Mechanical properties of JPCA and Alloy800H irradiated up to 19 dpa at SINQ target 4

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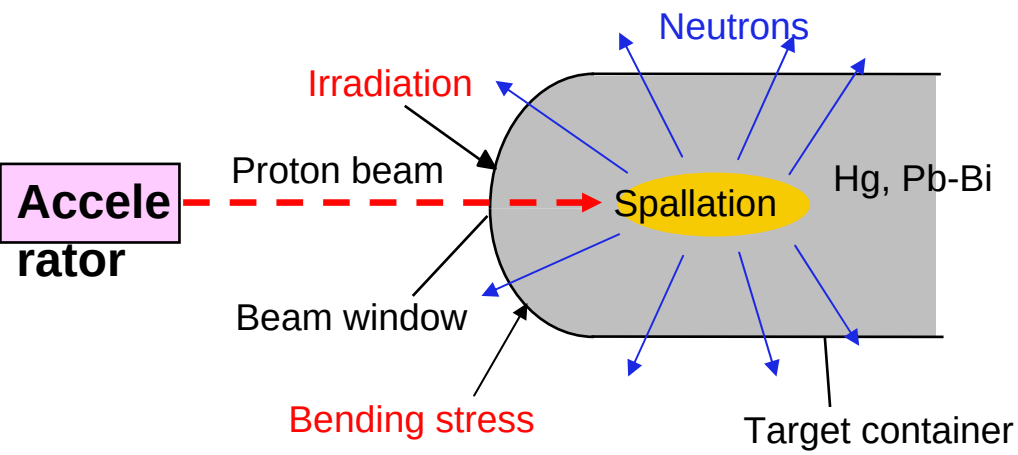
Back ground

- Austenitic stainless steels（316SS, JPCA, etc., ）are one of the candidate materials for a beam window of spallation target and ADS (accelerator-driven transmutation system）.
- The beam window of spallation target is subjected to high energy proton and spallation neutron.
- To obtain the irradiation data, the samples irradiated in SINQ target 4 (STIP-II) were transported to JAEA and PIE were performed.
- In this study, the results of tensile tests on JPCA and Alloy800H will be reported.

Spallation target



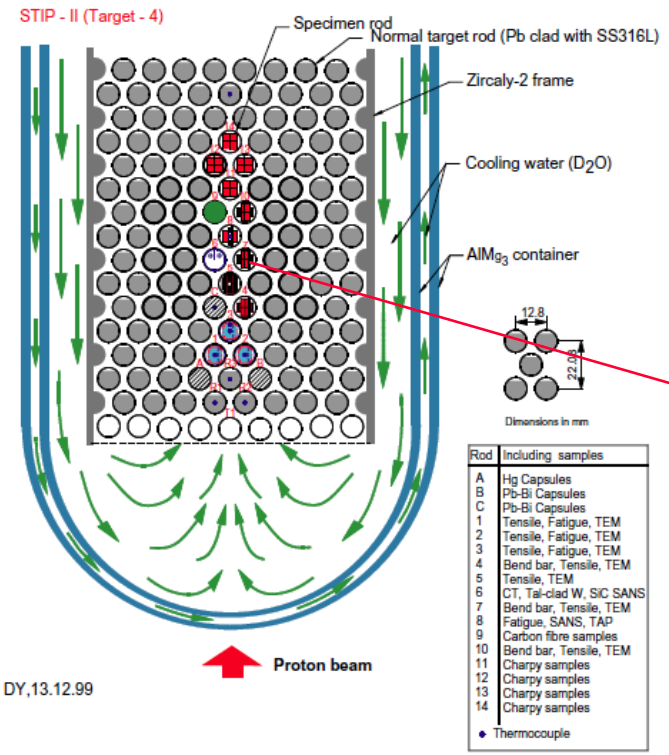
Irradiation at Spallation environment

・High energy of proton and spallation neutron

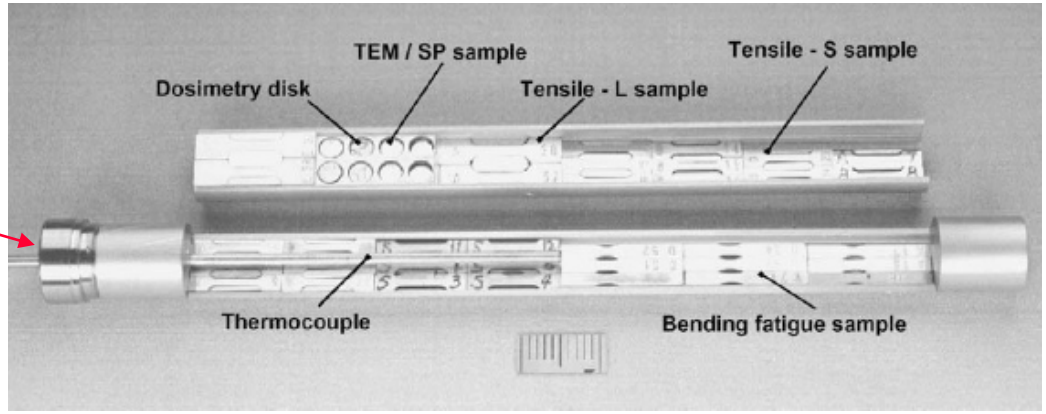
・High gas production ratio（H, He）

Irradiation condition

- Irradiation : STIP-II (SINQ target-4)
- Proton energy : 580 MeV
- Irradiation temperature : 107 - 454℃
- dpa (proton+spallation neutron) : 6.5 - 19.5 dpa
- Gas production（calculated value) : He : 80 appm/dpa, H : 500 appm/dpa



