Computing and Engineering

University of HUDDERSFIELD

MSc Engineering Management

NMM3570-2324: Individual Project

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EARLY WARNING FOR CREEP CAVITATION RUPTURE 2: DEVELOPMENT OF CREEP CAVITATION DAMAG MODEL FOR THE MANAGEMENT OF HIGH TEMPERATURE STRUCTURAL INTEGRITY

INTRODUCTION

- High temperature applications are structural in nature and most needed in power generation industries, aerospace, manufacturing etc.
- Parts in these surroundings can be exposed to a variety of Thermal and Mechanical stress, making it mandatory to incorporate a material that is ultimatley resistant to high periods of heat.
- It is especially important to maintain the structural performance stability in such conditions to avoid catastrophic failures, guarantee the safe operation, and increase the components' service life (Pohja et al. 2022).
- Damage is one of the mechanisms that should be managed; nevertheless, it is only possible if its specific attributes such as creep cavitation are comprehended..

RESEARCH AIM AND OBJECTIVES

Aim

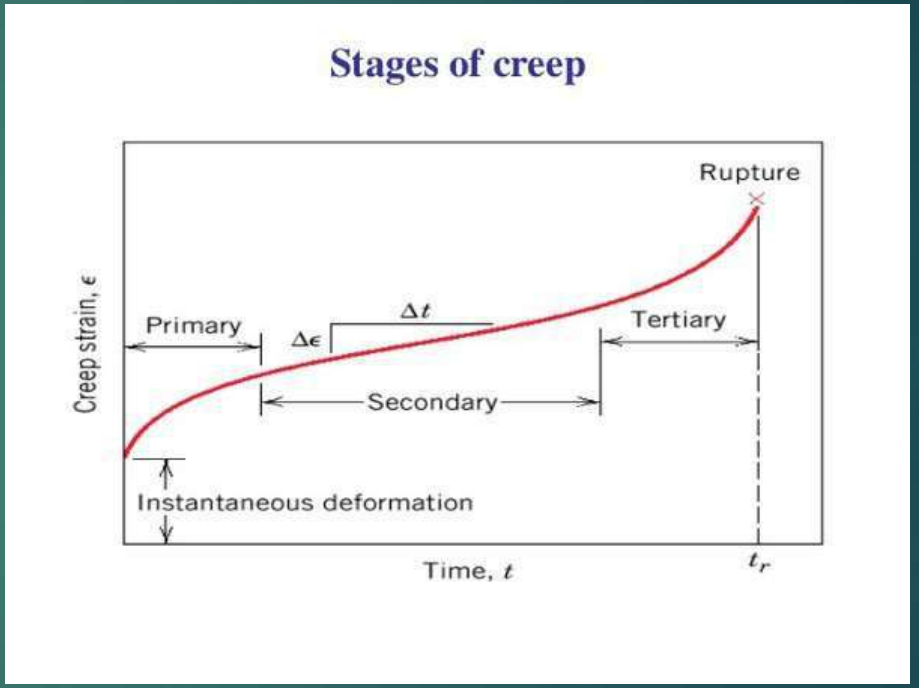
- The Aim of the present work is to create a new effective and reliable creep cavitation damage model for the checking of the structural integrity in high-temperature applications at the very initial stage.

Objectives

- ● To assess the critical parameters that are responsible for creep cavitation in high temperature materials.
- ● To build a model that will determine the exact moments when the creep cavitation occurs and how it progresses.
- ● To check the applicability of the developed model, experimental data obtained from the high temperature material tests should be incorporated.

LITERATURE REVIEW

- Creep cavitation is a time dependent deformation on material that is exposed to high temperature and constant stress for long time duration.
- During the process of creep, micro-voids or cavities are developed at the grain boundaries as a result of vacancies, diffusion, and dislocations' movements (Dvorak et al. 2024).
- These cavities join together, and hence creates cracks to happen and grow , and ultimately leads to the failure of material.



