# Numerical modelling of the Low Cycle fatigue in Austenitic Stainless Steel.

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# CONTENT

# INTRODUCTION

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- Elasto-plastic failure of the component above the yield stress occurs below $10^5$ loading cycles.
- The fatigue of the steel.
- LCF is an important design consideration for metallic machine components, steel structures, and significantly influences the degradation mechanism and serving life due to which this is the hot topic for the research.
- It is very difficult to create actual reactor working environment such as extreme temperature, etc. Hence, the finite element method can be used for the investigation to estimate the fatigue behaviour of the steel.

# INTRODUCTION (2)



- In the presented research, low cycle fatigue test experiment for 0.2% strain on AISI304L steel is performed and a numerical simulation is performed for the same LCF experiment. For the numerical simulation a combination of the isotropic hardening and the Chaboche kinematic hardening is used for the material modelling. The parameters for the Chaboche model for AISI 304L steel at strain amplitudes of 0.2% is estimated. For the preparation of FE model, LS-DYNA and ANSYS software’s are used. The simulation results are compared with the experimental result for the validation of the numerical model.

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# Experimental LCF Test

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# 1.1. Material and Specimens

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- Test specimen manufacturer Creusot Loire Industries
- AISI304L Steel, annealed between 0.5-2hrs for temperature between 1050°C to 1100°C.

**Table 1** Mechanical properties of AISI 304L steel.

| Temperature, °C | Yield Stress, MPa | Ultimate Tensile Strength, MPa | Elongation, % | Youngs Modulas, GPa |
|---|---|---|---|---|
| 20 | 278 | 610 | 84 | 200 |
| 300 | 220 | 499 | 42 | 157 |

# 1.2. Low Cycle Fatigue Test Method

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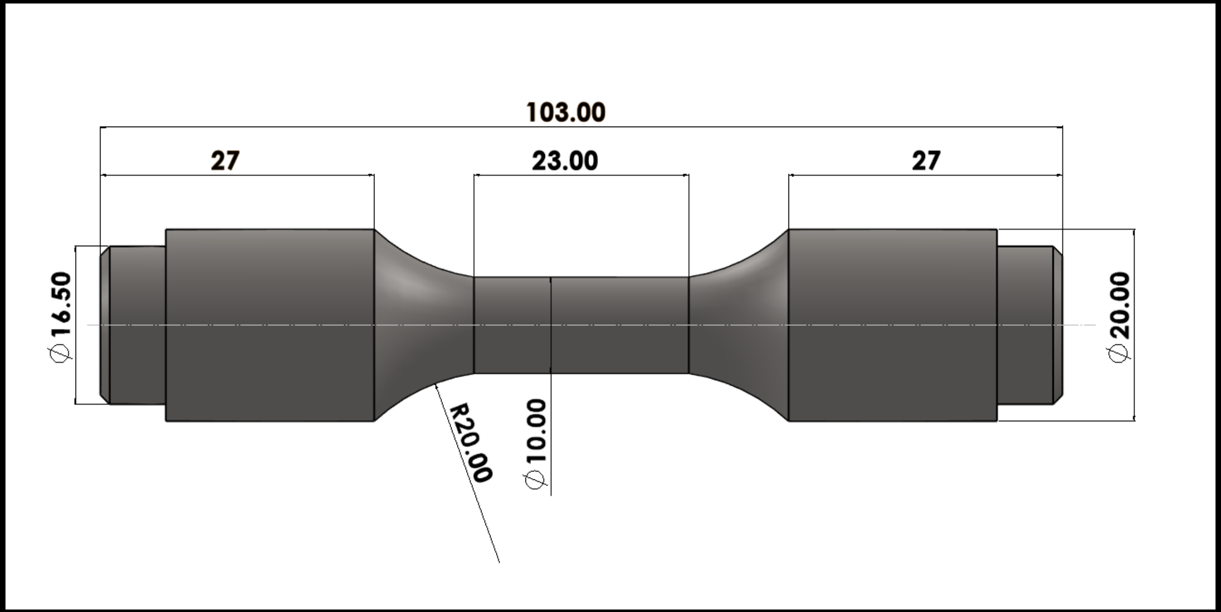


**Figure 1.** LCF test specimen drawing.

- The low cycle fatigue test was carried out using Instron Model 8801 at 300°C and for the strain amplitude of 0.3% .
- ASTM E606 Standard Practice for Strain-Controlled Fatigue Testing.
- This experimental were performed under the project INCEPA-PLUS for the preparation of the guidelines to improve the assessments of environmental fatigue damage.