STIP-II (SINQ target-4)



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Materials and Specimens

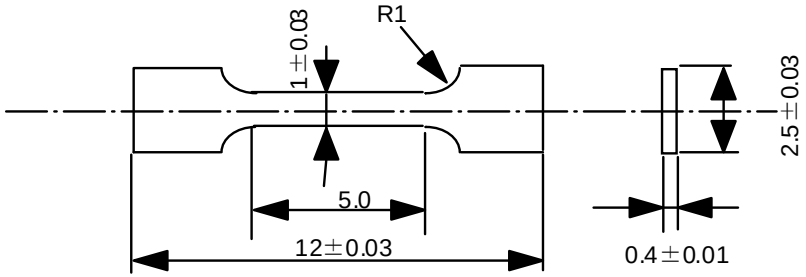
- Material : JPCA (Solution annealing :1120℃, 1 hour, water quench)
  :Alloy800H (Solution annealing :1170℃, 1.2 hour, water quench)
- Specimen : Tensile（S-size and L-size）

Chemical composition of JPCA and Alloy800H

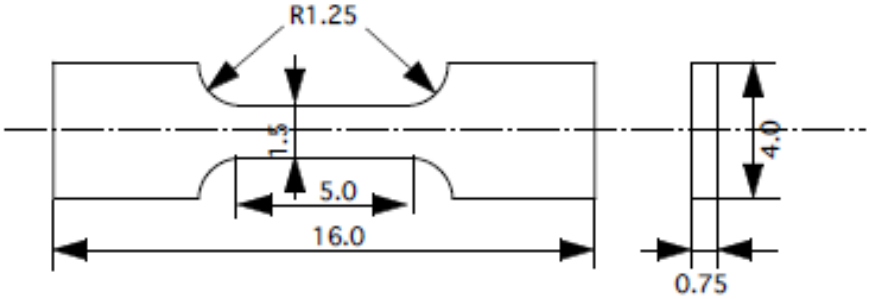
	Fe	Cr	Ni	Mo	Mn	Ti	Co	C	Si	P	S	N	B
JPCA	bal.	14.5	15.6	2.50	1.48	0.24	<0.005	0.053	0.52	<0.005	0.0017	0.0012	0.004
Alloy800H	bal.	19.9	31.1	-	0.98	0.5	-	0.07	0.39	0.011	0.002	-	-

- JPCA has been developed for fusion application based on SS316.
- Alloy800H is high nickel steel developed for high temperature application.

