



Creep Studies in Nuclear Structural Materials (Stainless Steel)

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Brief Overview

- Steel as a Structural Material in Power Plants.
- Importance of Creep.
- Current Work.
- Experimental Setup.
- Compression Tests at high temperatures.
- Creep Results and Analysis.
- Future Work.



Importance of Steel in the Power Plant Sector

- The development of power plant technology towards larger units and higher efficiencies is linked to the development of creep resistant ferritic steels.
- Large forgings and castings are used to build turbines, whereas tubes, pipes, plates and fittings are the typical products for application in pressure vessels, boilers and piping systems. In addition to high creep strength other material properties are also important, like hardness, corrosion resistance, and weldability.

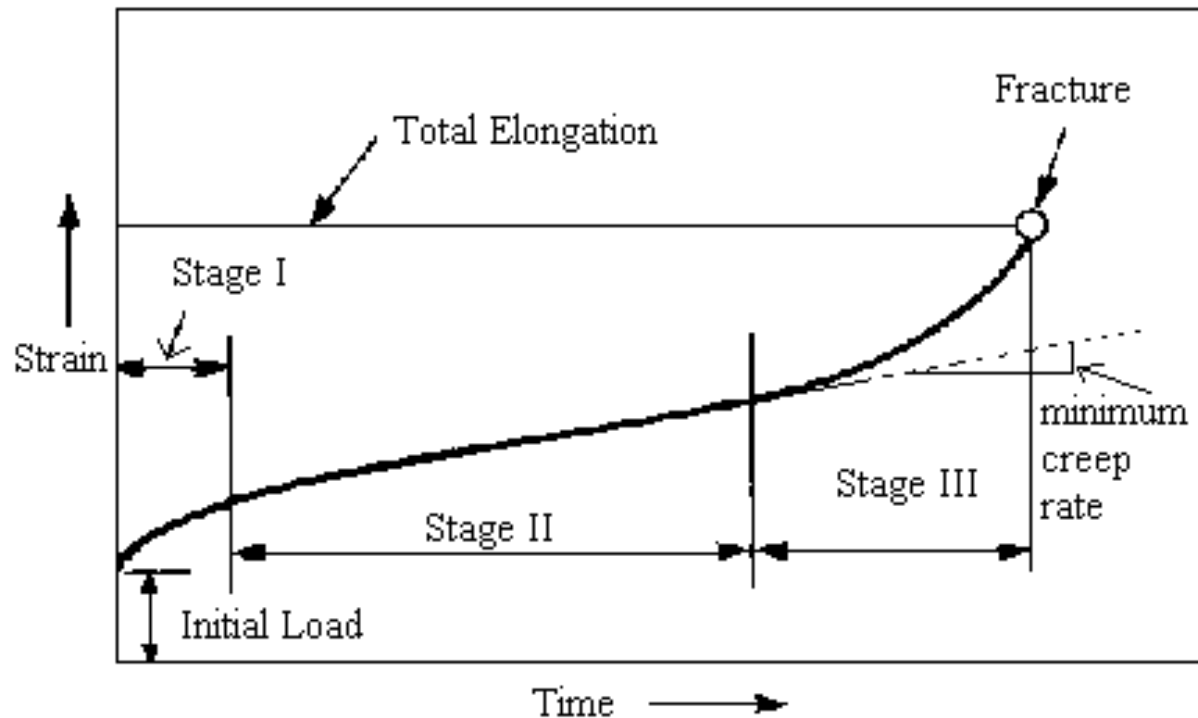


Creep

- Permanent deformation occurring below the yield point of the material due to prolonged exposure to stress below yield stress.
- More prominent at high temperatures.
- Certain components in power plants have operating conditions which are in excess of 400deg C. At such temperatures creep would play a prominent role in the design and maintenance of the components.
- 600 deg C is generally considered the operating limit for austenitic steels. The current research deals on the behaviour of steel at this extreme end.



