

HIGH TEMPERATURE MEASUREMENTS USING 3D DIGITAL IMAGE CORRELATION

Correlated Solutions Inc VIC-3D, 3D - Digital Image Correlation

For Non Contact Full Field

Displacement and Strain Measurement & Frequency Analysis.

A Brief Application Note on the Tests Carried out by Pyrodynamics

At Various Organizations in India using VIC-3D, 3D DIC System.

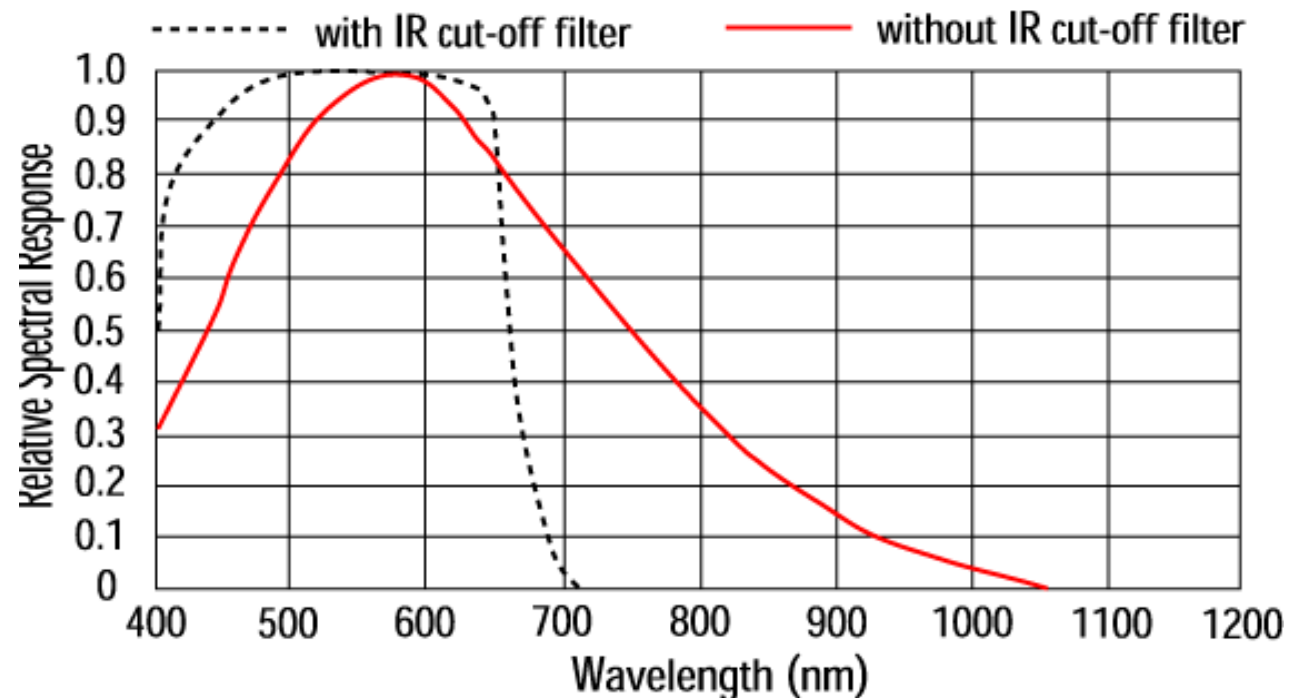
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Experimental Challenges Faced during High Temperature Tests.

1. Paints must withstand at High Temperatures.
2. Cameras should be isolated from the Heat waves emitted from the specimens.
3. Metallic specimen heated to high temperatures emit huge IR radiation.
4. Uniform Heating of the Specimen.

- ❖ Point Grey Research 2MP Cameras used for 3D DIC Measurements. The CCD sensor is sensitive in the IR range.
- ❖ An IR +UV cut-off filter was fitted to the front end of the Lens.

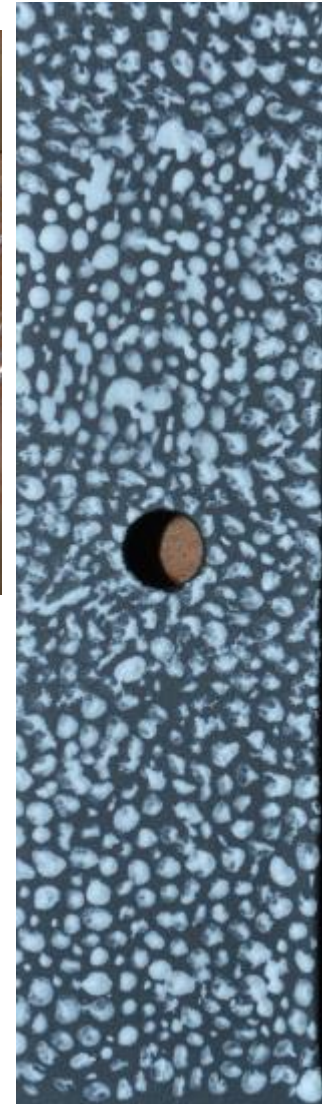


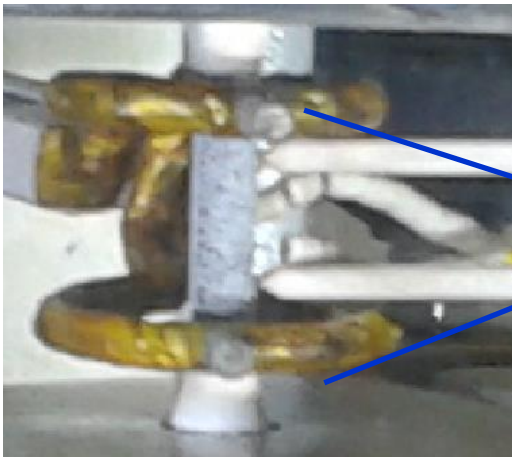
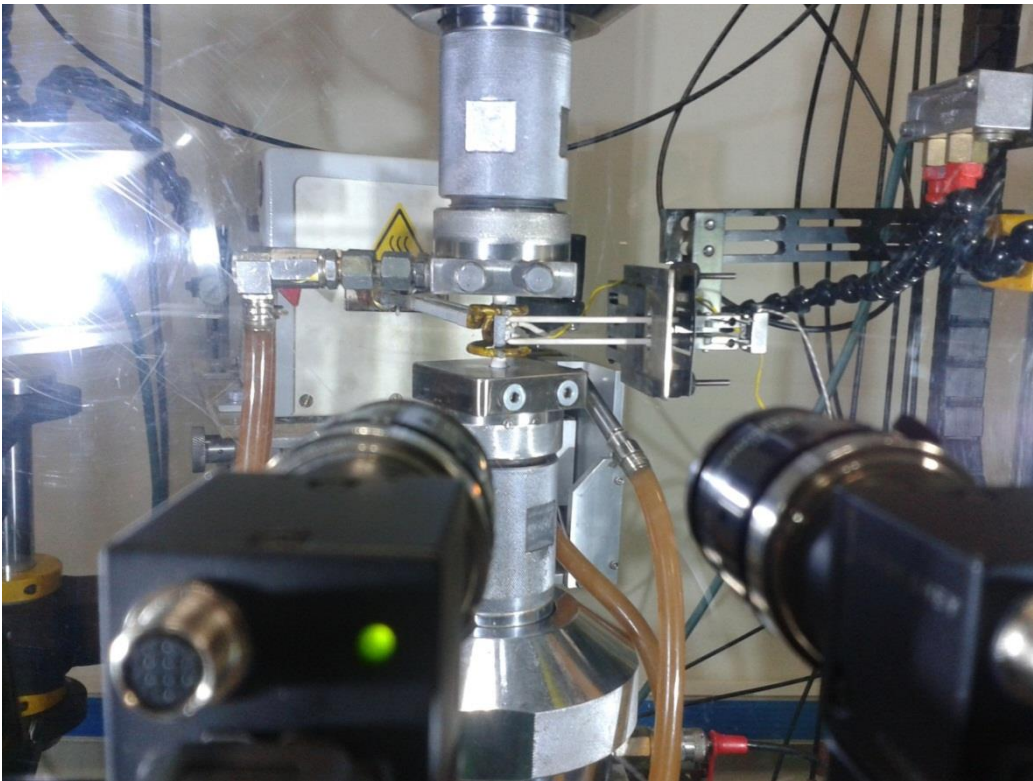
- ❖ High Temperature Paints was used for these experiments.

These paints are available in a spray Can.

- ❖ These Paints can withstand temperatures upto **1000 °C.**
- ❖ The specimen was painted white. Black Color speckle were applied on it.





