

Irradiated T91 Testing from the MEGAPIE Experiment

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MEGAPIE!



- Megawatt Pilot Experiment
- Inserting a lead-bismuth target as the spallation target in the SINQ neutron source (590MeV Protons)
 - ADS R&D
 - Provides irradiated T91 (~9Cr, 1Mo, 0.1C, Si, Ni, V, Mn etc.) and 316SS samples
 - Lead-bismuth corrosion studies
- 15+ year project, ending this year
- 10 Labs, throughout the world
 - CEA, KIT, PSI, SCK-CEN, JAERI, LANL/DOE
 - CNRS, ENEA, KAERI







Operated by Los Alamos National Security, LLC



























Nuclear Energy





Computed temperatures in lower structures (1)



Beam Window



PIE Technical Meeting

Aix en Pce Sept. 24 2008





Heat Treated Control Specimens

- Heat Treated at 750C for 2 hr
- Hardness dropped 301 (+/-13) to 233 (+/-6)
- Machined a few flat specimens out of curved control sample to test later...





No alignment hole, slight curvature (0.25mm under grip section) necessitates adjustments to tensile jig. Slight differences in thickness along height of calotte.





















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Test Set-up – Testing Conditions

- Testing performed at RT
- Strain rate = 5 x 10⁻⁴/s
- Compliance tests performed to remove machine compliance from stress/strain curves.







Mechanical Tests





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Control

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Irradiated 4.5 dpa Tirr =312C

Lens MX(G)-20167 · No

Irradiated 2.08 dpa Tirr=256C Lens MX(G)-2016Z : Normal : x120 H-View 2.215 mm Resolve 0.002 mm

0.5 mm



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Lens MX(G)-2016Z : Normal : x120 H-View 2.215 mm Resolve 0.002 mm

0.5 mm





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	Sample	Yield	UTS	UE	TE		Sample
		MPa	MPa	%	%		
MEGAPIE	Control A	598	716	5.7	29.9	Megapie LANL	Control A Z2
MEGAPIE	Control B	592	718	5.85	*	Megapie LANL	Control B Z2
MEGAPIE	Control C	600*	707	7.05	30.5	Megapie LANL	Control C Z2
MEGAPIE	Tirr, 251C, 1dpa	752	826	7.9	30.9	Megapie LANL	H02-1-05-C-Z2, Tirr = 253C, 1dpa
MEGAPIE	Tirr=256C, 2.08dpa	800	859	7.8	26.5	Megapie LANL	HO2-1-05-B-Z2 Tirr=256C, 2.08dpa
MEGAPIE	Tirr=312C, 4.5 dpa	890	959	5.9	19.3	Megapie LANL	H02-1-05-A-Z2, Tirr=312C, 4.5 dpa
	Tirr=309C, 5.1 dpa	1125	1146	2.3	12.4	Megapie PSI	Tirr=309C, 5.1 dpa
	Tirr=273C, 2.4dpa	955	956	3.3	24	Megapie PSI	Tirr=273C, 2.4dpa
	Tirr=260C, 1.24dpa	677	706	5.8	23.1	Megapie PSI	Tirr=260C, 1.24dpa
ATR	Control 1c	610	734	7.28	17.5	ATR LANL	Control TA#1c
ATR	Control 2c	610	726	6.32	16.4	ATR LANL	Control TA#2c
ATR	Tirr= 290C, 6 dpa	1055	1102	1.07	5.7	ATR LANL	Irradiated TA04 Tirr= 290C, 6 dpa
ATR	Tirr =290C, 6dpa	1005	1078	0.9	3.8	ATR LANL	Irradiated TA05 Tirr =290C, 6dpa
	High Temperature Tests						
MEGAPIE	Control A-Z3 Test temp =250C	543	624	3.9	25.3	Megapie LANL	CONTROL A Z3
MEGAPIE	Control A-Z1 Test Temp = 300C	534	614	4.1	25	Megapie LANL	CONTROL A Z1











Conclusions



- Hardening and yield behavior consistent with previous runs of irradiated T91 and other
 MEGAPIE tests, some irregularities to explore in continued testing.
- Continued testing (bend and high temp tension) and examination of specimens.







Finite Element Simulation of a Curved Bend Test





Figure1: Curved bend sample geometry. Units in mm.



 A unique test fixture was designed in A2 Tool Steel hardened to 55RC to accommodate the curved bend sample.

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• All dimensions in mm.



Finite Element simulation



- Abaqus 6-14, Standard
- Elastic-plastic material model
- Contact algorithm between all surfaces.
- Friction coefficient of 0.3, between all contact surface.



Figure 5: FE assembly a) Curved sample assembly and b) Flat sample assembly

A			
B			

Figure 6: X-Y View of the sample mesh a) Curved sample and b)Flat sample.

	Element	Number of	Material	
	Туре	Elements		
Din	C3D4R	0190	A2 Tool	
PIN		9180	Steel	
	C2D4D	2040	A2 tool	
Loau Fixture	CSD4K	2040	steel	
Specimen	C3D8R	46240	T91	
flat/ curved				



True Stress vs. True Strain forTirr=256C,



Mechanical Properties

	Elastic Modulus [GPa]	Poisson Ratio	Yield Strength [MPa]	UTS [MPa]
Tirr=256 C, 2.08 dpa	207	0.28	740	859
Control A Z2	207	0.28	598	716

Engineering Stress vs. Engineering strain for Tirr=256C and Control A

2.08dpa and Control A 1000 1000 900 Tirr=256C. Engineering Stress [MPa] ControlA 2.08dpa 800 800 True Stress [Mpa] 700 600 600 500 400 400 300 200 200 100 0 0 0 0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.05 0.1 0.15 0.25 0.2 0.3 0 **Engineering Strain [%]** True Strain [%]



Load Vs Displacement Bend Test

Load vs. Displacement for Tirr=256 and Control A









Maloy, Journal of Nuclear Materials 343 (2005) 191-196



Results: Stress contour plot of Tirr=256, 2.08 dpa and control A

elastic response



Results: Stress contour plot of Tirr=256 mos





Future Work

- Comparison between curved test of bend sample and previous geometries.
- Addition of damage and irradiation parameters to the material model.