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# Numerical Simulation of LCF

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# 2.1. Finite Element Model

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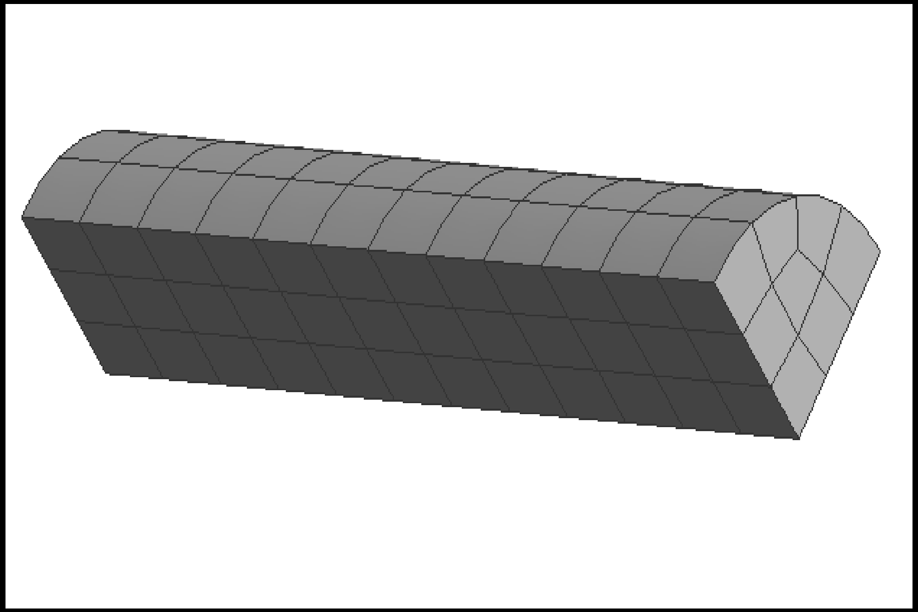

**Figure 2** Finite Element Meshed Model.

LS-DYNA

- 8 node constant stress soild elements.

ANSYS

- SOLID185 element, 8-node.

All translation DOF.

# 2.1. Finite Element Model (2)

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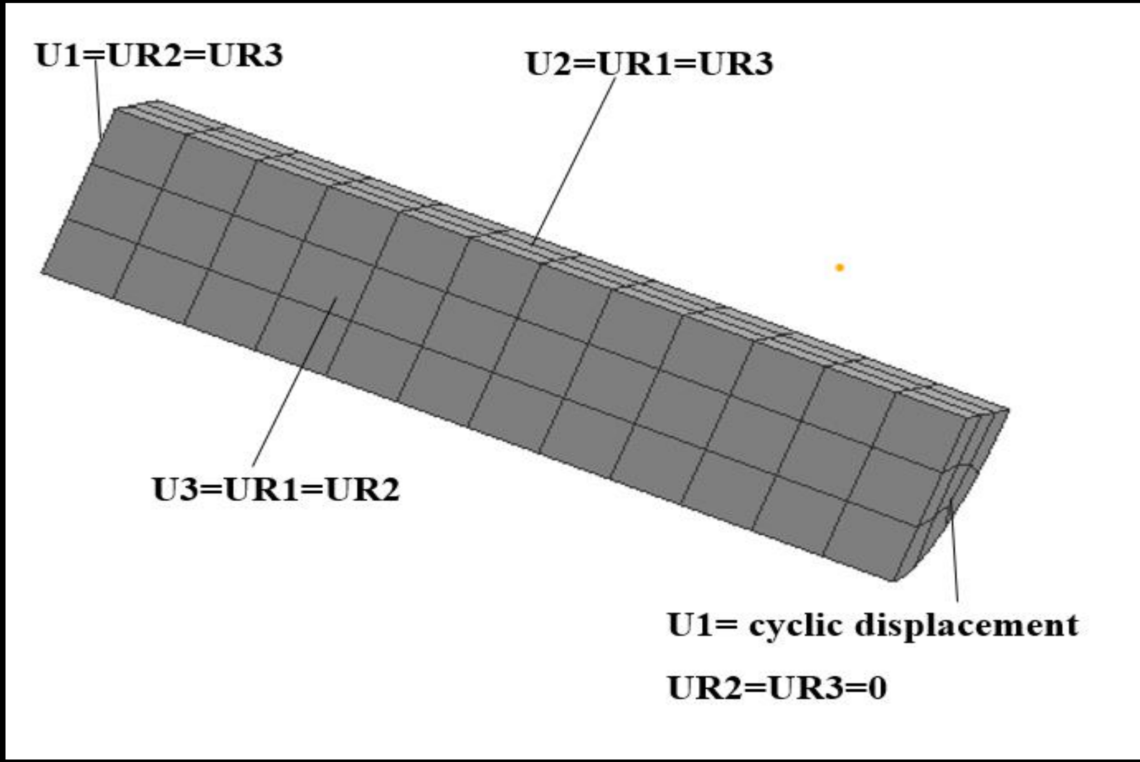