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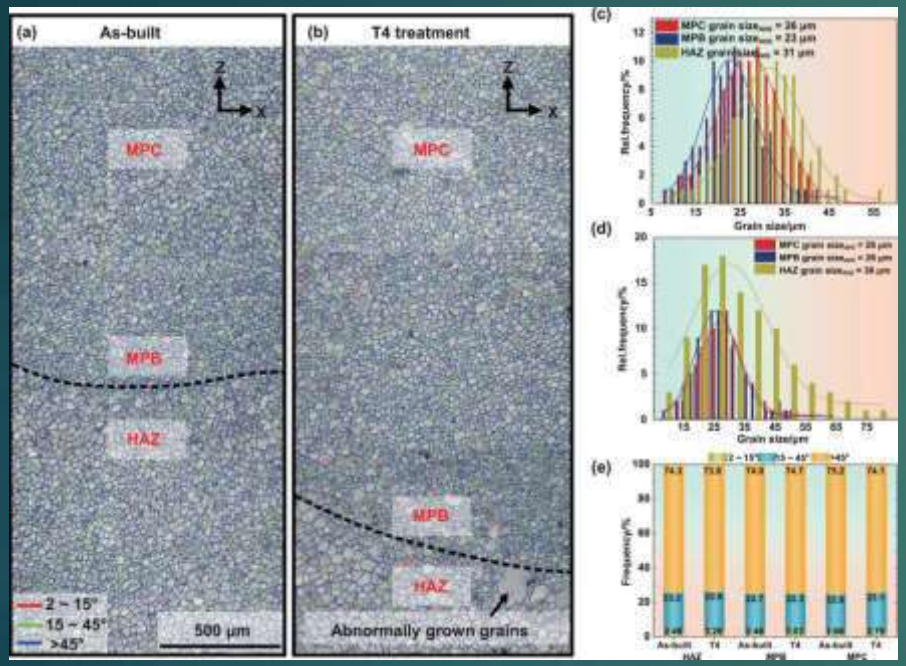

- The parameters used in existing models to predict the creep cavitation damage are based on the macroscopic and microscopic concepts. Indeed, the Norton-Bailey law is used to define creep deformation as a function of stress, temperature, and strain rate.
- At the microstructural relational level, the description involves the nucleation, growth and coalescence of microstructural defects such as cavities and are described in microscopic models like the continuum damage mechanics (CDM) approach (Ma, 2022).