Typical Creep Curve





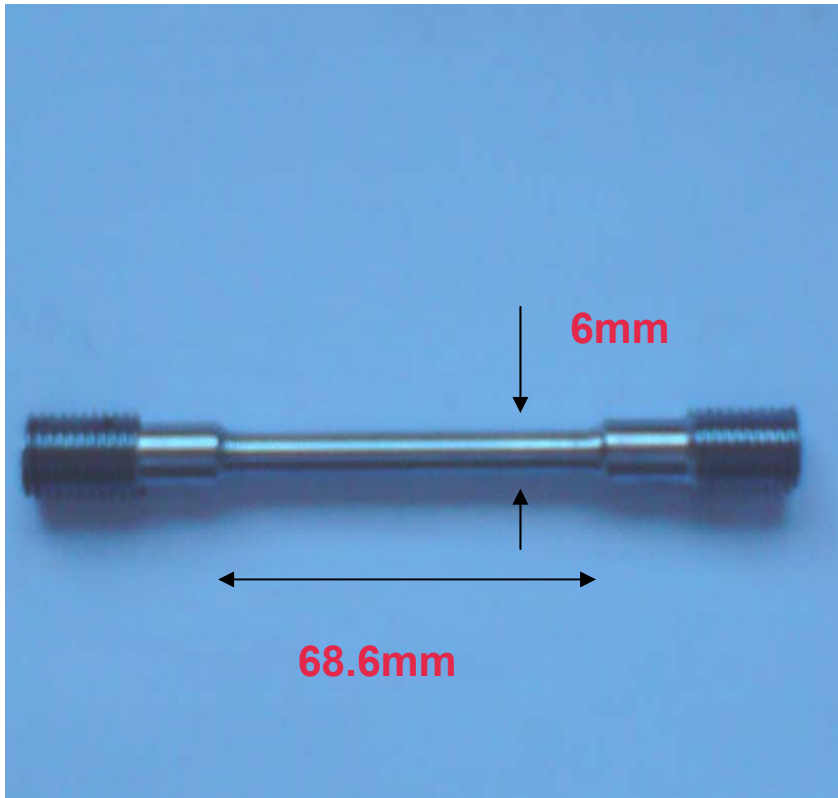
Experimental Setup

- Setup consists of a Tensile Specimen around which a furnace is placed.
- Furnace is a single wound induction furnace. Consists of a single heat zone.
- PID Controller for the furnace.
- Specimen is 304s grade 68.4mm length with 6mm diameter.