S-size tensile specimen

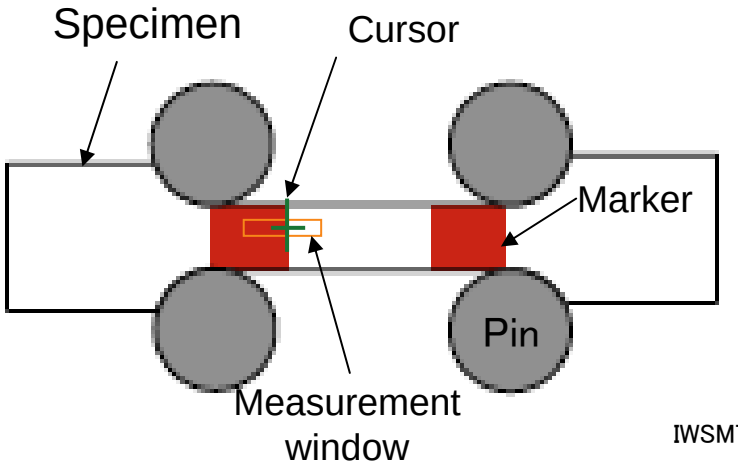


L-size tensile specimen

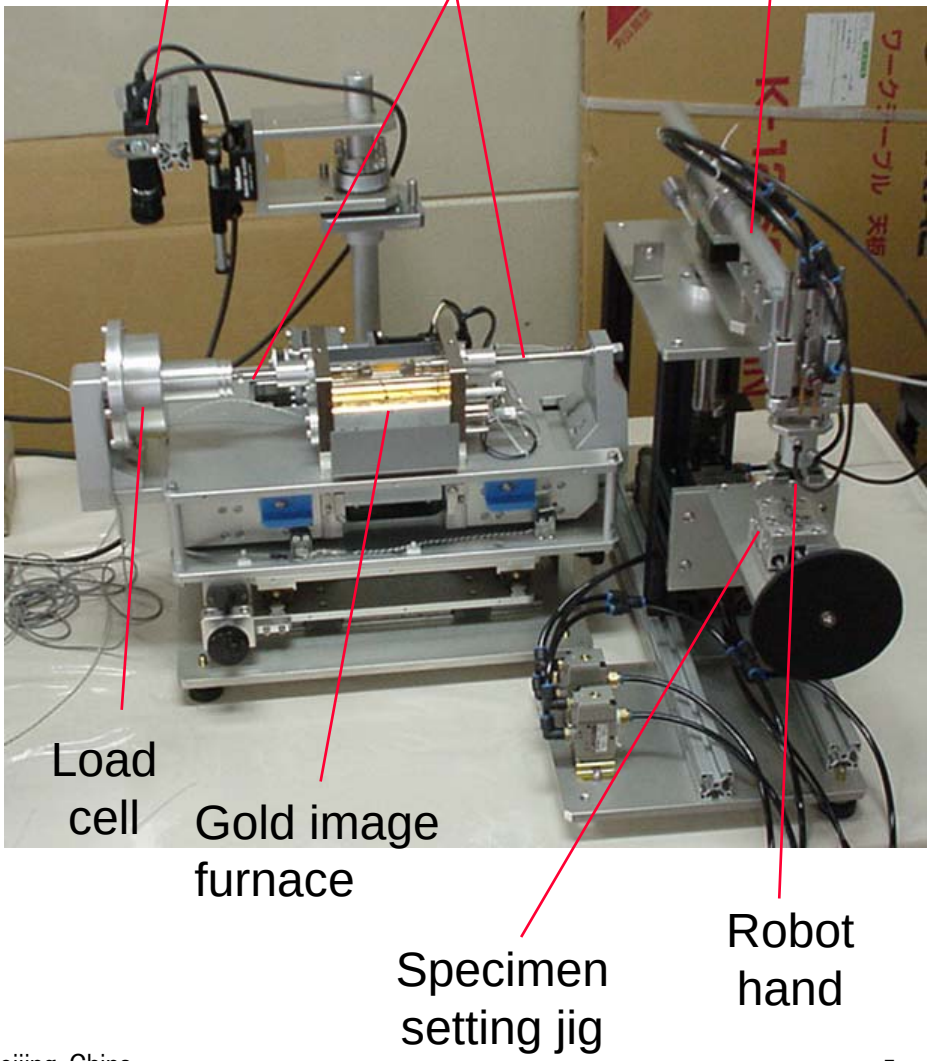


Experiment

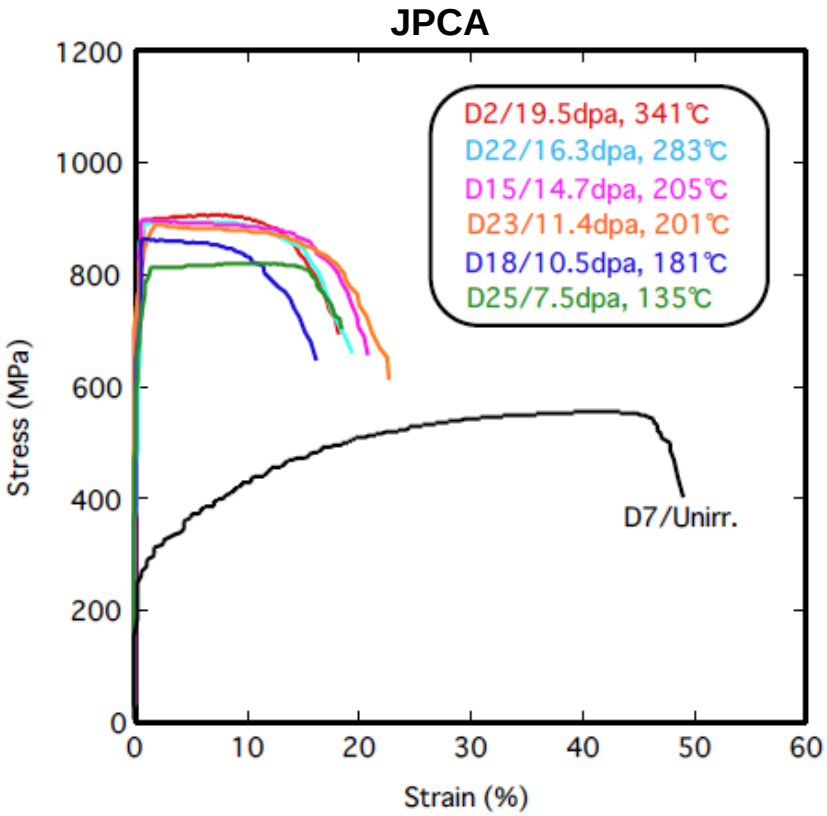
- JAEA Tokai, WASTEF
- Tensile testing machine for small specimen
- Test temp. : R.T., 250℃, 350℃
- Atmosphere : Air
- Cross-head speed : 0.1 mm/min.
- Measurement : Load, Displacement, strain (CCD camera)
- SEM observation of fracture surface (RFEF)