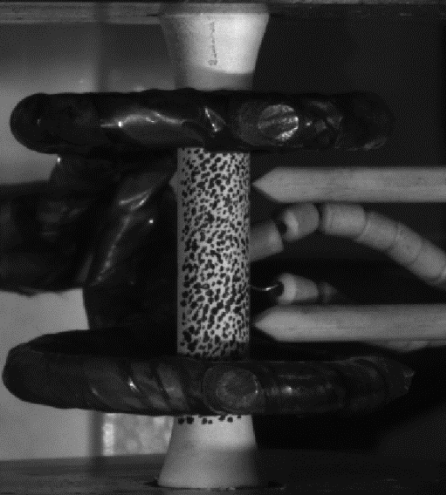


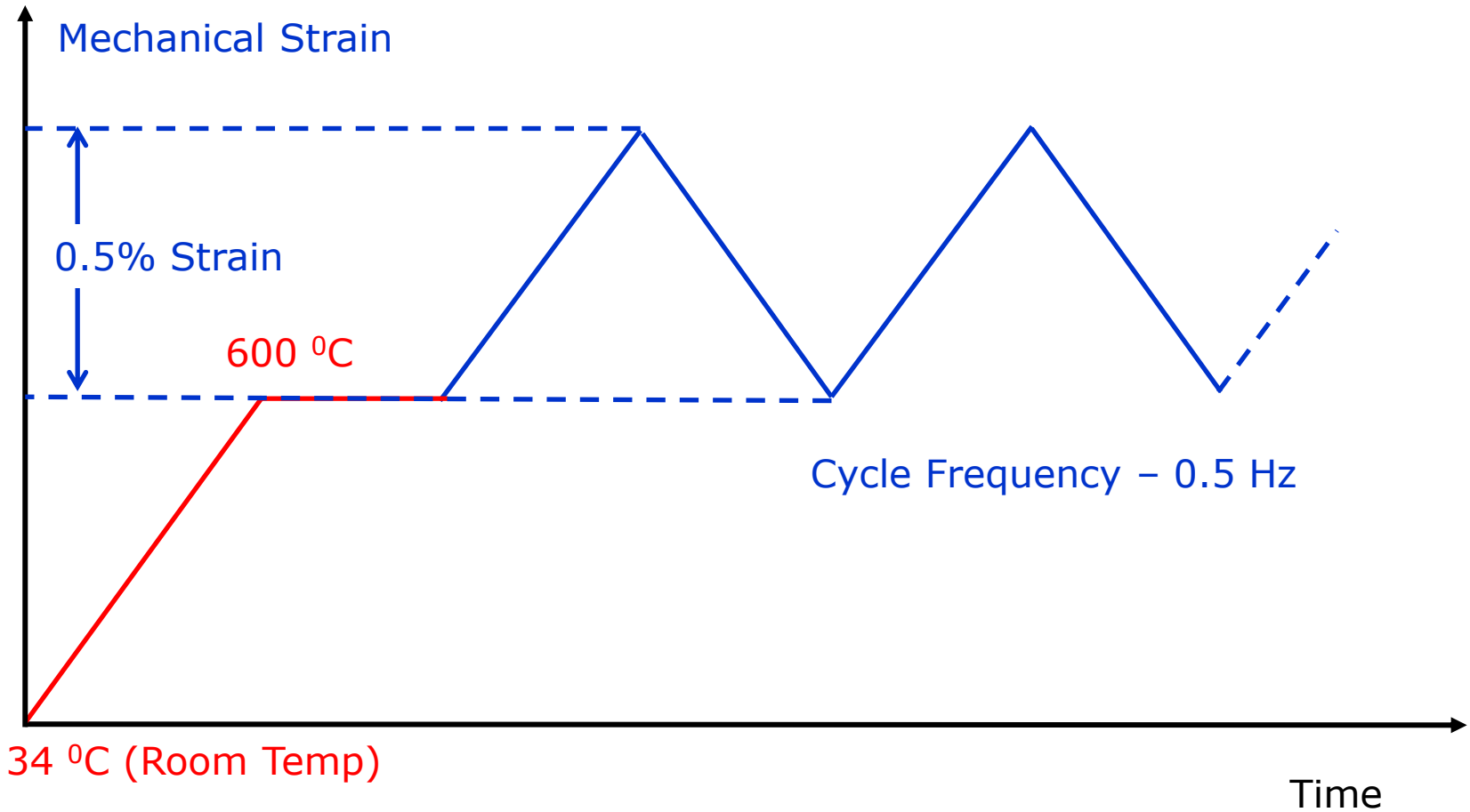
**Test Specimen
heated using
Induction Coil.**

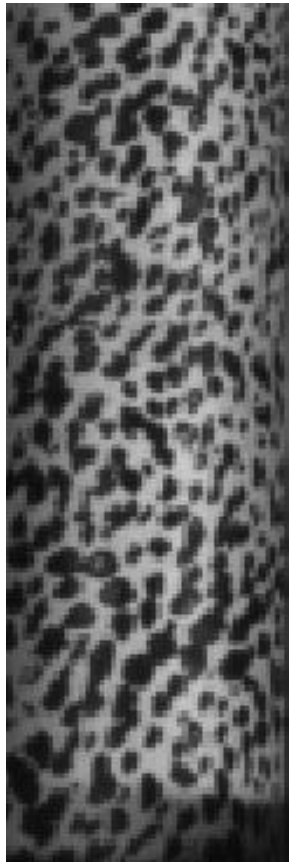
**Upper Jaw is
fixed and
lower jaw
moves down.**

- ❑ High Temperature Low Cycle Fatigue (LCF)**
- ❑ In-Phase Thermo Mechanical Fatigue (TMF) Cycle**
- ❑ High Temperature Creep Studies.**
- ❑ Component (Turbo Charger) Test**

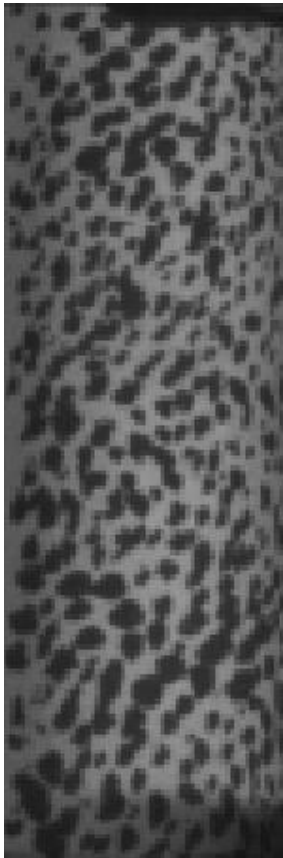
Experimental Data will be used for Material Modeling and FEM Analysis.

| | |
|---|---|
| Test Component | Circular Tensile Specimen - Cast Iron |
| Cross Section Area | 31.67 mm ² |
| Load Method | Strain Controlled 0.5% Strain Amplitude Stress = 330 Mpa Strain Rate:- 1% s ⁻¹ Load = +/- 10kN |
|  | |
| Heating Rate | 10 °C per second |
| Temperature | 600 °C |
| Cycle Frequency | 0.5 Hz. |
| Camera Rate | 5 fps. |
| Image Correlation | Subset:- 21. Step Size:- 5. Strain Filter Size:- 15. |

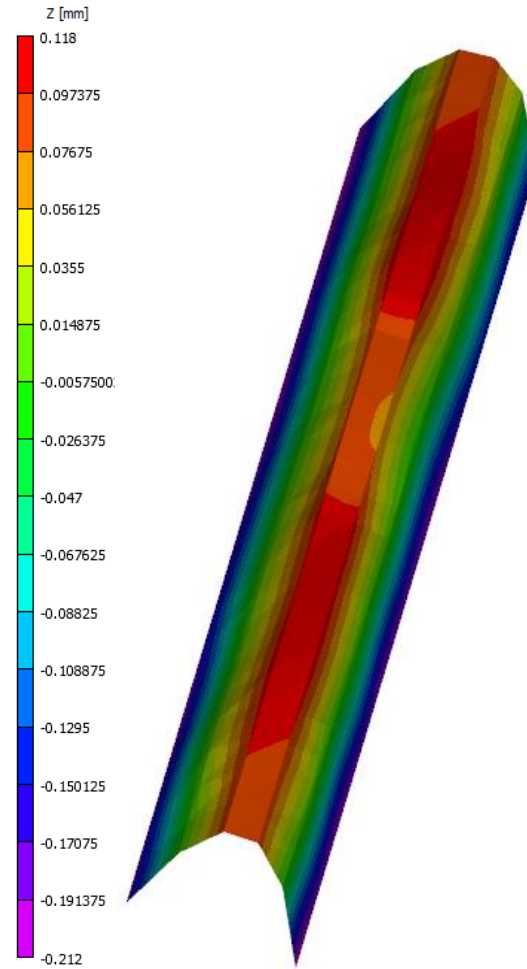




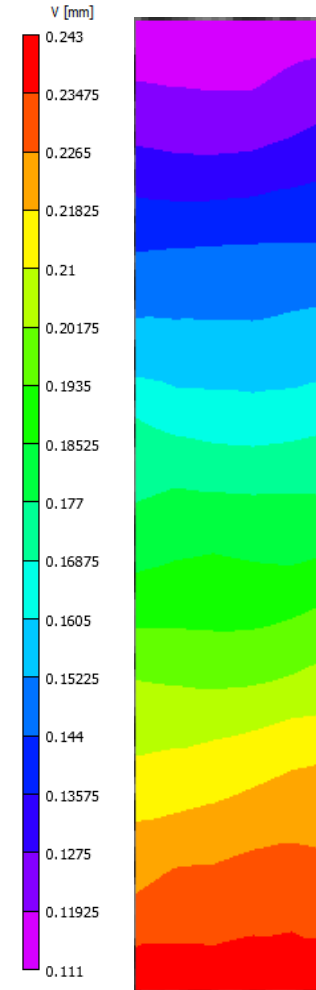
Raw Image
(34 °C)



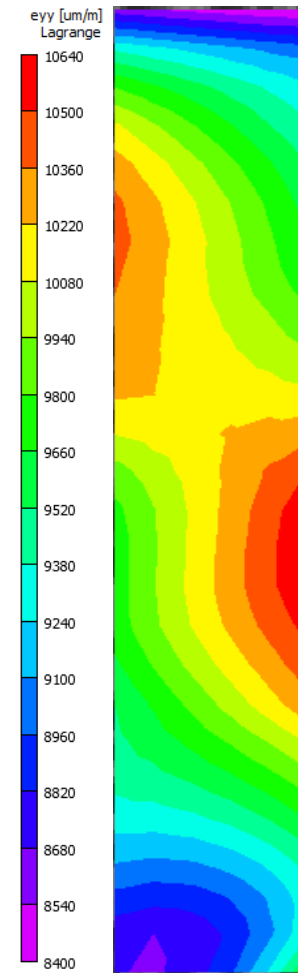
Raw Image
(600 °C)



Z Co ordinate
(mm)