Setup Pictures

Specimen



Furnace



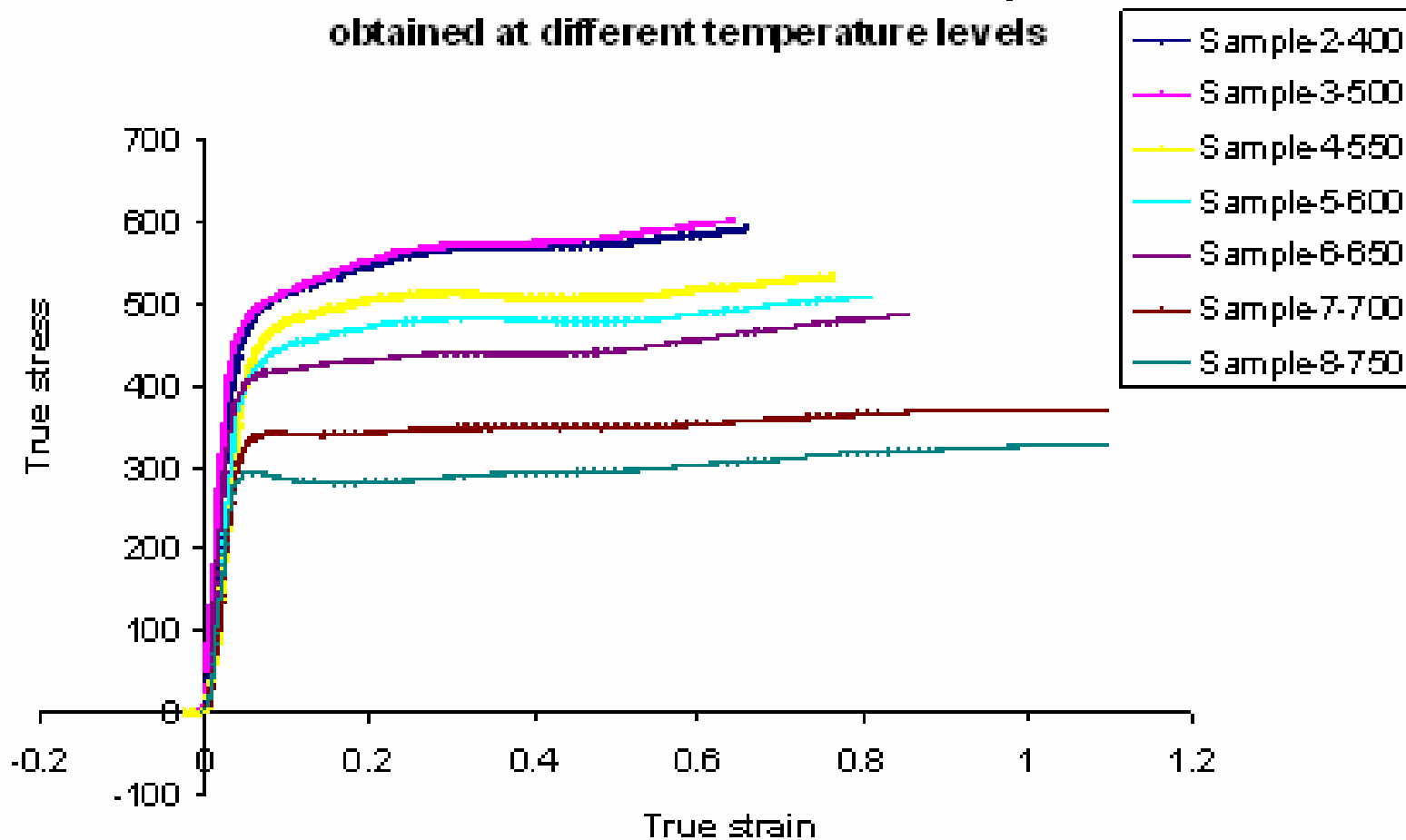


Experimental Work

- Compression Tests done at various temperatures to ascertain flow stresses for the material.
- Results were used along with operating conditions in power plants to decide the temp-stress values for the creep tests.
- 600deg C is considered as the limit for current austenitic steels.
- Experiments were conducted around this temperature range to determine the material behaviour over a period of time.



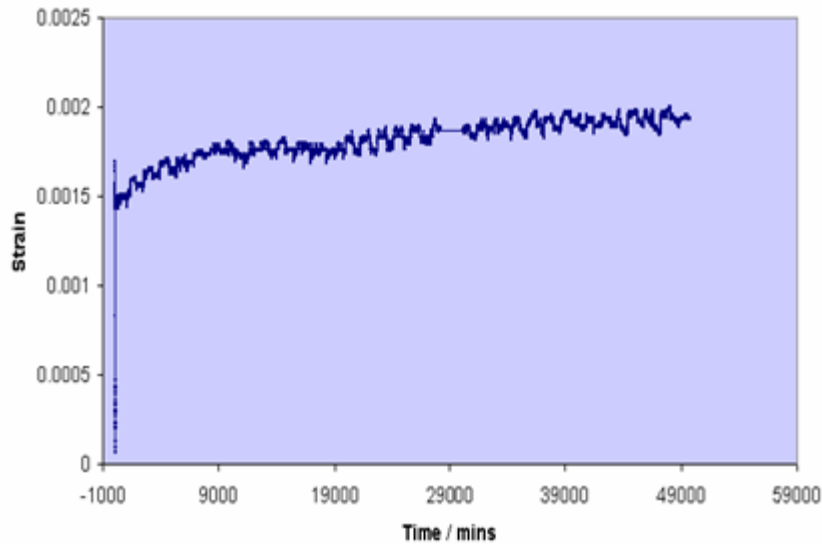
True stress - strain curves for stainless steel compression tests obtained at different temperature levels