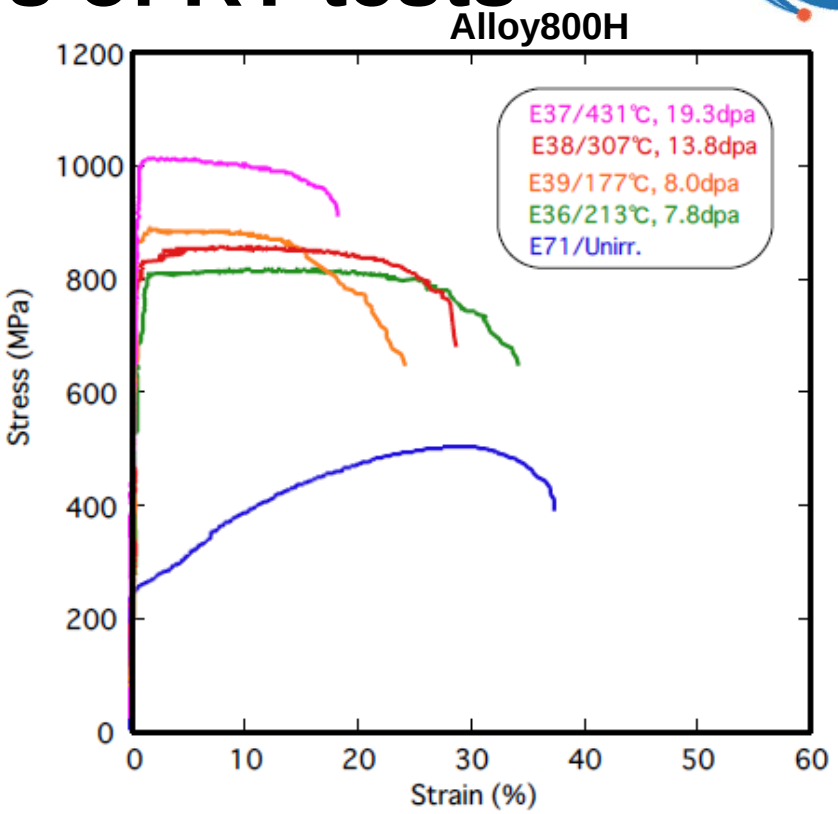


Tensile testing machine



SS curves of RT tests

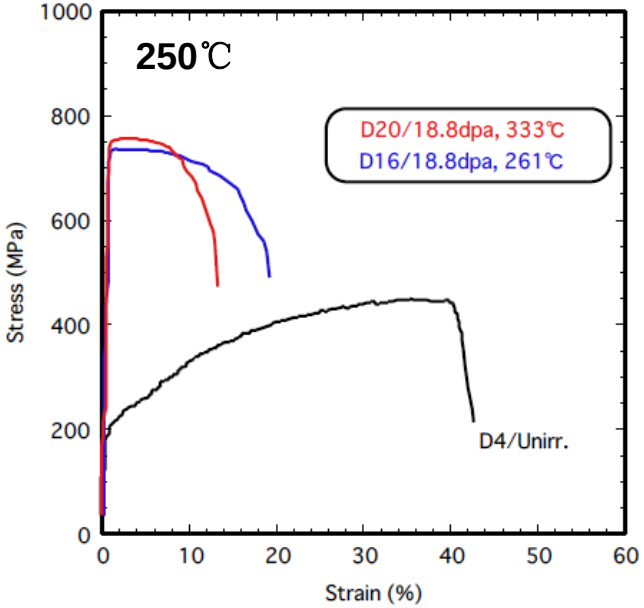




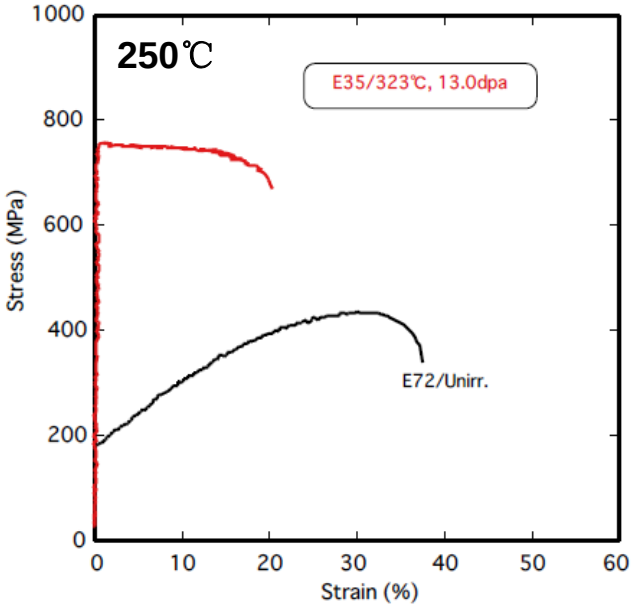
- Both steels show considerable hardening and degradation of ductility are caused by the irradiation.
- Increase of hardening and degradation of ductility on JPCA saturate around 11 dpa.
- Increase of hardening on Alloy800H does not saturate up to 19 dpa.