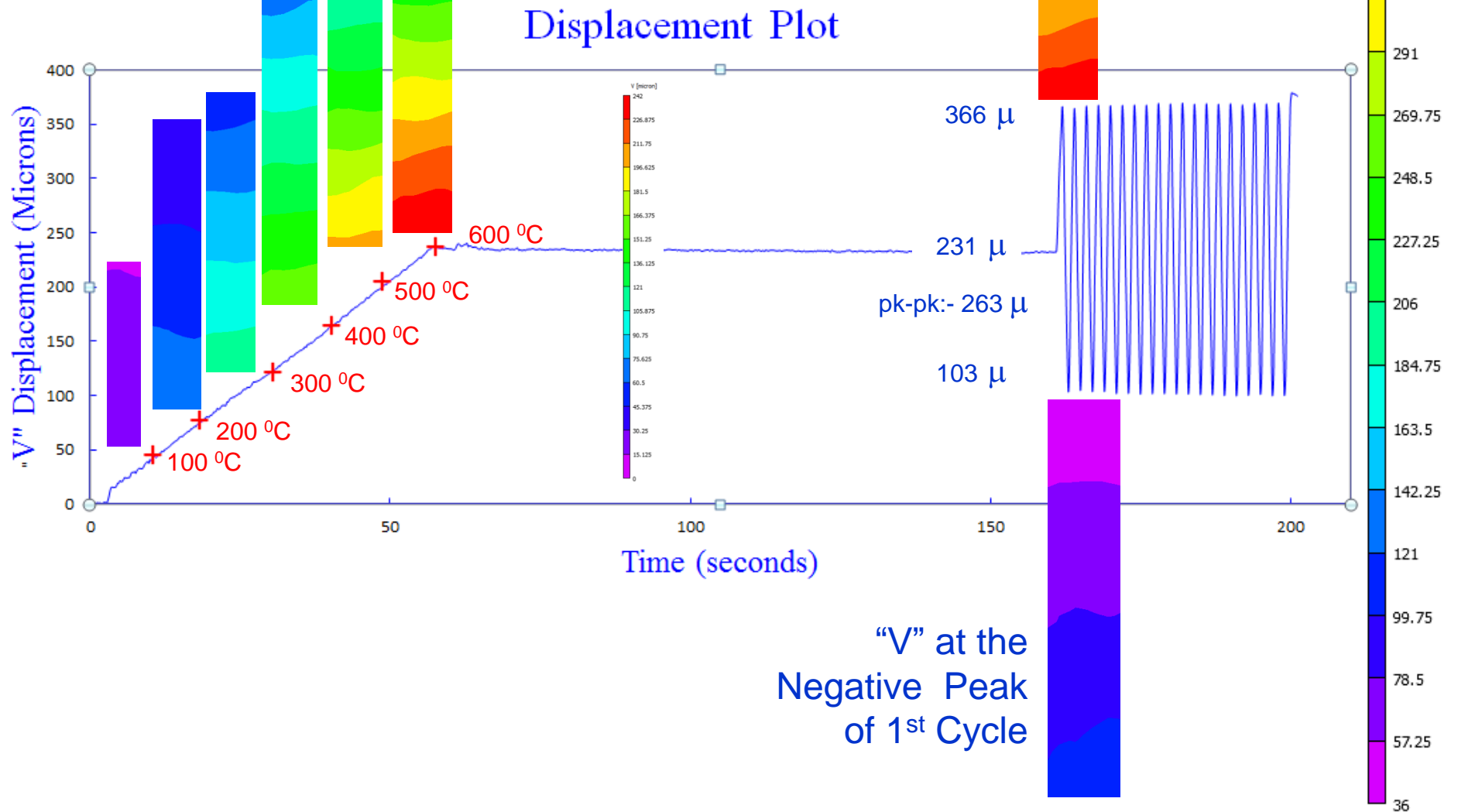


"V" Displacement(mm)
At 600 °C

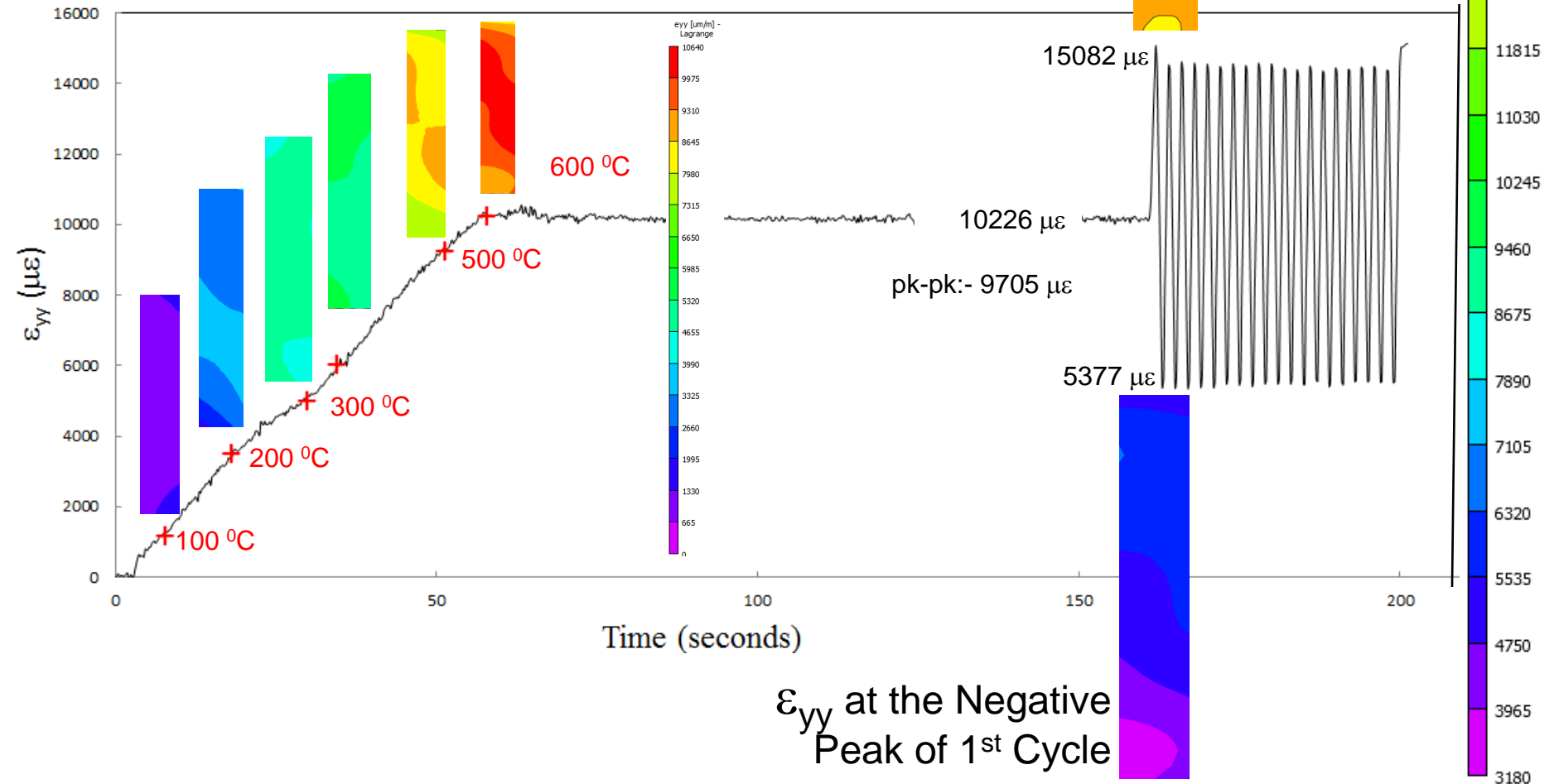


ϵ_{yy} ($\mu\epsilon$)
At 600 °C

(Under isothermal Conditions – Prior to commencement of Fatigue Cycle)