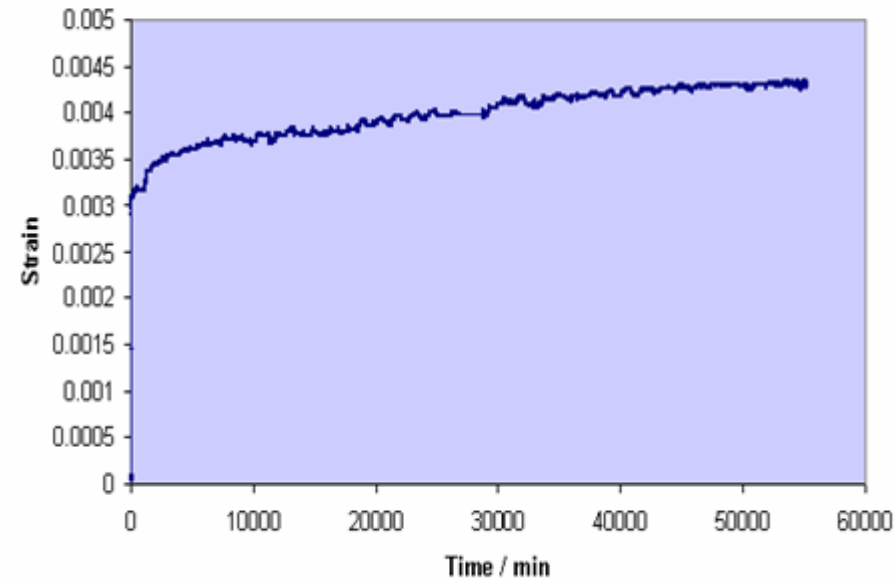
Creep Curves

Creep curve @ 550 °C and constant stress 200 MPa
Result shown after 825 hours



550degC and 200 MPa

Creep curve @ 550 °C temperature and 250 MPa load
Result shown after 1248 hours

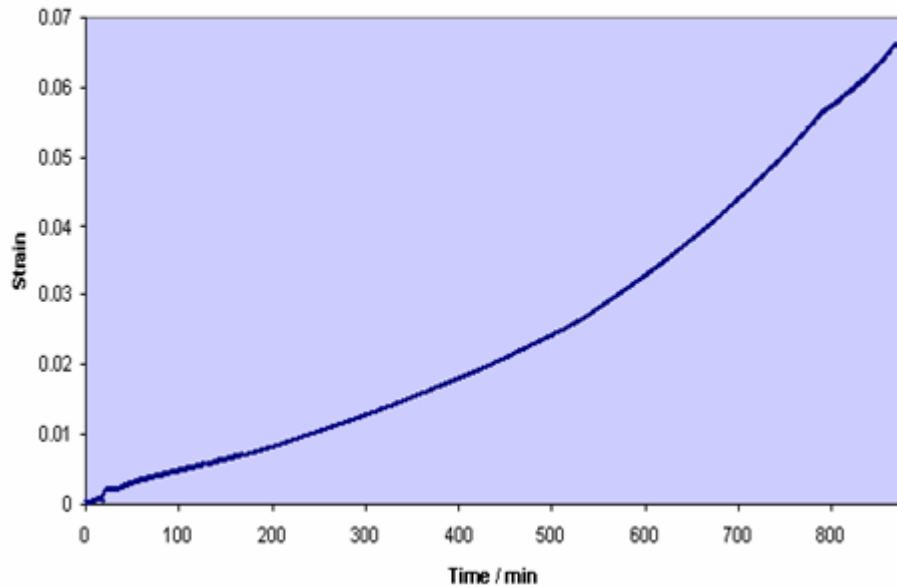


550degC and 250 MPa



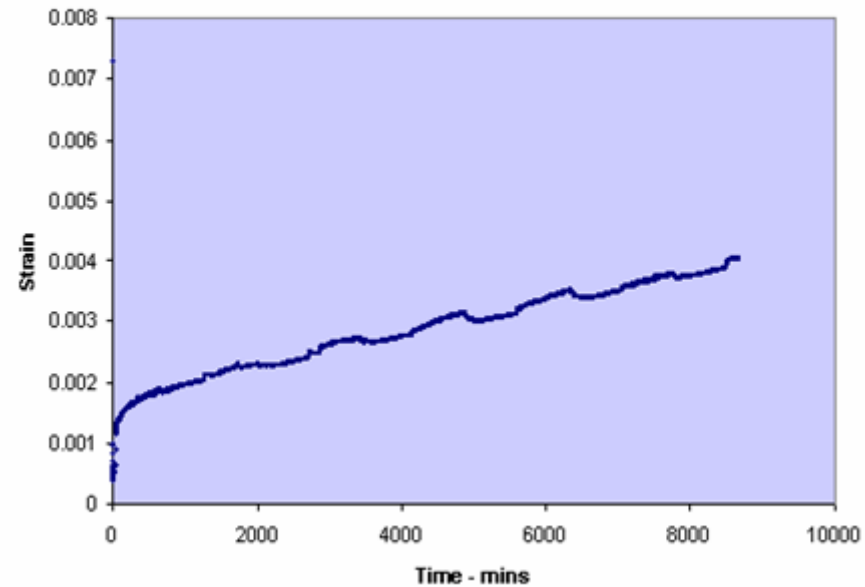
Creep Curves

Creep curve @ 700 °C and constant stress of 150 Mpa
Sample ruptured after 15 hours



700degC and 150 MPa

Creep curve @ 700 °C and at constant stress of 100 MPa
Result shown after 144 hours - test still in progress