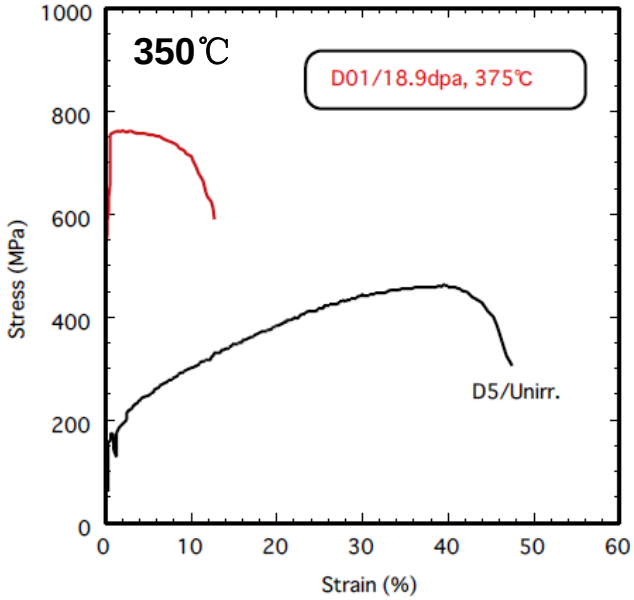
SS curves of 250℃ and 350℃ tests

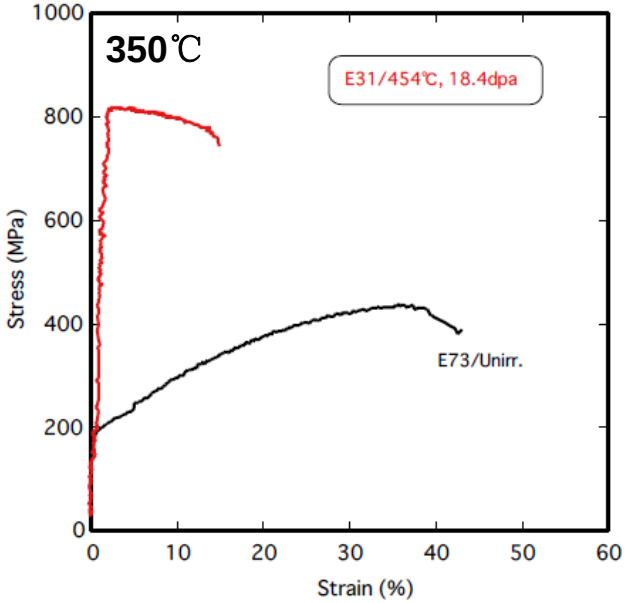
JPCA



Alloy800H







SS curves of 250℃ and 350℃ tests

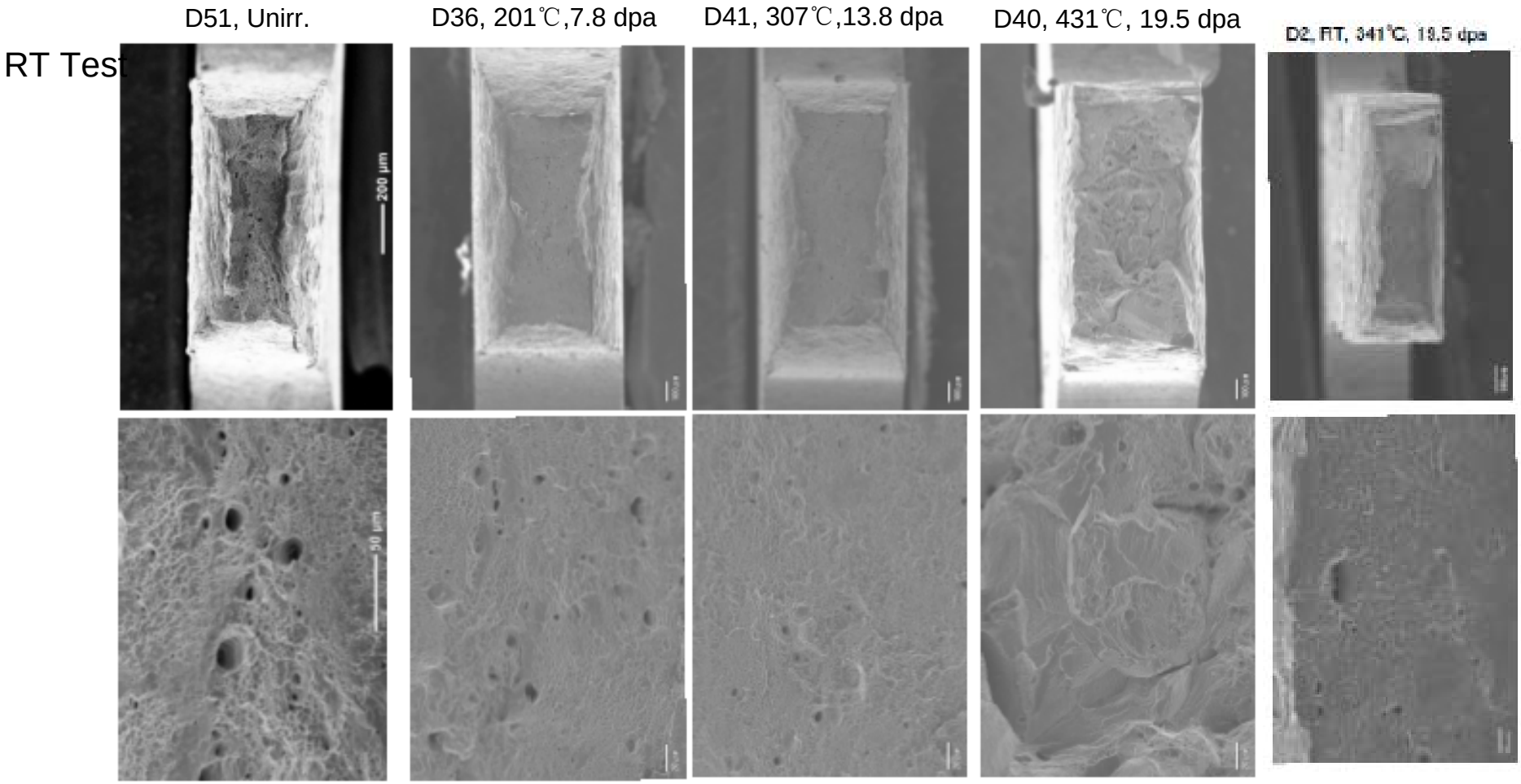
•Similar to RT tests, considerable hardening and degradation of ductility are observed for both steels.