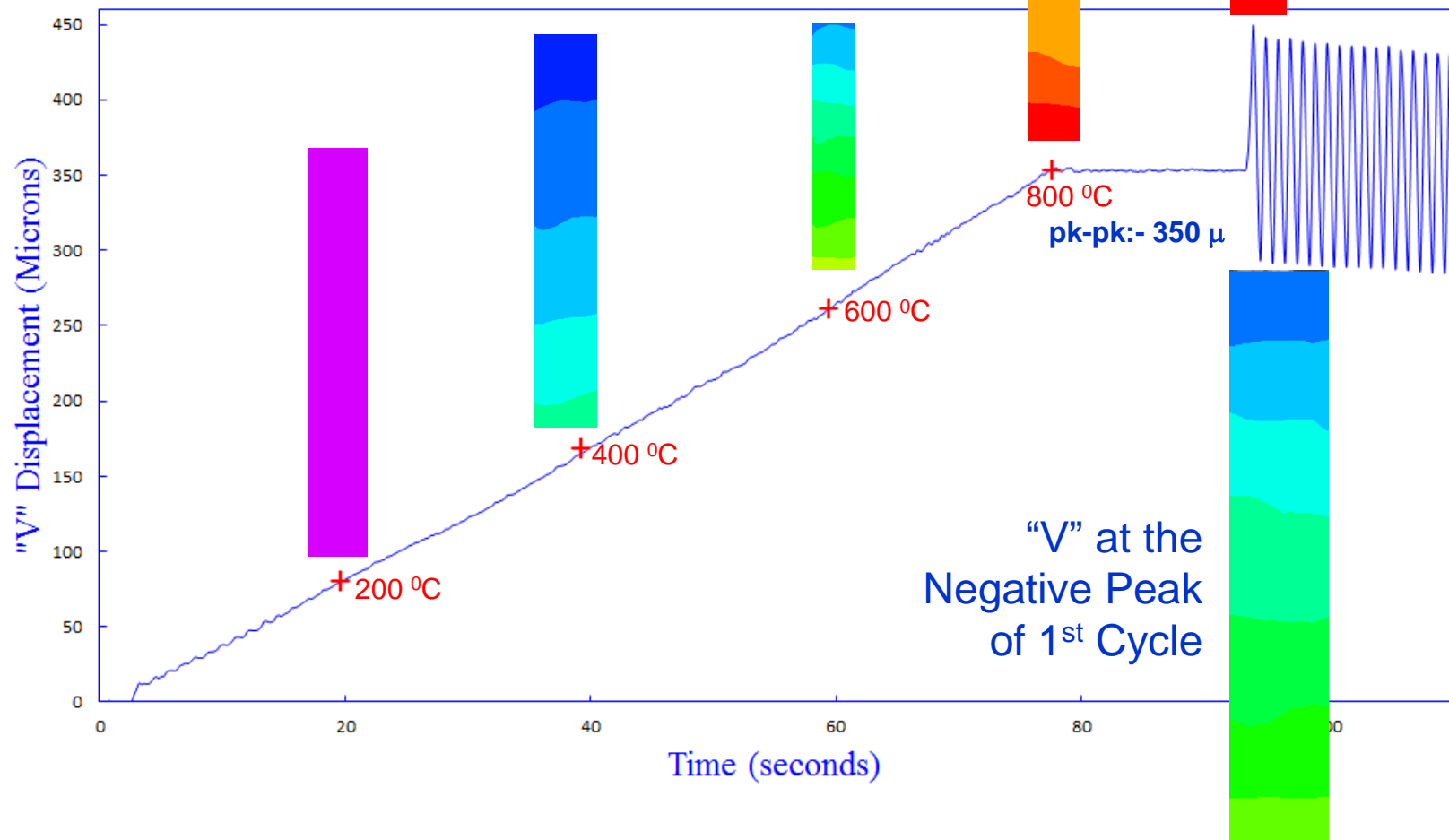
Strain Plot

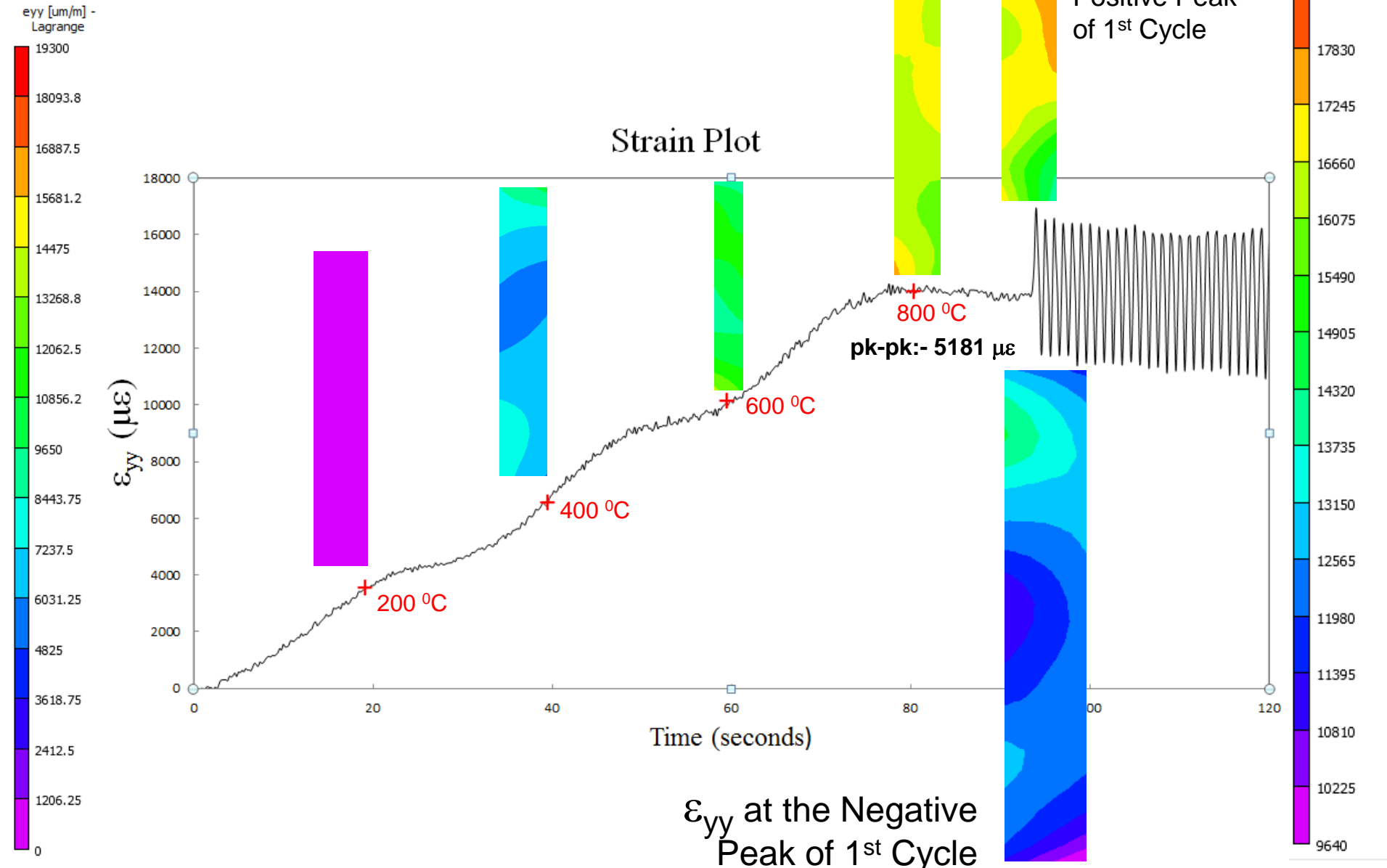


Load Method:- Strain Controlled –
0.5% Strain Amplitude.

Stress:- 150 Mpa ; Frequency:- 2 Hz.

Displacement Plot



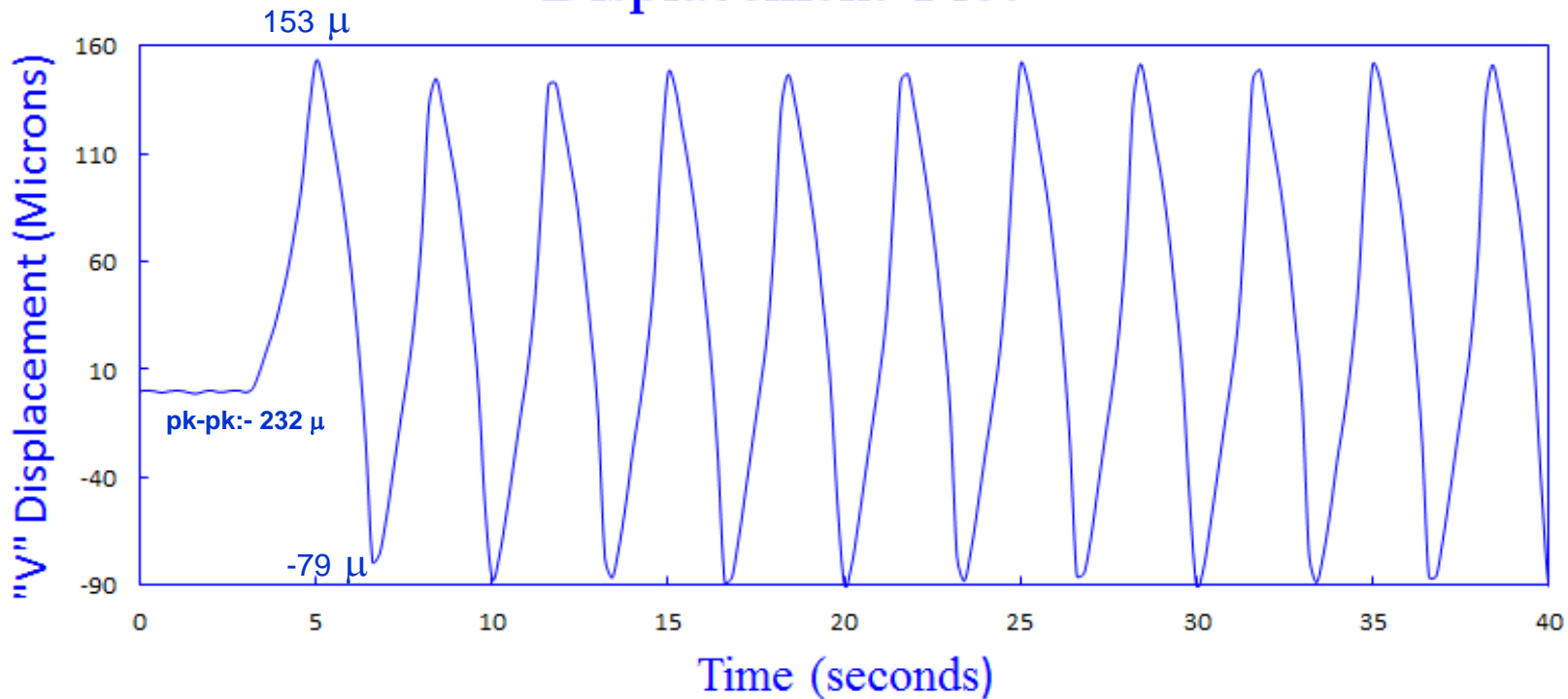


Load Method:- Strain Controlled –
0.5% Strain Amplitude.

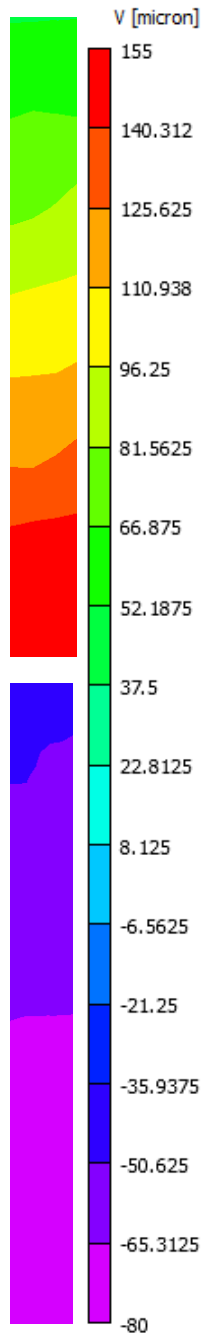
Stress:- 200 Mpa ; Frequency:- 0.3 Hz.