**Figure 3** Applied boundary conditions for finite element model.

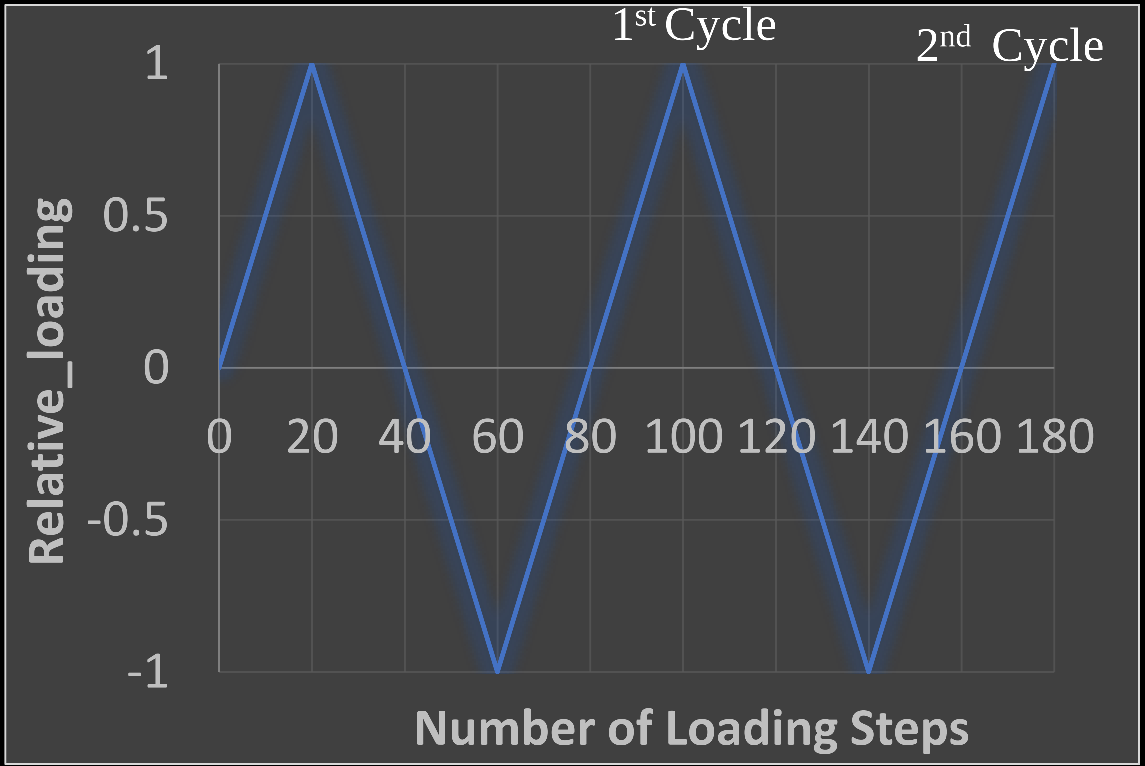


**Figure 4** Waveform of cycle load used for numerical simulation

# 2.2. Material Model

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**Table 2.** Parameters used to describe the AISI 304L Steel at 300 ° C for 0.3% strain.