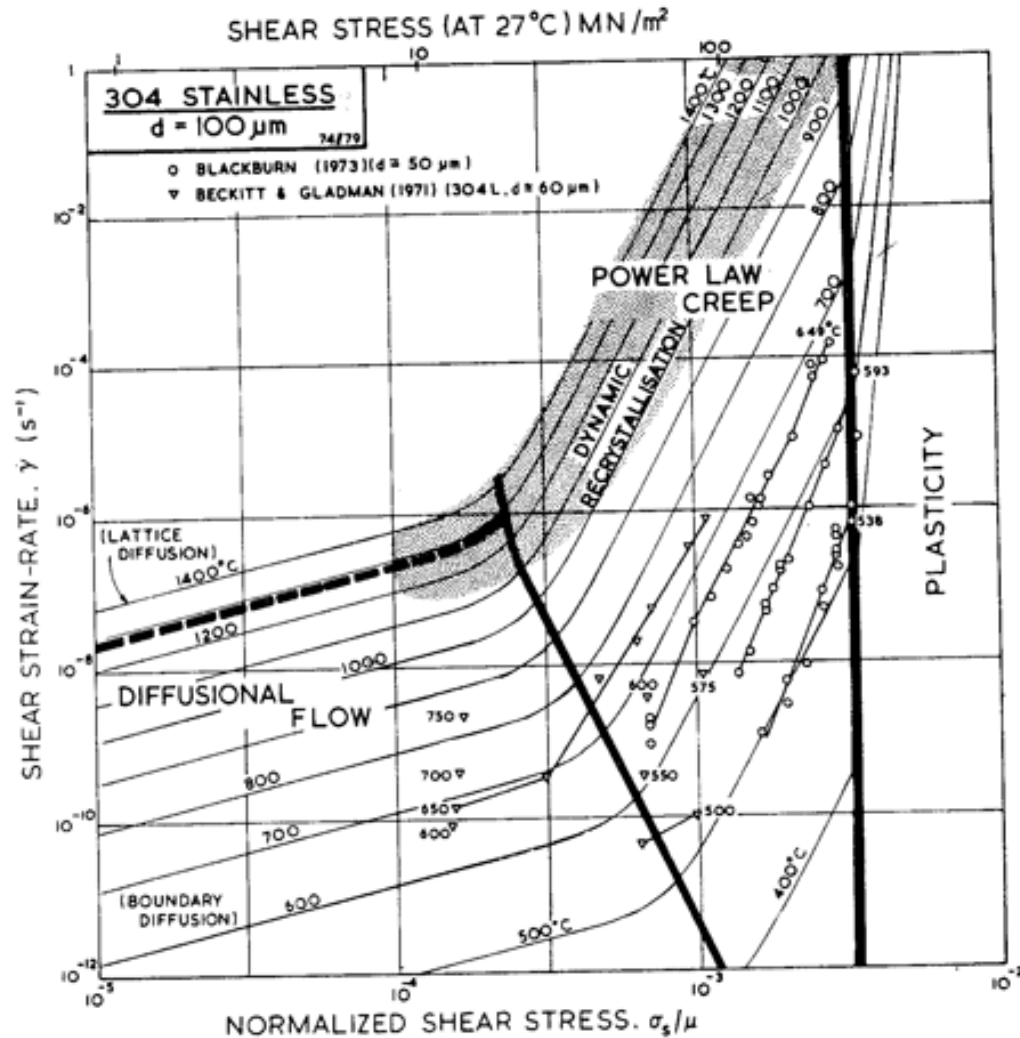
700degC and 100 MPa

Summary of Creep Results till date



Frame	Temperature (°C)	Stress (MPa)	Creep-rate (dε/dt)[s ⁻¹]			Comments
			Secondary	Tertiary	Overall	
1	550	200	7.697E-11	-		Sample was not tested till rupture result shown till 825 hours
1	600	200	1.052E-09	-		Test in progress. Result shown till 248 hours
2	550	250	1.745E-10	-		Sample was not tested till rupture result shown till 1248 hours
2	650	200		-	6.845E-07	Sample ruptured within 28 hours
2	700	150		-	1.271E-06	Sample ruptured within 15 hours
2	700	100	1.412E-10			Test in progress. Result shown till 144 hours
4	650	150	7.673E-08	6.4349E-07	8.258E-07	Sample ruptured within 84 hours.