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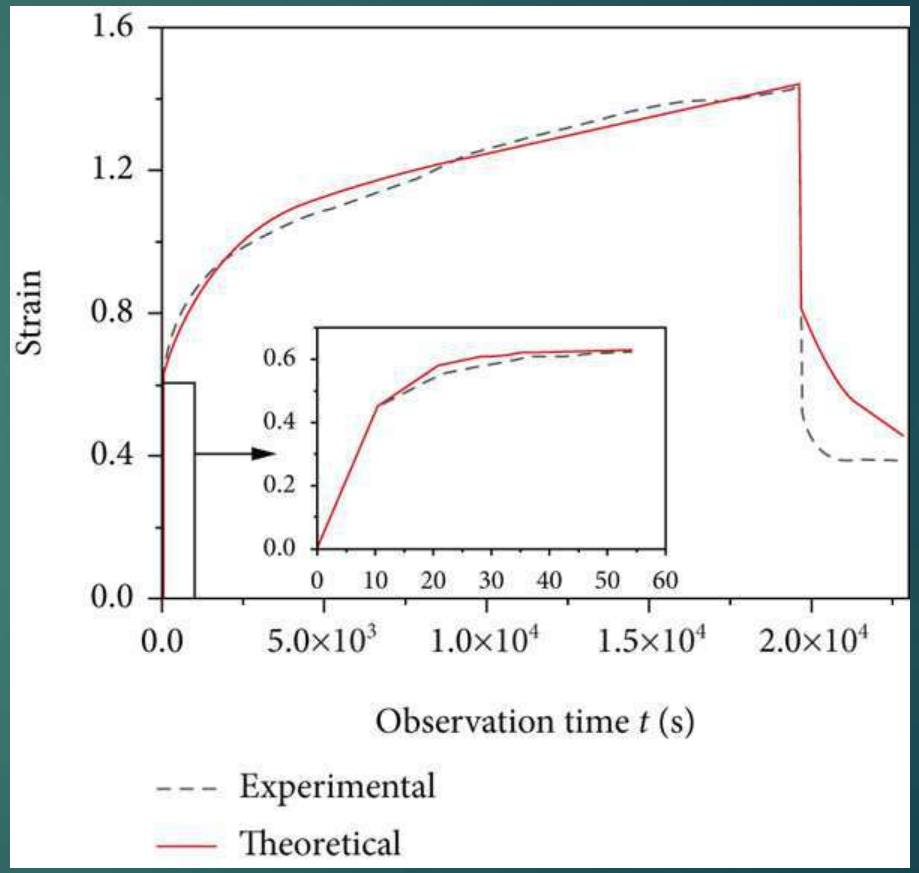
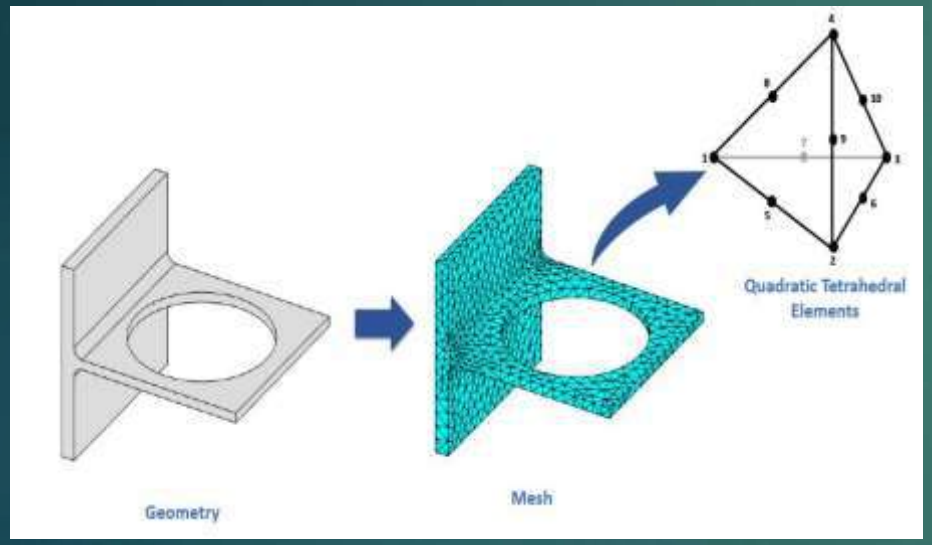
- This is a critical area in the use of creep models since the models have to be validated so that their performance under high-temperature conditions can be accurately predicted for the various classes of materials.
- As it will be reviewed in detail in the following sections, experimental studies are fundamental in addressing these questions thus allowing for the evaluation of models, the definition of their boundaries and the improvement of their predictive power.



METHODOLOGY



- Creep cavitation is a very important phenomenon for materials operating at significantly raised temperatures and under prolonged stress, which, in turn, leads to micro-void formation resulting in material failure.
- Precise predictions of creep behavior for such extreme conditions faced by the materials in power plants and aerospace, respectively, are required to prevent catastrophic failure and to ensure structural safety.