Results of tensile tests

•Ductility is still remain for both steels, for instance, large total elongation (TE) is over 10% after 18-19 dpa irradiation.

•Some differences are observed in a plastic deformation behavior, necking of JPCA is large and that of Alloy800H is small.

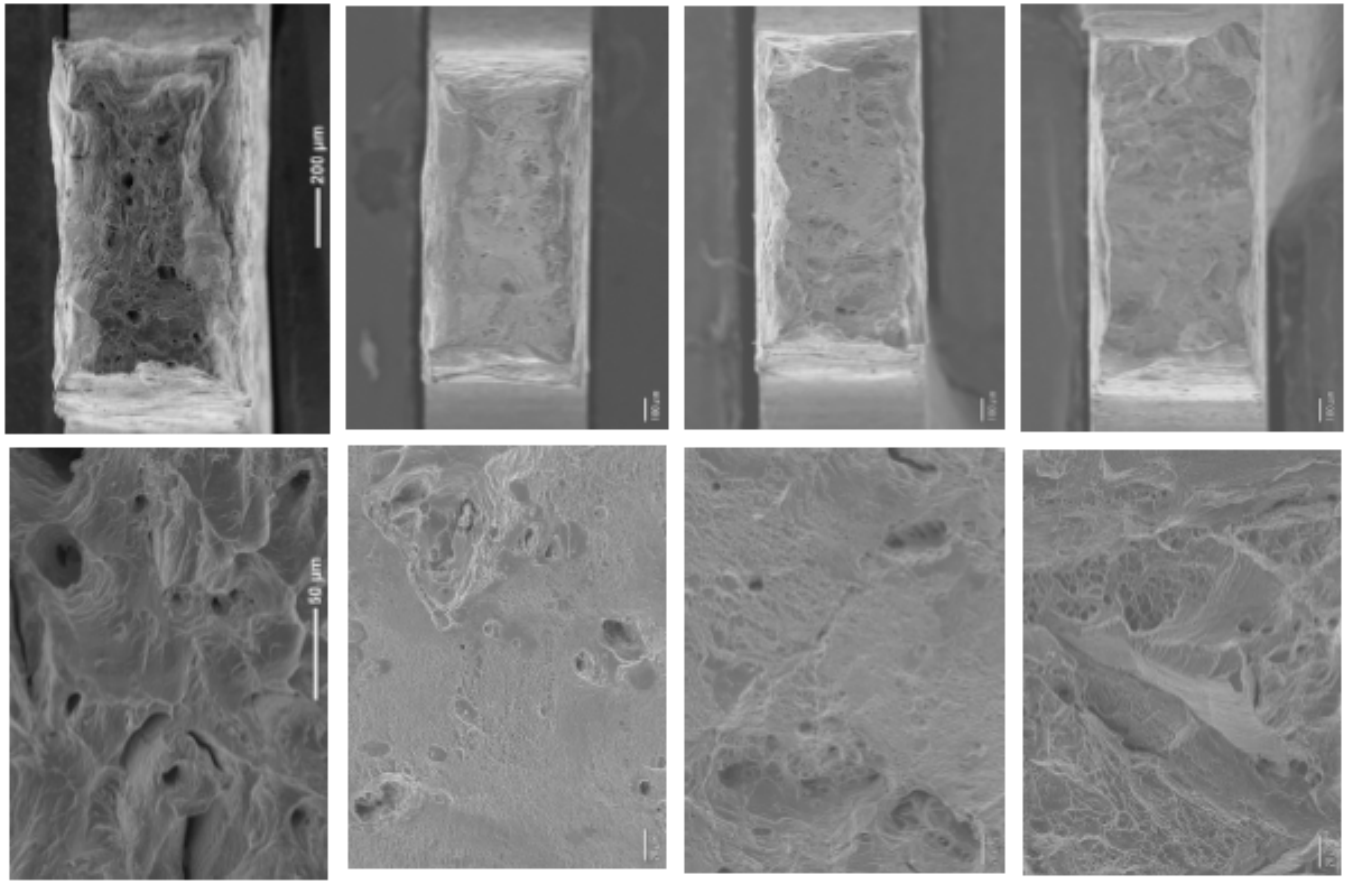
Fracture surface -JPCA-



- Lower dpa specimens fractured in ductile manner and show large necking. Higher dpa specimen irradiated at 430℃ shows partially intergranular surface.