“V” at the Positive Peak
of 1st Cycle

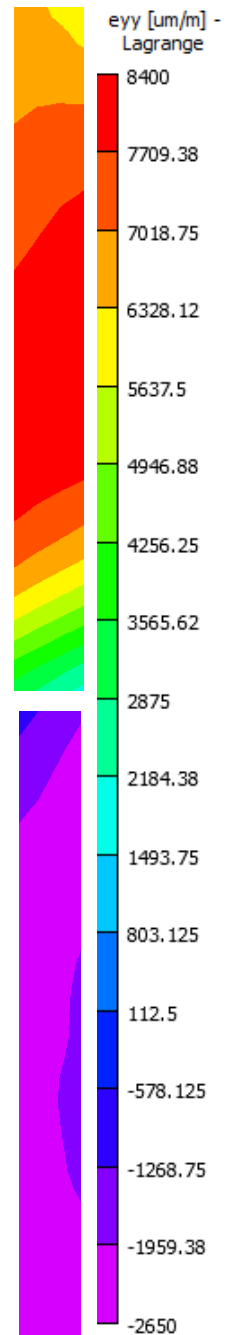
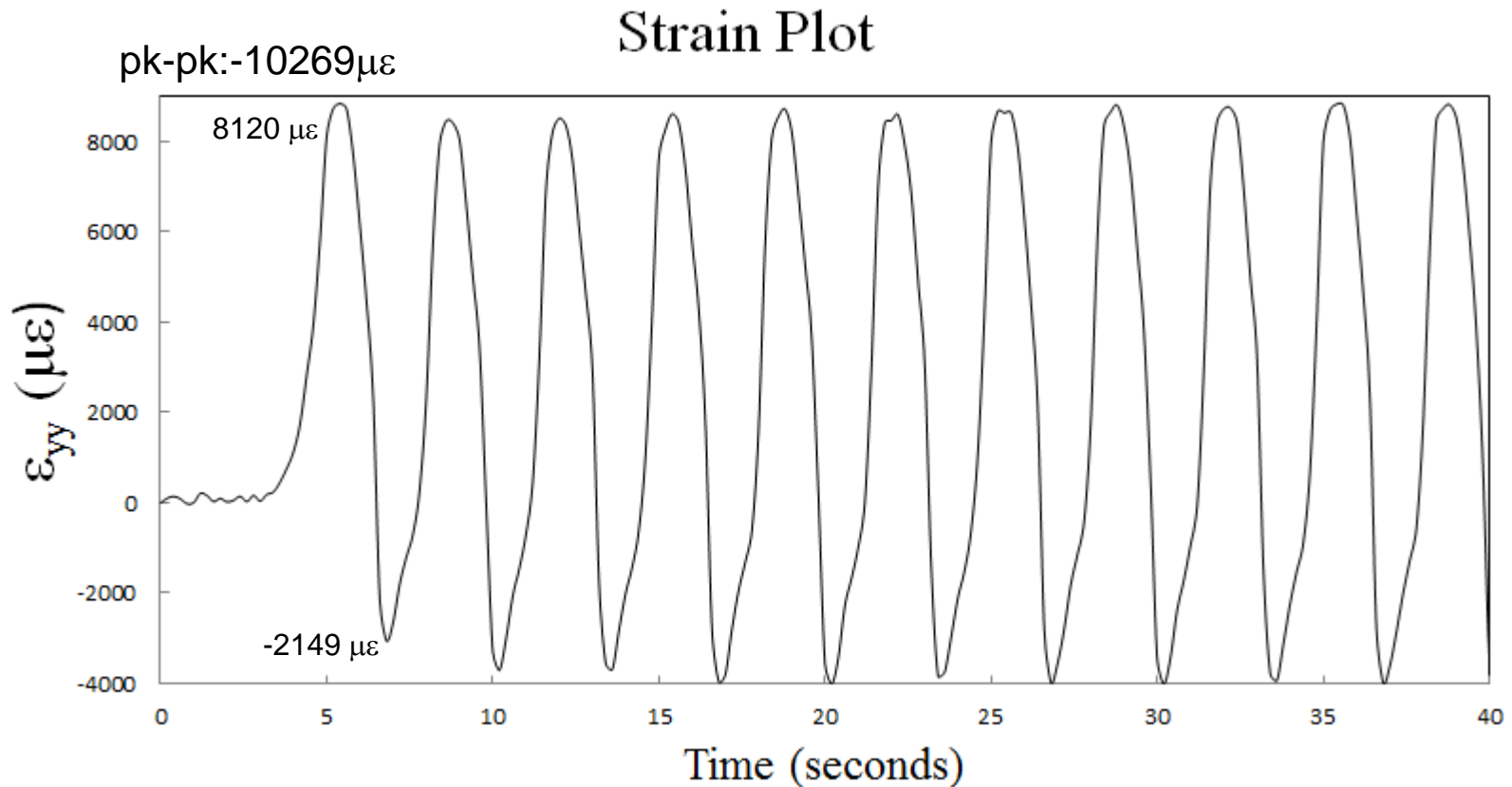
Displacement Plot



“V” at the Negative Peak of
1st Cycle

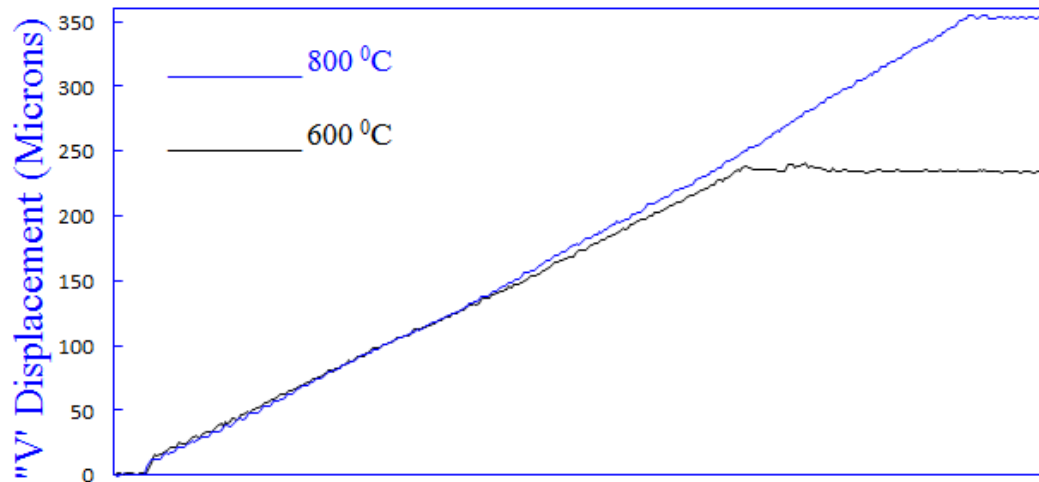


ϵ_{yy} at the Positive Peak of 1st Cycle

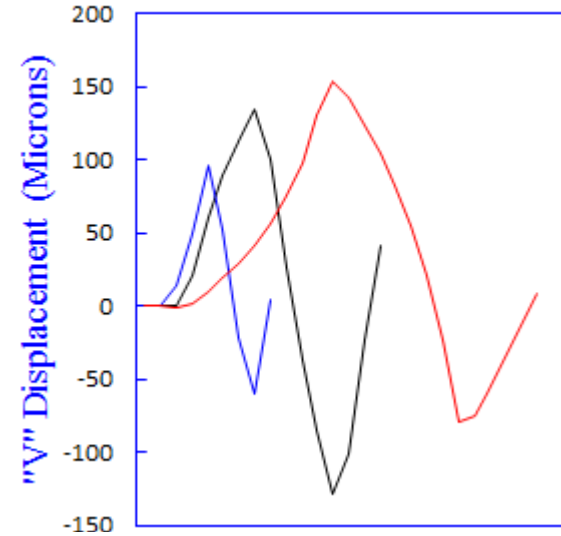


ϵ_{yy} at the Negative Peak of 1st Cycle

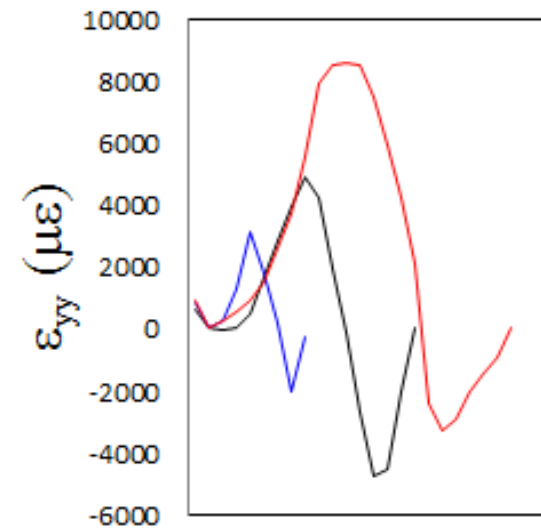
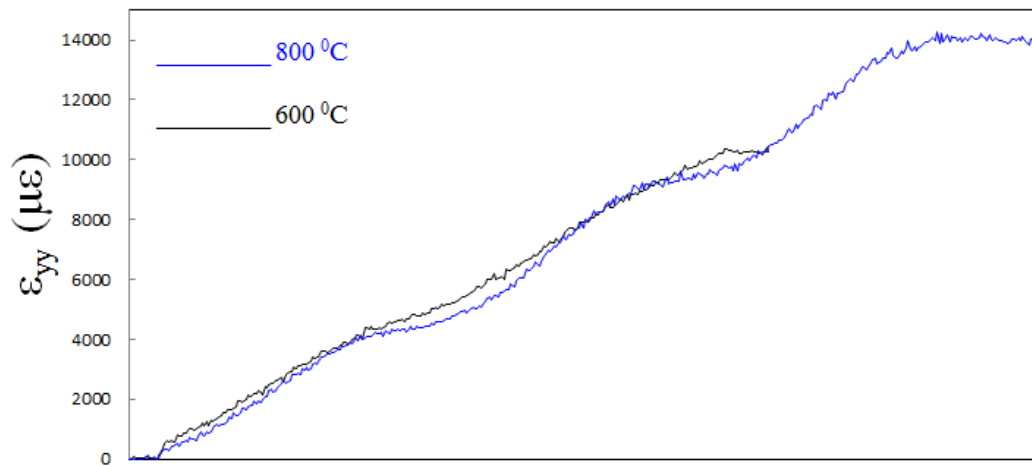
Displacement Plot at 600 & 800 °C



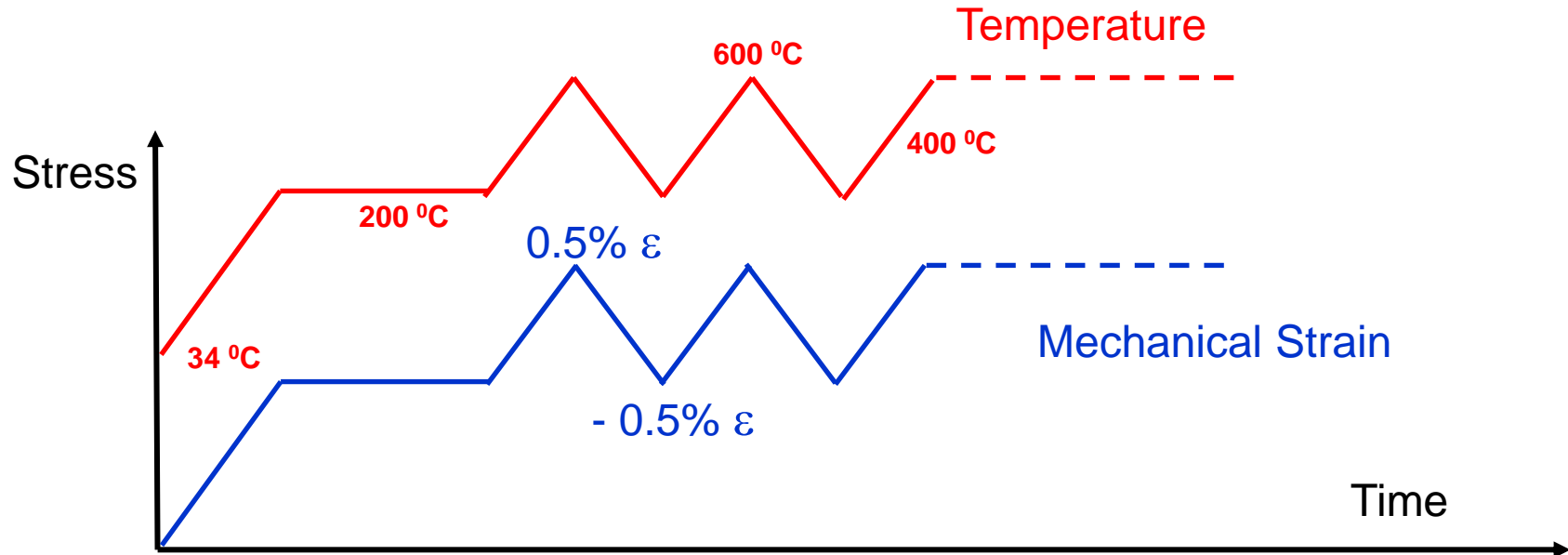
600 °C – 330MPa – 0.5 Hz
800 °C – 150 MPa – 2 Hz
900 °C – 200 MPa – 0.3 Hz



