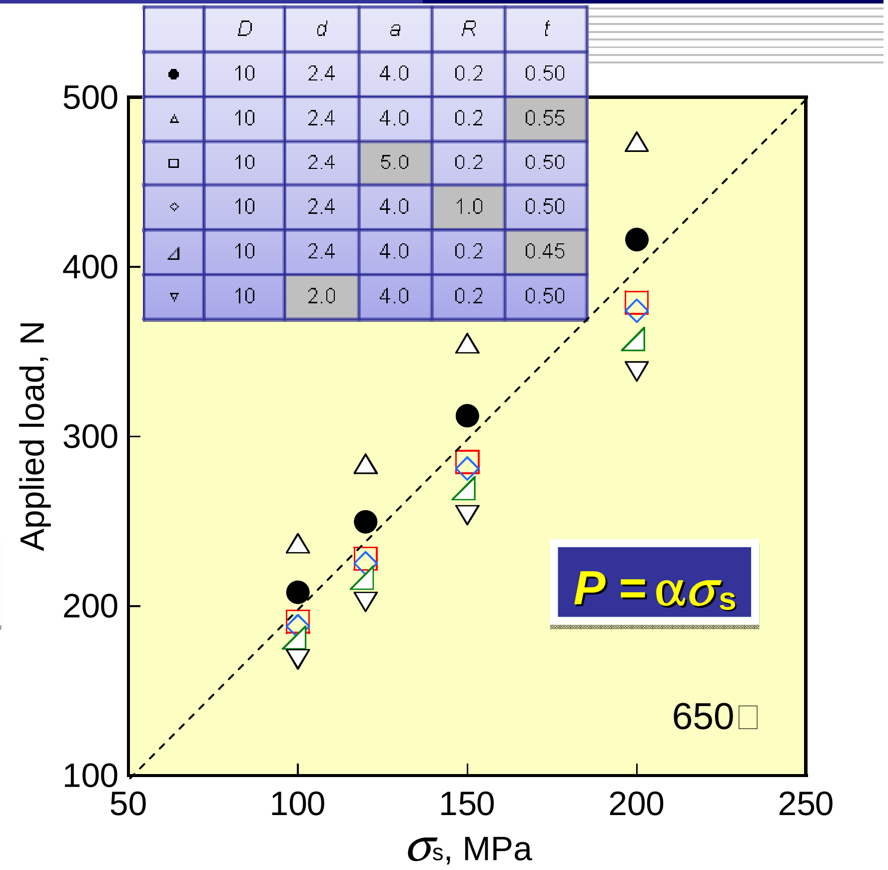
- ***t*, *d* : Their increases cause the increase in creep rupture strength.**
- ***a*, *R* : Their increases cause the decrease in creep rupture strength.**

Rearrangement of Results by σ_s



	D	d	a	R	t
○	10	2.4	4.0	0.2	0.50
△	10	2.0	4.0	0.2	0.50
□	10	2.4	5.0	0.2	0.50
◇	10	2.4	4.0	0.2	0.55

Fig. Average equivalent Mises stress at the most severe position plotted as a function of testing time.



	D	d	a	R	t
●	10	2.4	4.0	0.2	0.50
△	10	2.4	4.0	0.2	0.55
□	10	2.4	5.0	0.2	0.50
◇	10	2.4	4.0	1.0	0.50
⊿	10	2.4	4.0	0.2	0.45
▽	10	2.0	4.0	0.2	0.50

Fig. Relationship between applied load and average equivalent stress in steady state σ_s.

- **The σ_s are observed on all the results, although it's value is dependent on the geometry or dimension of rig and specimen.**
- **The relationship between applied load and σ_s, namely, the slop of the line is slightly dependent on the geometry or dimension of rig and specimen.**