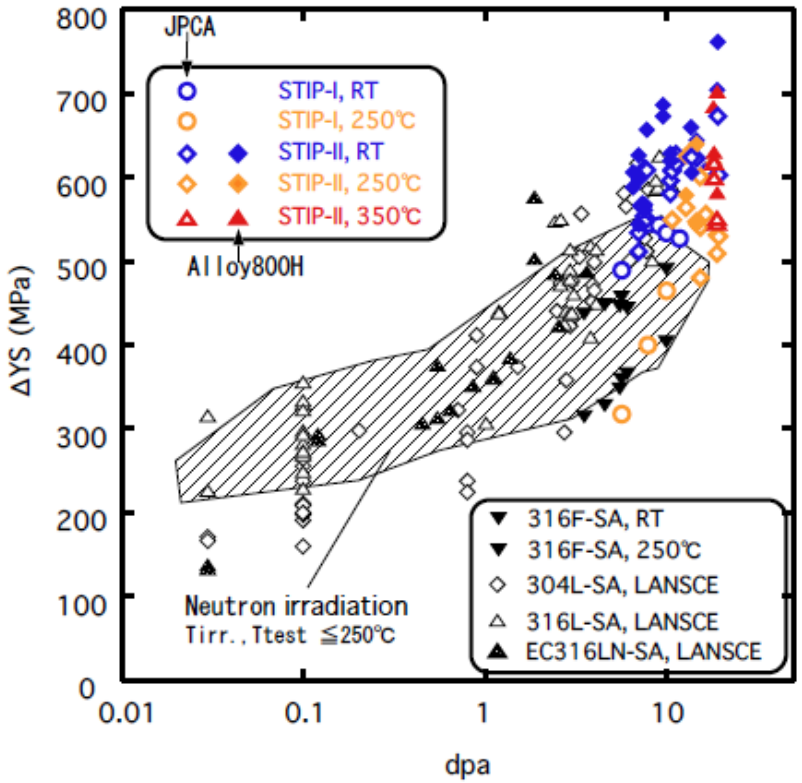
Fracture surface -Alloy800H-

RT Test



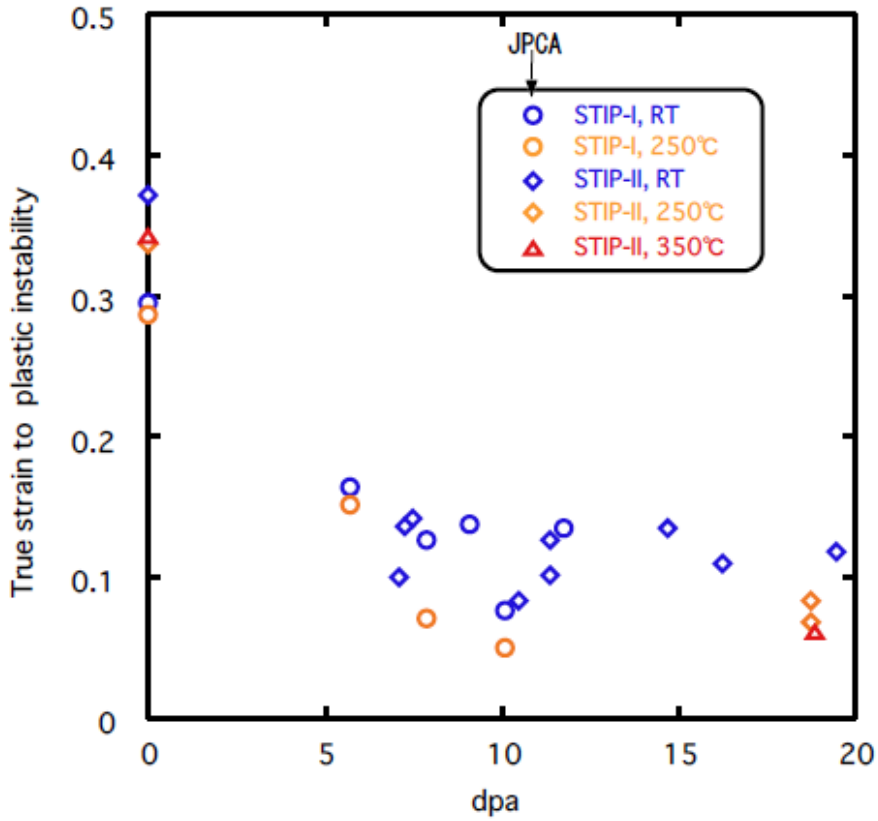
- Lower dpa specimens fractured in ductile manner and show small necking.
- Higher dpa specimen shows partially intergranular surface.

Comparison for data -Hardening-



- The increase in YS of the proton irradiation is within the fission data band at lower dose (<5dpa).
- The YS increase shows a tendency to exceed the upper bound of the fission neutron data band.
- The increase in YS of Alloy800H is larger than that of JPCA.