Strain Plot at 600 & 800 °C



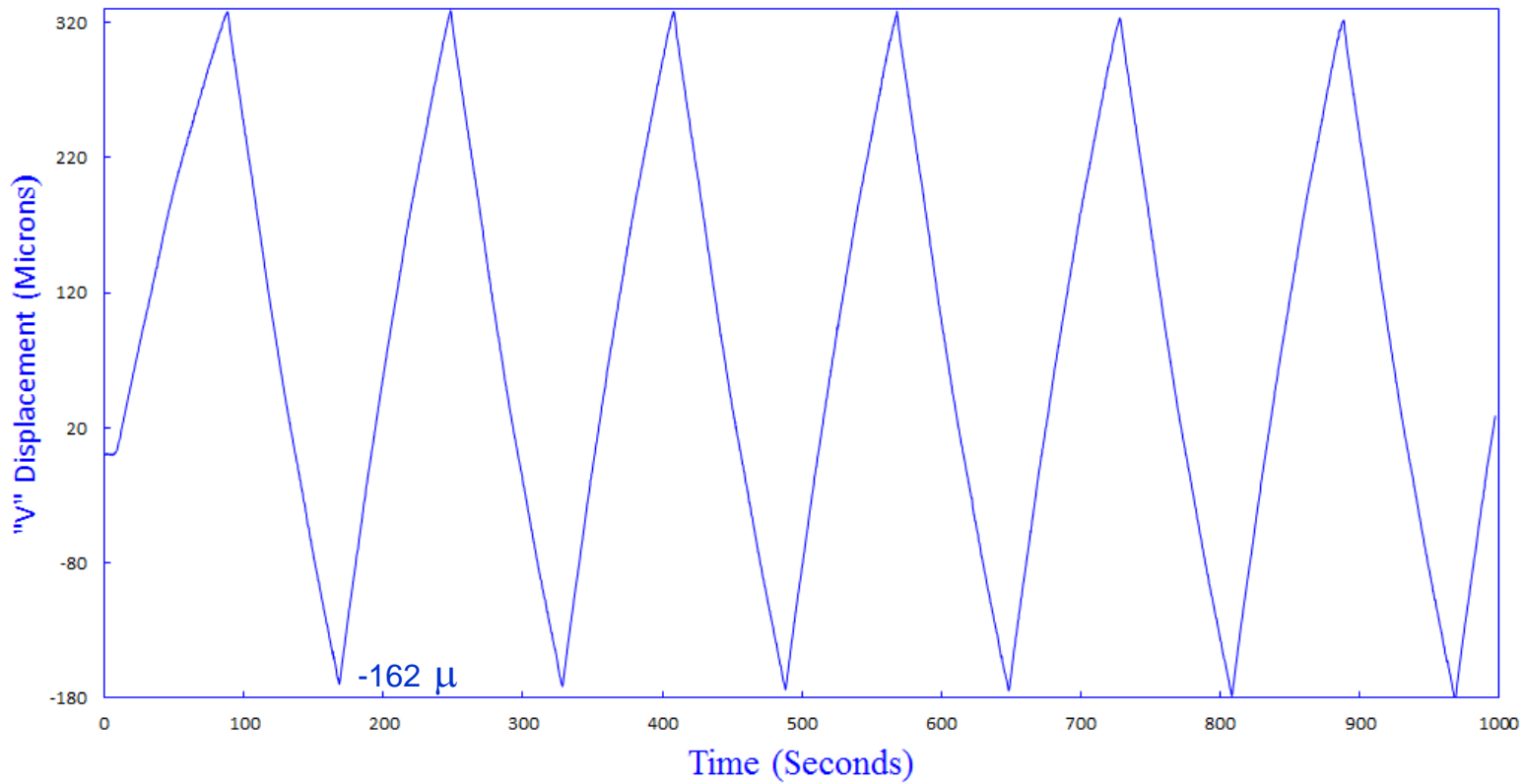
In-Phase Thermo Mechanical Fatigue (TMF) Cycle



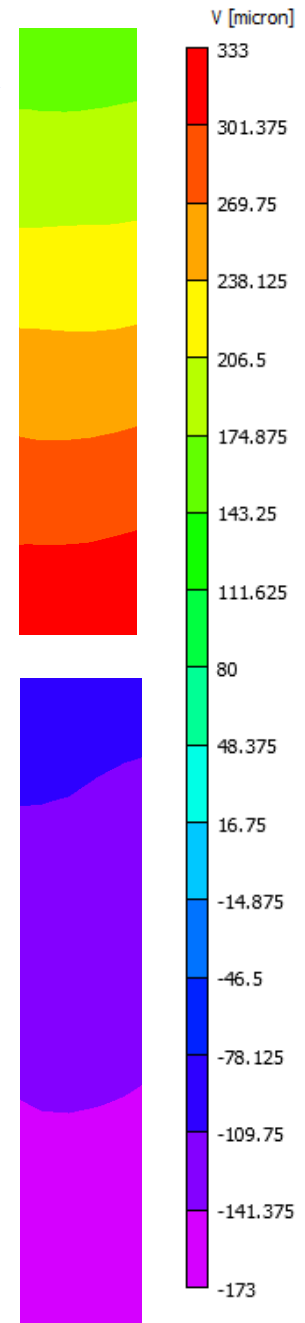
| | |
|-----------------|---|
| Thermal Cycle | 200 to 600 °C. Heating Rate:- 5 °C per second |
| Load Cycle | Displacement Controlled - 0.5% Strain Amplitude |
| Cycle Frequency | 0.5 Hz. |
| Reference | Reference Image Taken at 200 °C under iso thermal condition |