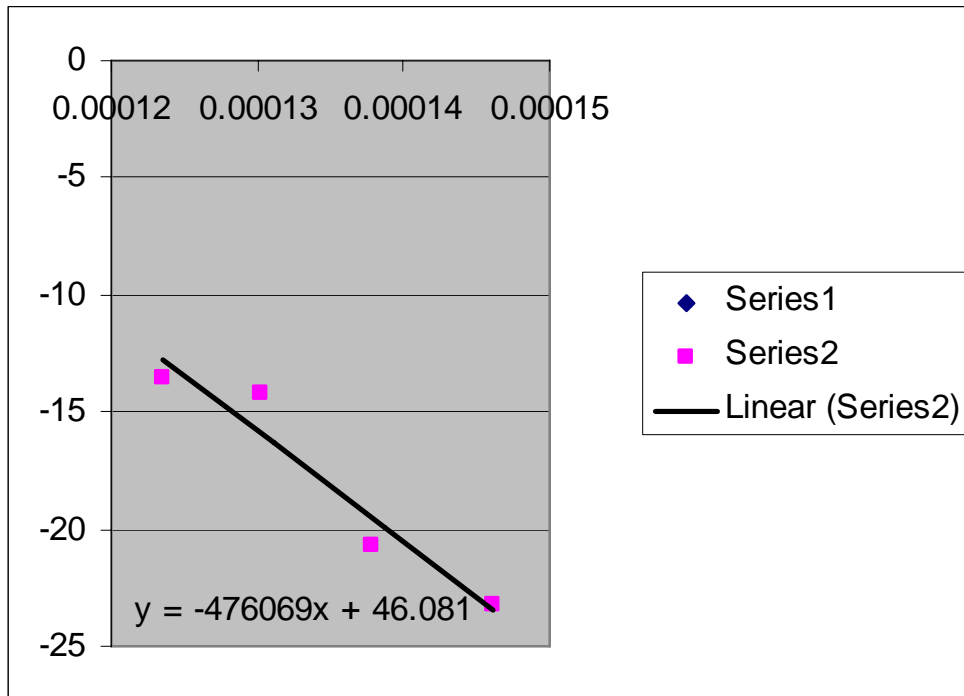
Creep Mechanism Map





Analysis and Calculation of Activation Energy and Material Constants

- $\dot{\varepsilon} = A \cdot \sigma^n \cdot \exp(-Q / RT)$



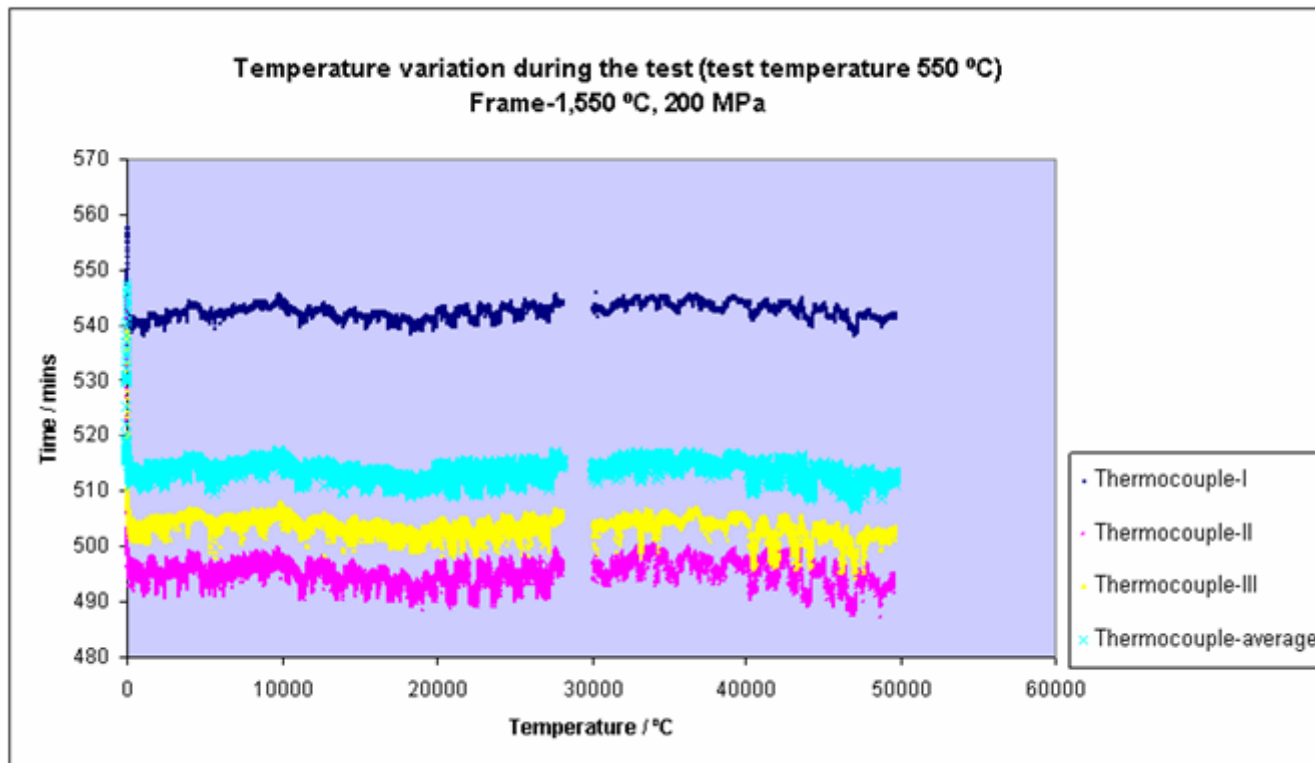
Activation Energy(Q)=
476KJ/mole

n=4.1