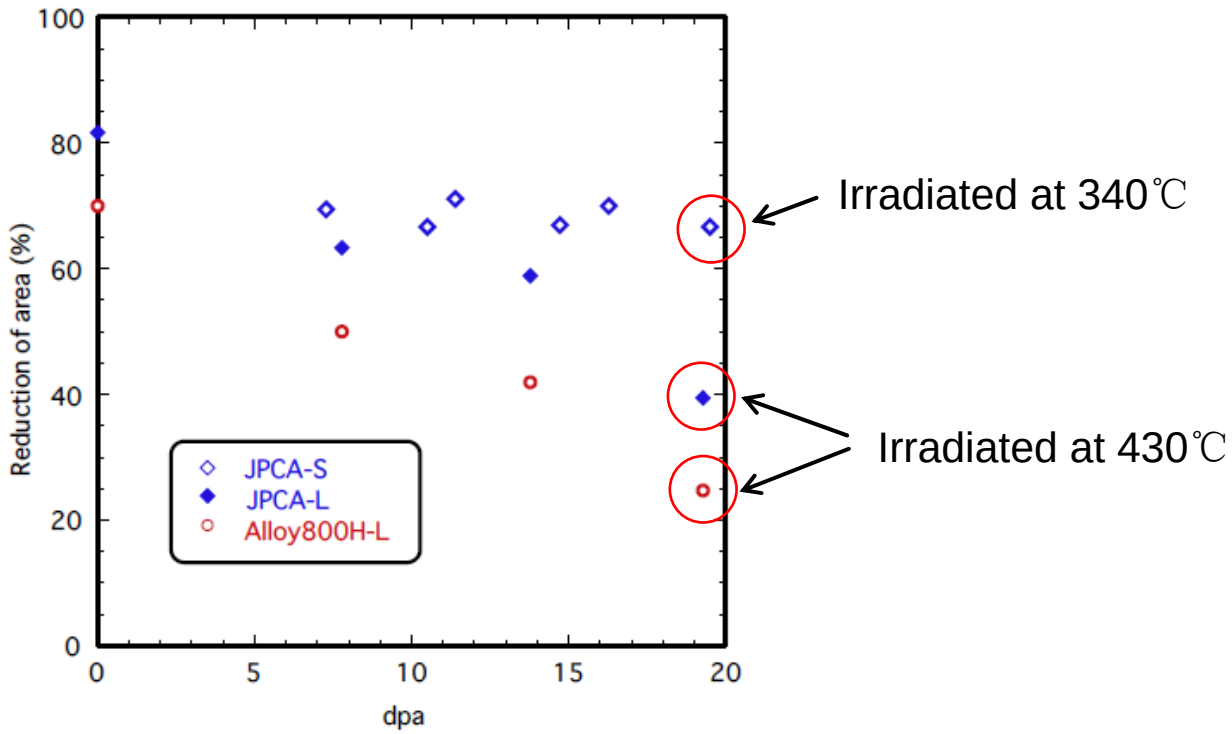
Ductility -JPCA-



- Degradation of ductility on JPCA stopped around 10 dpa.
- JPCA specimens irradiated up to 19 dpa still have ductility.

Discussion -RA-

RT test



- RA of JPCA is larger than that of Alloy800H.
- L-size specimens decrease with increasing dose level.
- RA of S-size JPCA is not changed between 7-19 dpa.
- RA of specimens showed intergranular surface are lower than that of ductile specimen.

Discussion -JPCA-

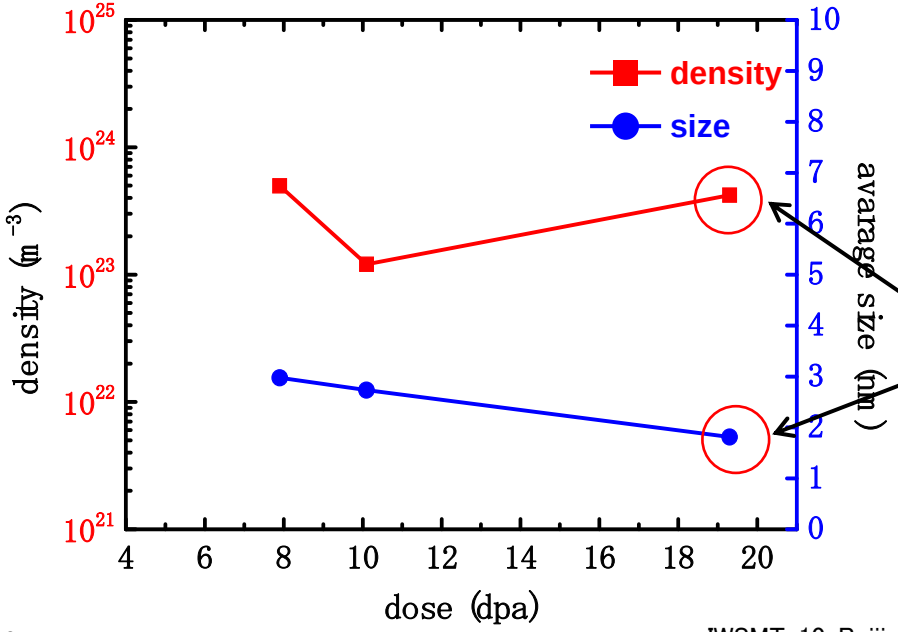
・Ductility of S-size specimens is not changed between 10-19 dpa.

・Ductility is kept after 19 dpa irradiation in spite of about 1600 appm He.

From the results of TEM observation (Hamaguchi et. al.),

・There is no change in density and size of He bubble between 10-19 dpa.

・He bubbles distribute homogeneously and precipitation of He is not observed.



Samples were cut from grip part of the S-size tensile specimen and prepared by electrolytic etching.

Irradiated at 340℃

Summary

- The tensile properties on high energy proton and spallation neutron irradiated austenitic stainless steels at 6.5-19.5 dpa were investigated.

- The YS increase of the proton irradiation increase shows a tendency to exceed the upper bound of the fission neutron data band at higher dose (>5dpa).
- The increase in YS of Alloy800H is larger than that of JPCA.

- Degradation of ductility on JPCA stopped around 10 dpa.
- JPCA specimens irradiated up to 19 dpa still have ductility.
- The results will be explained by the results of TEM observation.

- For both steels, lower dpa specimens fractured in ductile manner and higher dpa specimens irradiated at 430℃ showed intergranular surface.
- RA of JPCA is larger than that of Alloy800H.

Future plans (STIP specimens)

- TEM
  > JPCA (Irrad. at 430℃), Alloy800H, W, Ta

- Tensile tests
  > W, Ta (Next February - March)

- Bend-fatigue tests
  > 7.5-19.3 dpa irradiated JPCA.
  > Fatigue life is not changed after irradiation.
  > All JPCA specimens fractured in ductile manner.

- Contribution to target life-time evaluation
  > Spallation neutron source
  > ADS beam window