"V" at the Positive Peak of 1st Cycle

316 μ Displacement Plot

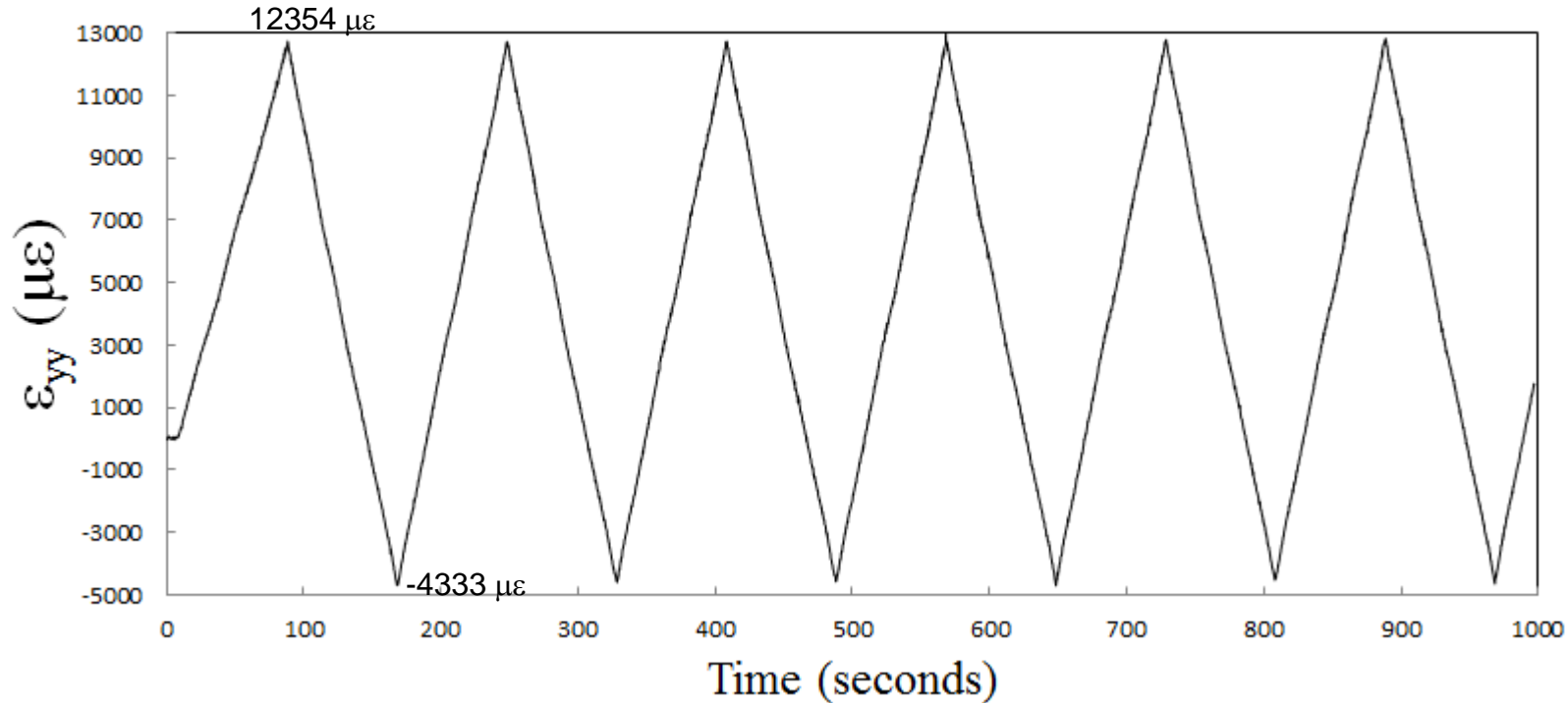


"V" at the Negative Peak of 1st Cycle



ϵ_{yy} at the Positive Peak of 1st Cycle

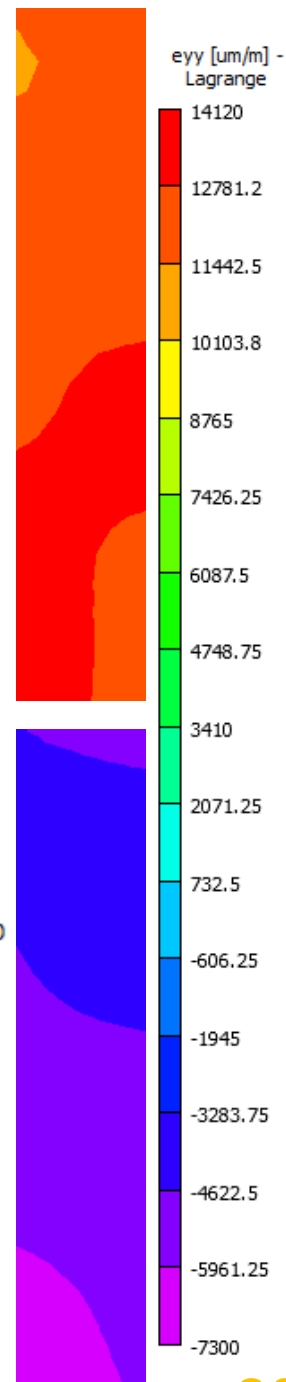
Strain Plot

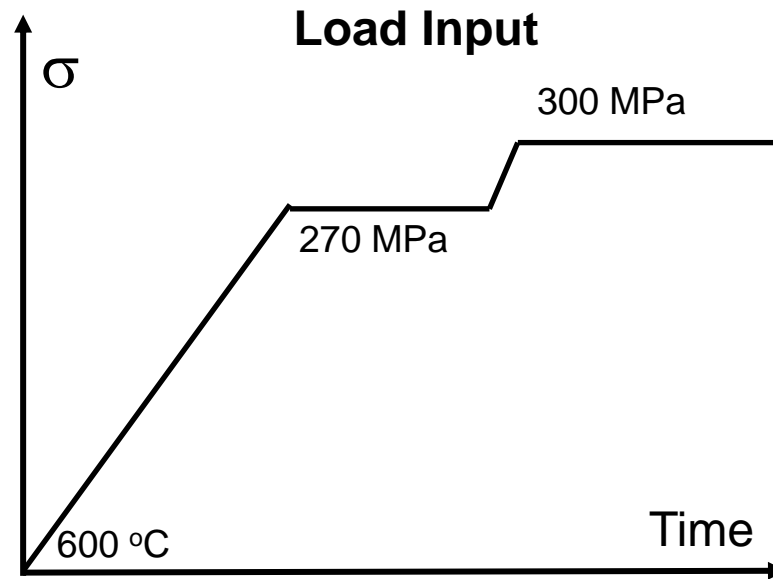


The Load method is Displacement Controlled :-
10000 $\mu\epsilon$ pk-pk.

The strain plot is a cumulative of Mechanical + Thermal Strain:- 16687 $\mu\epsilon$ pk-pk.

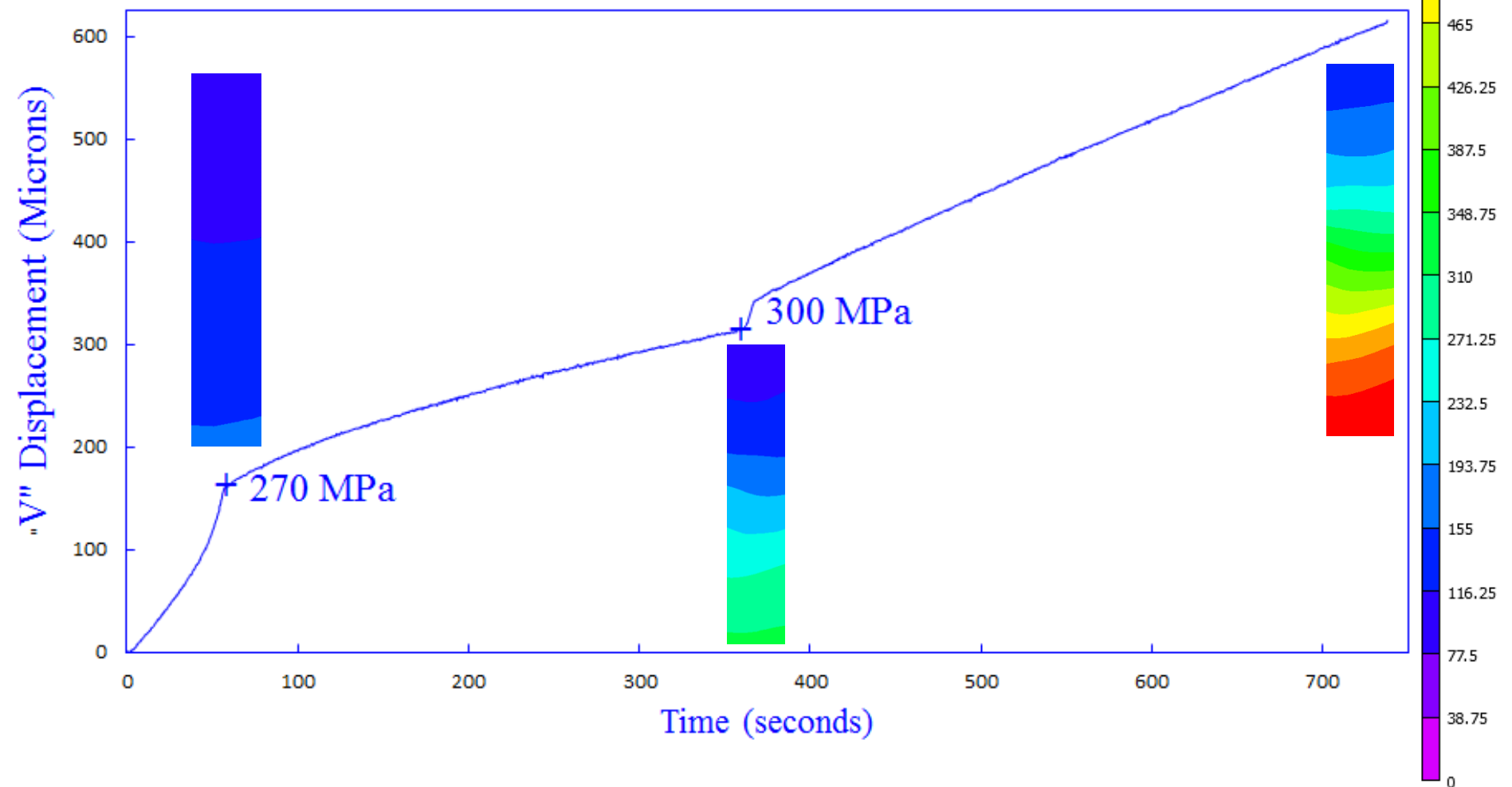
ϵ_{yy} at the Negative Peak of 1st Cycle



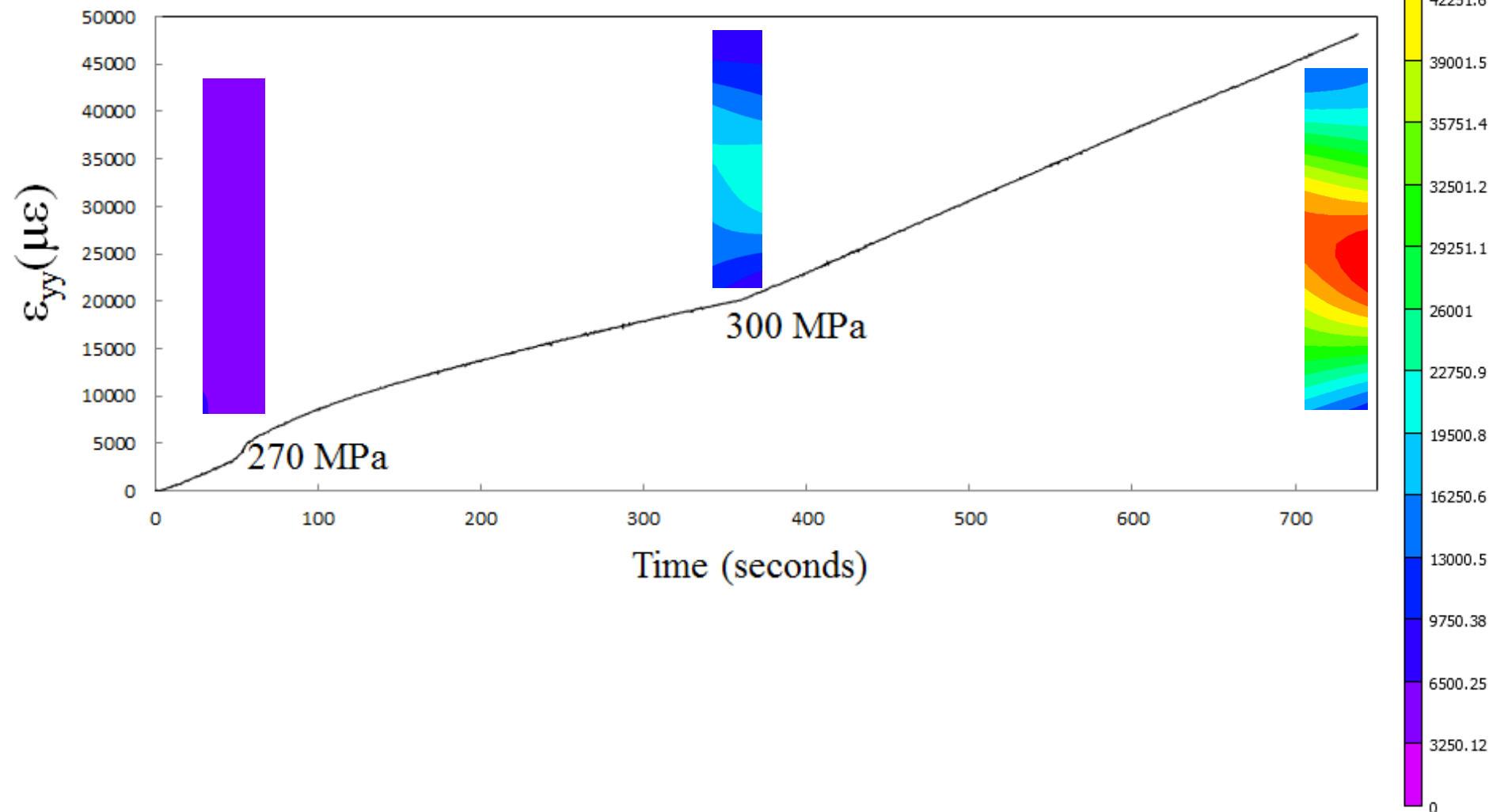


| | |
|-------------------|---|
| Load Cycle | Stress Controlled – Incremental Creep The specimen is heated upto 600 °C and then subjected to a constant stress of 270 MPa and incrementally increased to 300 MPa. |
| Load Rate | 5MPa/sec |
| Reference | Reference Image Taken at 600 °C under iso thermal condition |