| Parameters | Parameter value |
|---|---|
| Youngs Modulus, E, GPa | 157 |
| Poisson’s ratio ν | 0.27 |
| Yield Stress, $\sigma_y$, MPa | 220 |

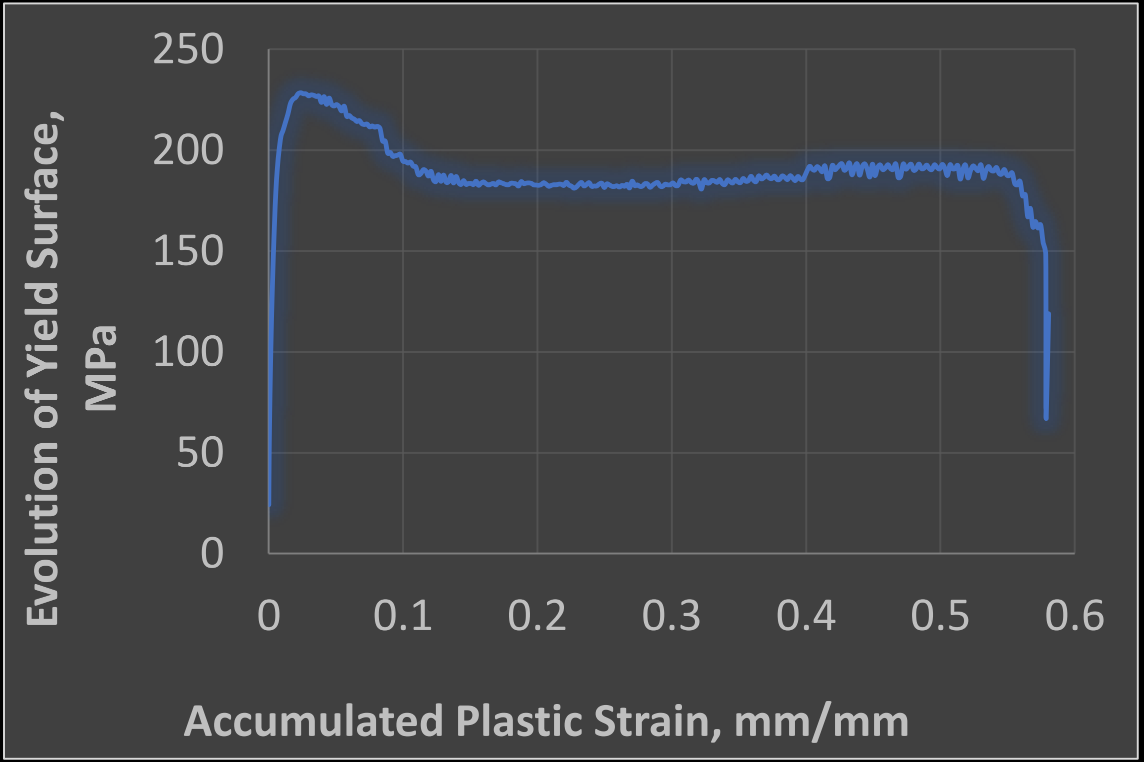


**Figure 5** Isotropic Hardening Curve

# 2.2. Material Model (2)

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**Table 3.** Kinematic harening parameters estimated for the strain range of 0.3%.

| | $C_1$ (MPa) | $\Upsilon_1$ | $C_2$ (MPa) | $\Upsilon_2$ | $C_3$ (MPa) | $\Upsilon_3$ | K.H Model |
|---|---|---|---|---|---|---|---|
| LS-DYNA | 195679 | 2750 | 250679 | 3500 | 375508 | 4500 | $\dot{\alpha}_j = 2/3\, C_j\, \dot{\varepsilon}^{pl} - \gamma_j\, \alpha_j \dot{\bar{\varepsilon}}^{pl}$ |
| ANSYS | 100350 | 2750 | 135180 | 3500 | 61508 | 1650 | $d\alpha_i = \frac{2}{3} C_i d\varepsilon^p - \Upsilon_i \alpha_i dp$ |