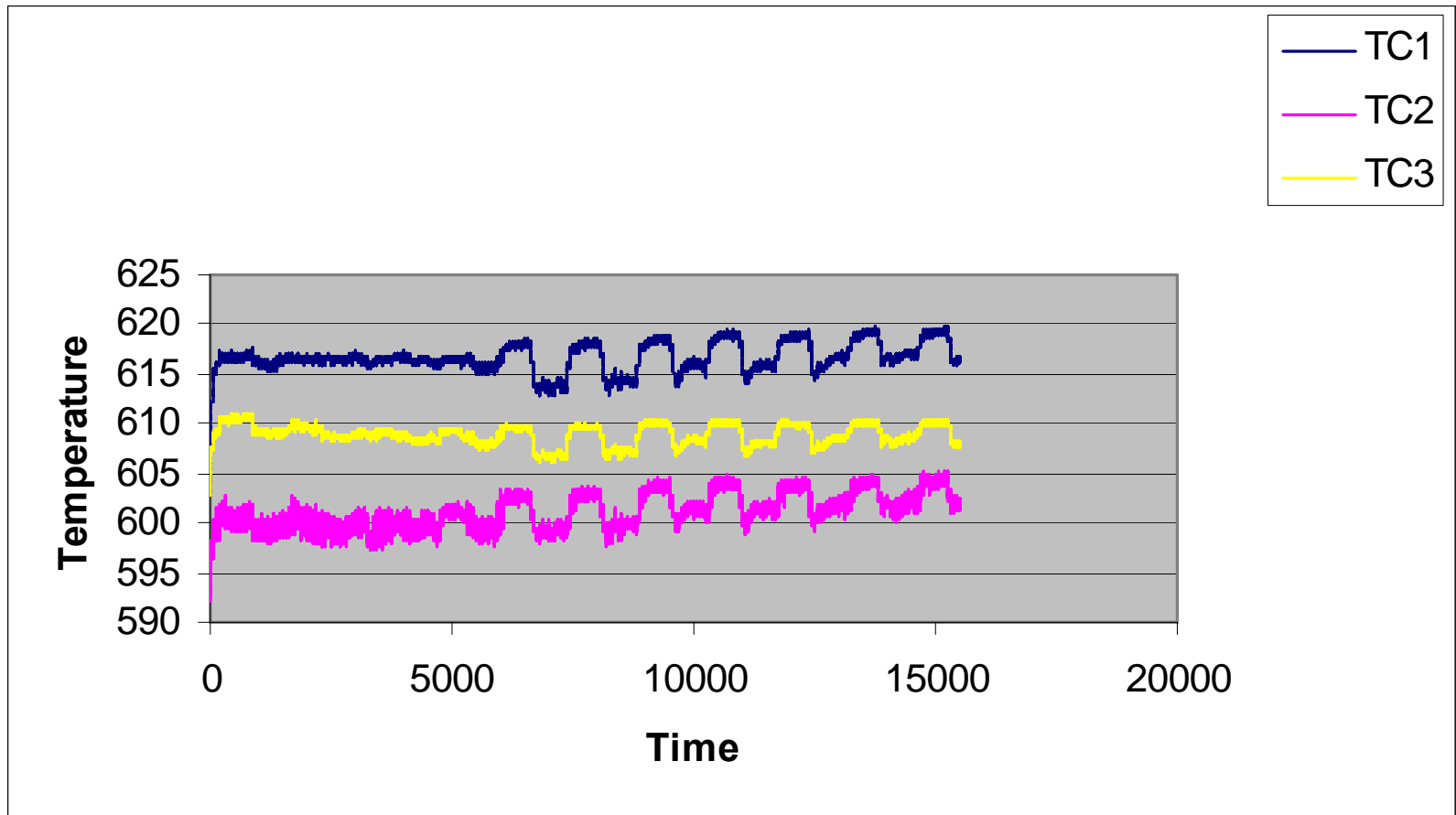
Problems Faced

- Temperature Variation across the specimen. Standards allow 10deg. variation across the specimen





Temperature Variation





Future Work

- Completion of the Current Set of Experiments.
- Texture and Grain Size of Raw, Failed and Stressed Material. This would be done using Optical Microscopy and EBSD.
- Development of a non-contact system to measure creep strains. Probable techniques might involve using Laser range finders or Digital Image Correlation.
- Creep in Zirconium and Nickel based Superalloys.
- Effect of Residual Stresses on Creep Strain.