Displacement Plot



Strain Plot



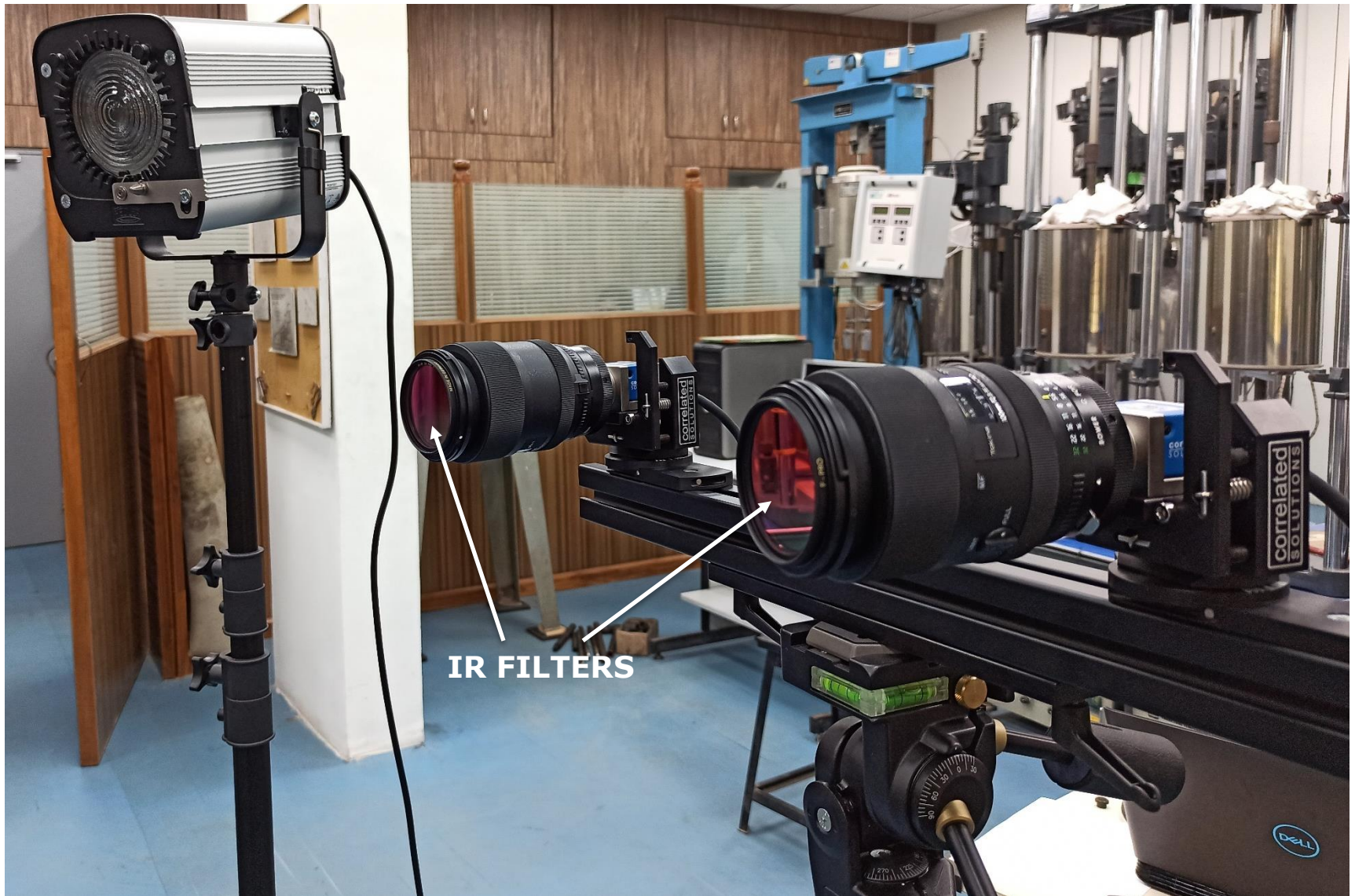
The Tensile Specimen was speckled using High Temperature Spray Paints. Since there was no view port in the furnace for the Cameras to view the specimen, a reference image was taken at room temperature and specimen was inserted into the furnace and heated up to 800 Degree C. After cooling, the furnace was lifted and the second image was captured to find out thermal strains and thermal displacements.



**Speckle Image at
Room Temp – 23 Deg C**

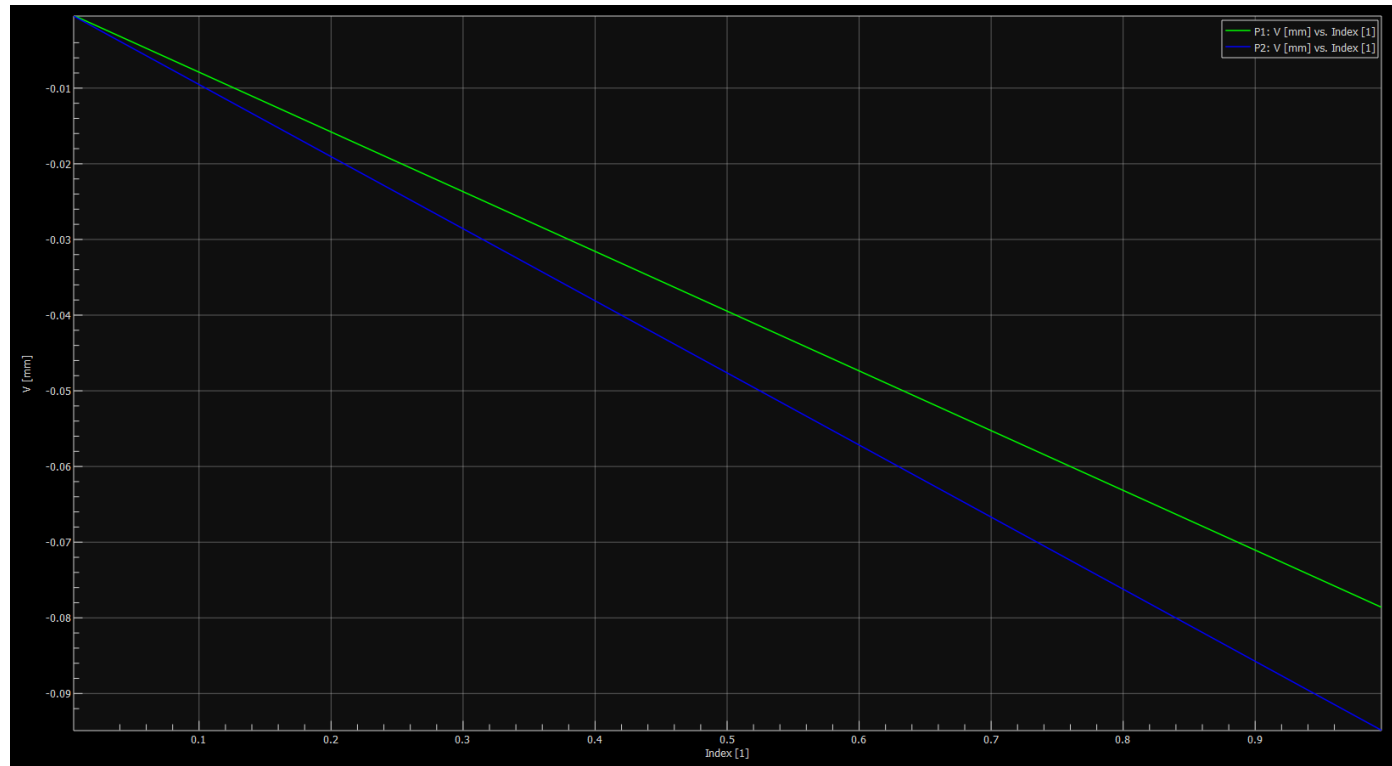
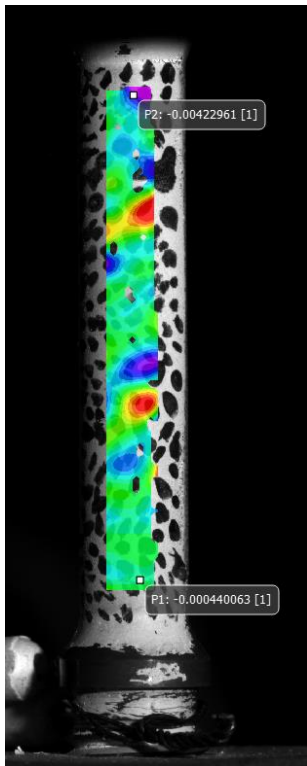
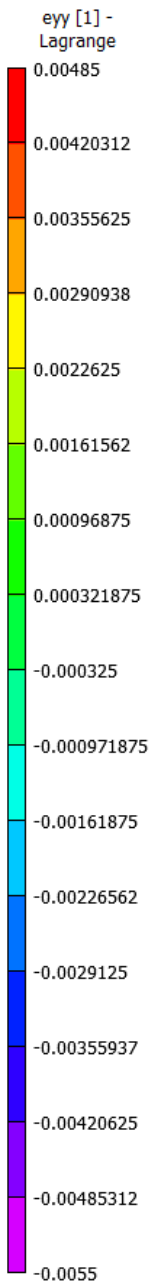


**Speckle Image at Elevated
Temp – 800 Deg C**



IR FILTERS

IR Filters were mounted in front of the lens to protect the camera sensor from being exposed to IR Radiations emitted by the Specimen at High Temperatures.



The tensile specimen had undergone a thermal strain of 485 ($\mu\epsilon$) Micro Strain after it was removed from the furnace.

Lets Think Collectively

Thank You

**Moto of
Pyrodynamics**

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**“A Company of
Value Rather
than a Company
of Success”**

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