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# Results

# 3.1. Experimental LCF Test

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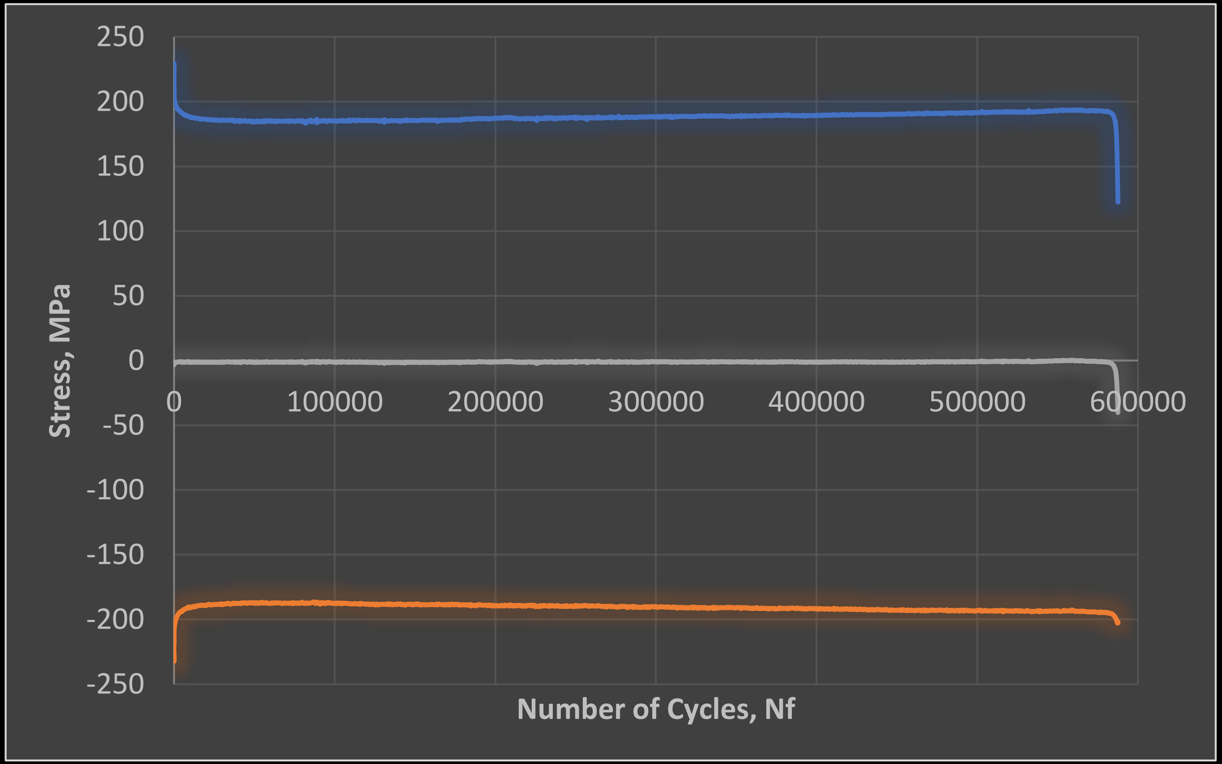


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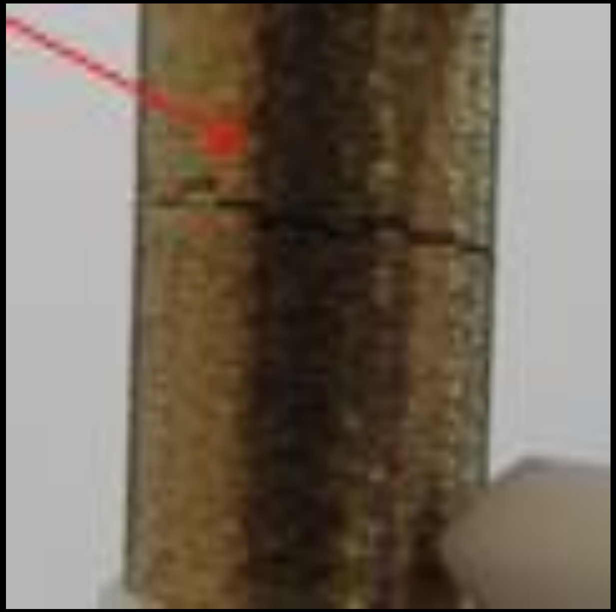

b

**Figure 6**. a) Maximum stress v/s number of cycles experimental results at strain amplitudes of 0.3% and b) specimen after failure