Rearrangement of Results by σ_s

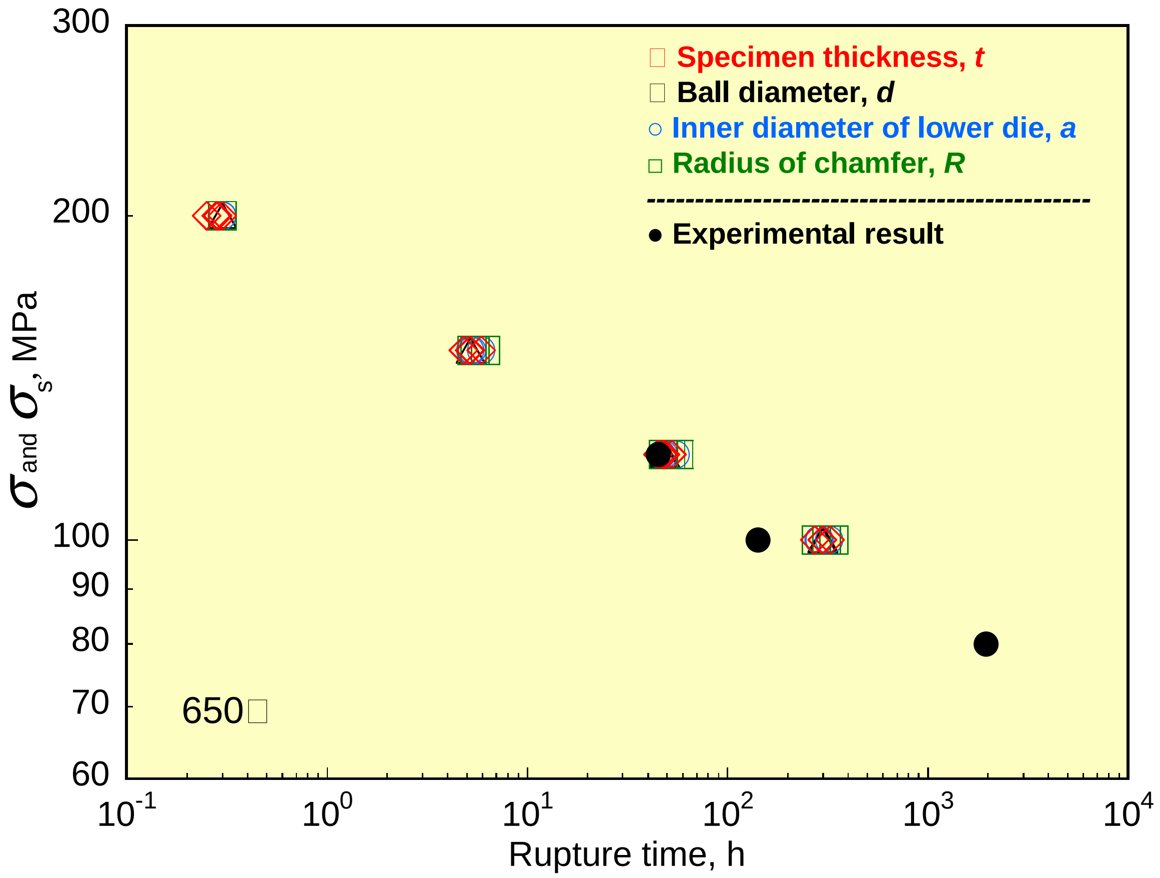
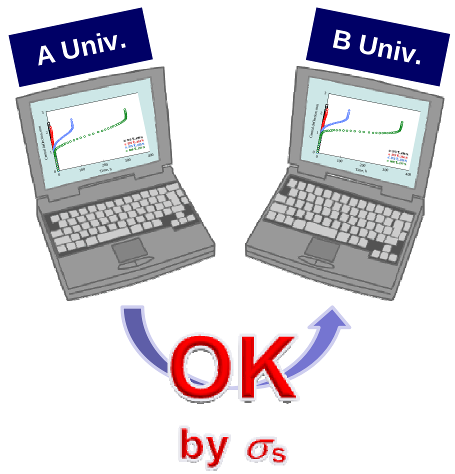


Fig. Creep rupture data rearranged by σ_s determined for each parameter and experimental results.



The SP creep rupture data obtained from the institutions using different test rig and specimen can be directly compared by the σ_s !

- ❖ **The rupture times are well arranged by the σ_s irrespective of the geometry or dimension of rig and specimen.**
- ❖ **The FEA results are in relatively good agreement with the experimental result.**

Summary

1. The SP creep test result is varied depending on the geometry or dimension of the test rig and specimen. The rupture time increases with increasing in specimen thickness and ball diameter. On the other hand, it decreases as the inner diameter and the radius of shoulder's chamfer of lower die increase. However, the specimen diameter has almost no influence on the SP creep property.
2. The time to rupture is well arranged by the average equivalent stress at steady state, σ_s , irrespective of the geometry or dimension of the test rig and specimen.
3. The SP creep rupture data obtained from the institutions using different test rig and specimen can be directly compared by the σ_s.

Thank you for your kind attention!

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