# 3.2. Numerical Simulation results and comparison

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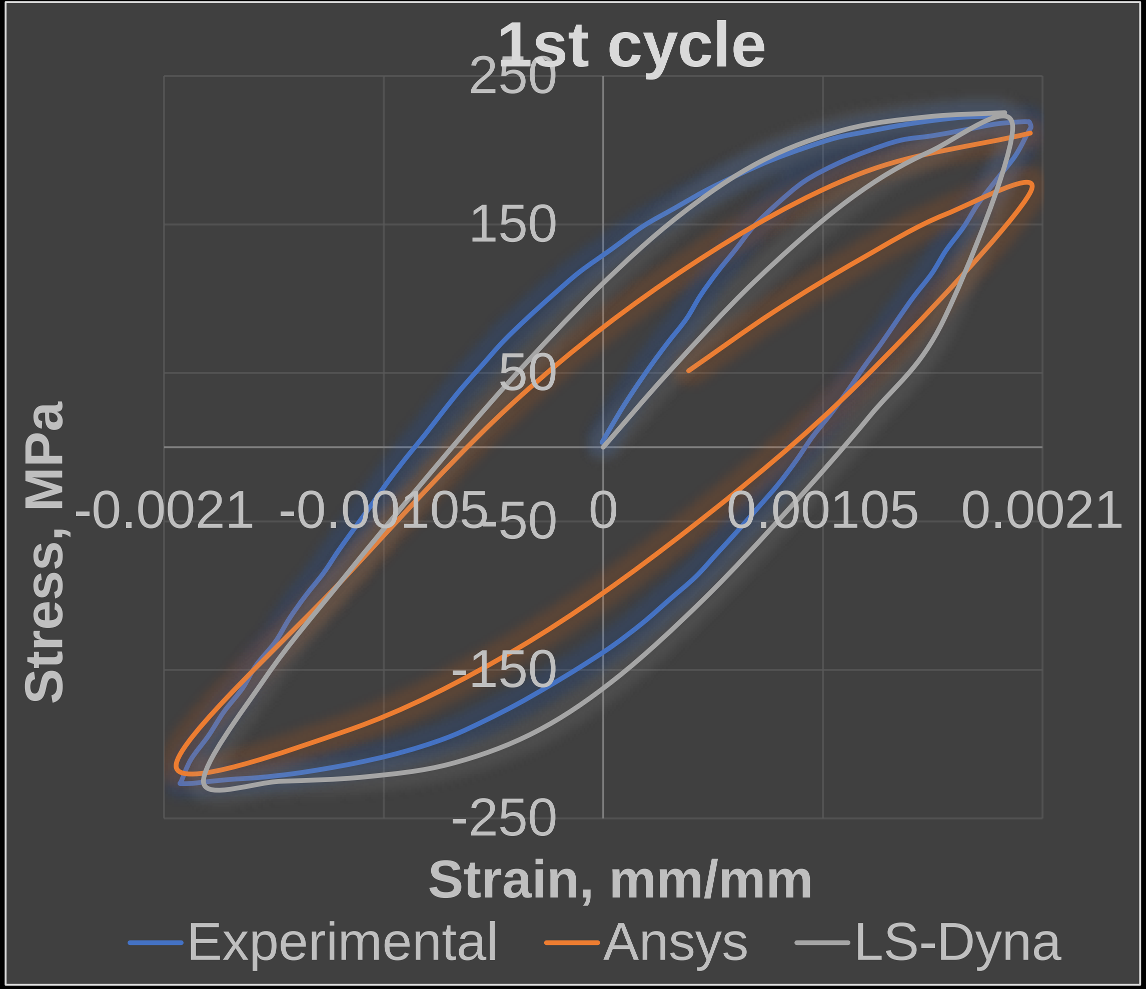


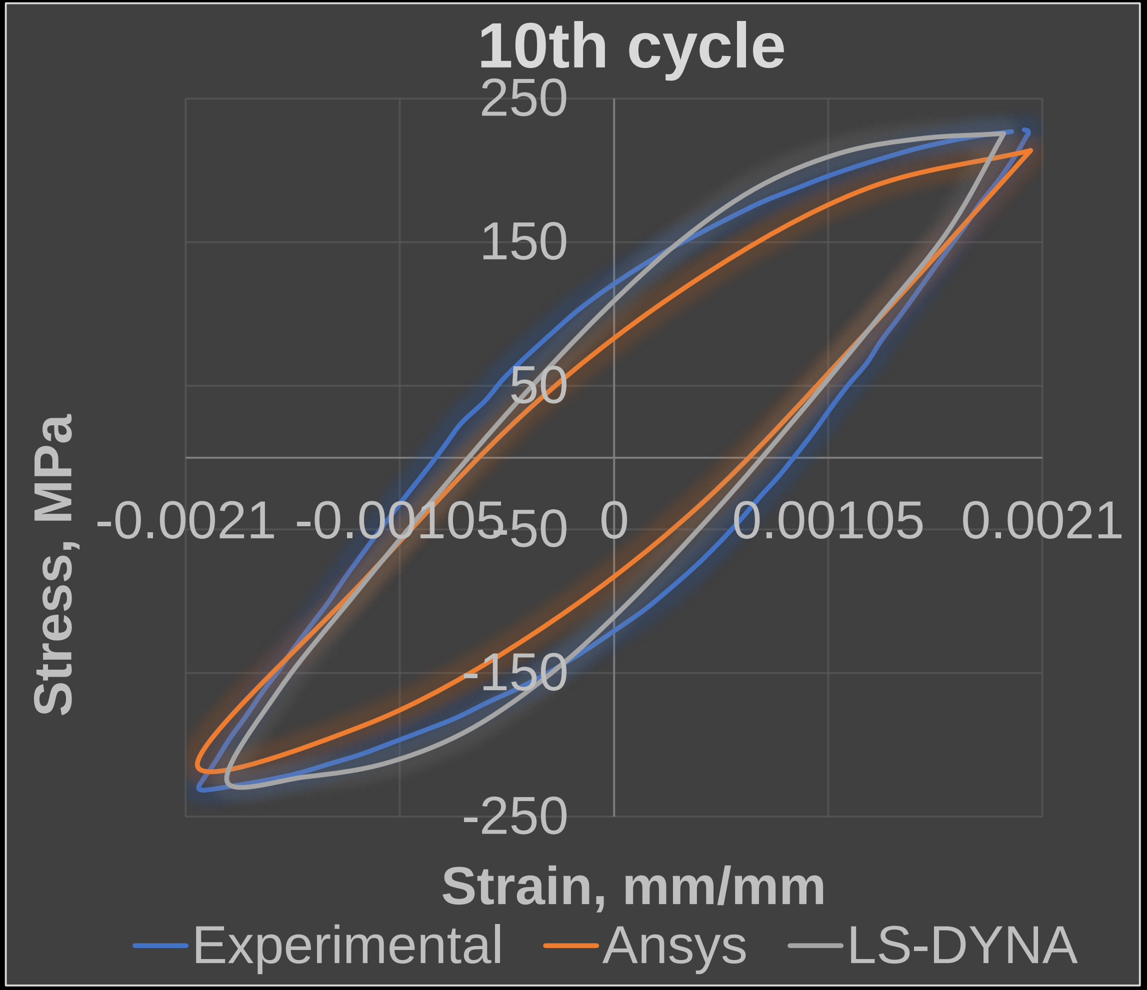


**Figure 7** Stress Versus Strain curve ploted for experimental and numerical simulation results

# 3.2. Numerical Simulation results and comparison (2)

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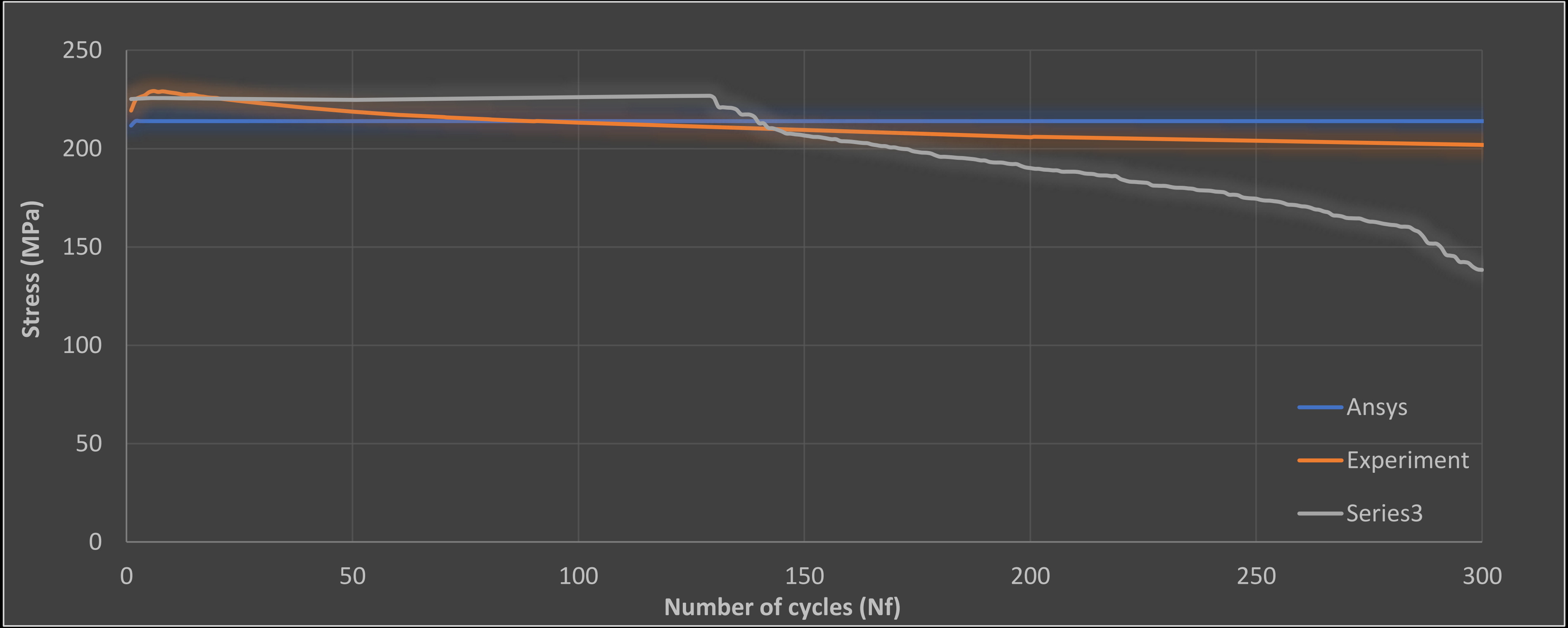


**Figure 8** Maximum stress versus number of cycles curve for experimental and simulation results

# CONCLUSION

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1. 0.3% strain controlled LCF test and on AISI304L Steel and numerical simulation for the same are performed.
2. Cyclic softening behaviour is observed in the experimental results.
3. For the material modelling Combined Isotropic and Kinematic hardening is employed.
4. Chaboche K.H. rule for ANSYS  and Armstrong and Frederick K.H rule for LS-Dyna.
5. 3.3% deflection in Ansys with  Experimental Results is observed and 31% deflection in case of LS-Dyna is observed.
6. ANSYS was not able to capture the cyclic softening behaviour were as in case of LS-Dyna, it captures the softening behaviour.

# CONCLUSION

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7. With the improvements in the material parameters and refinement in the model for LS-Dyna can be employed for such analysis. This methodology can be employed for the LCF numerical analysis to estimate the change in the behaviour of the material with the increase in the loading cycles and to predict the approximate fatigue life of the material undergoing cyclic loading.

# REFERENCE

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