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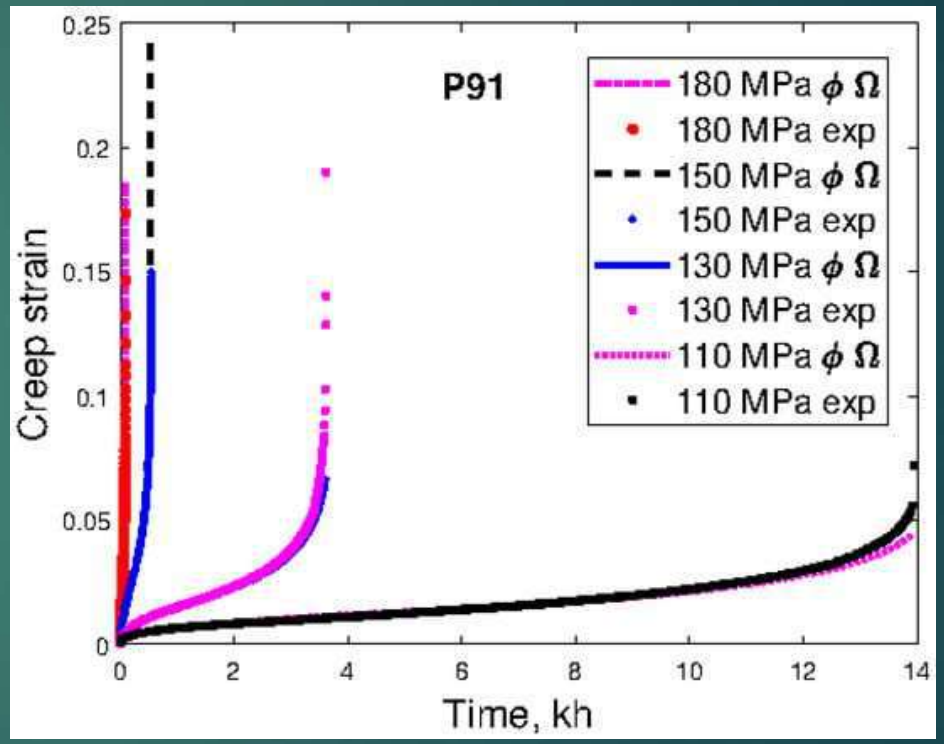
- In this study, the design involves the creation of an accurate simulation environment within ABAQUS CAE in the modeling of creep cavitation.
- The simulation is going to be structured into different stages with a critical view of material behavior under high-temperature and long-term stress conditions.
- Material properties definition shall be among the first stage definitions, targeting some parameters like elastic modulus, Poisson's ratio, and viscoelasticity.



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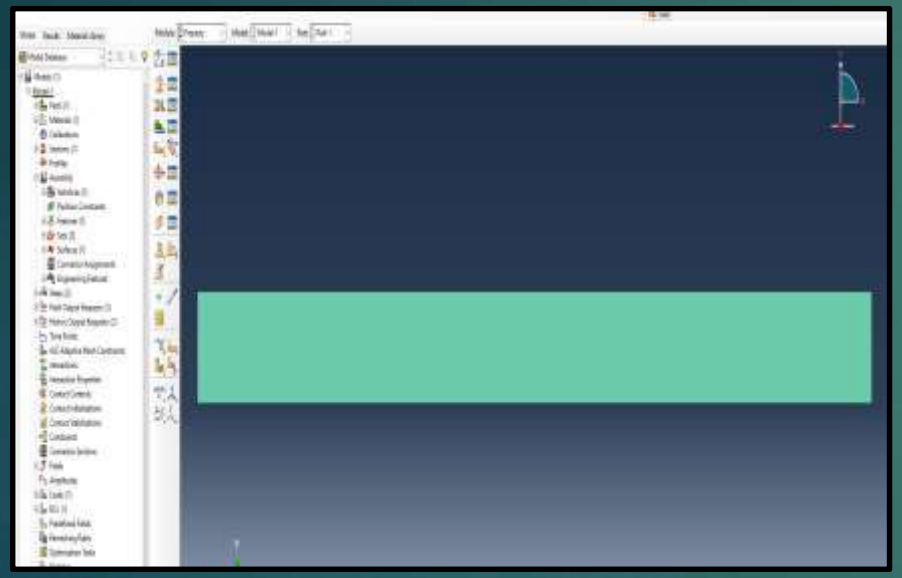
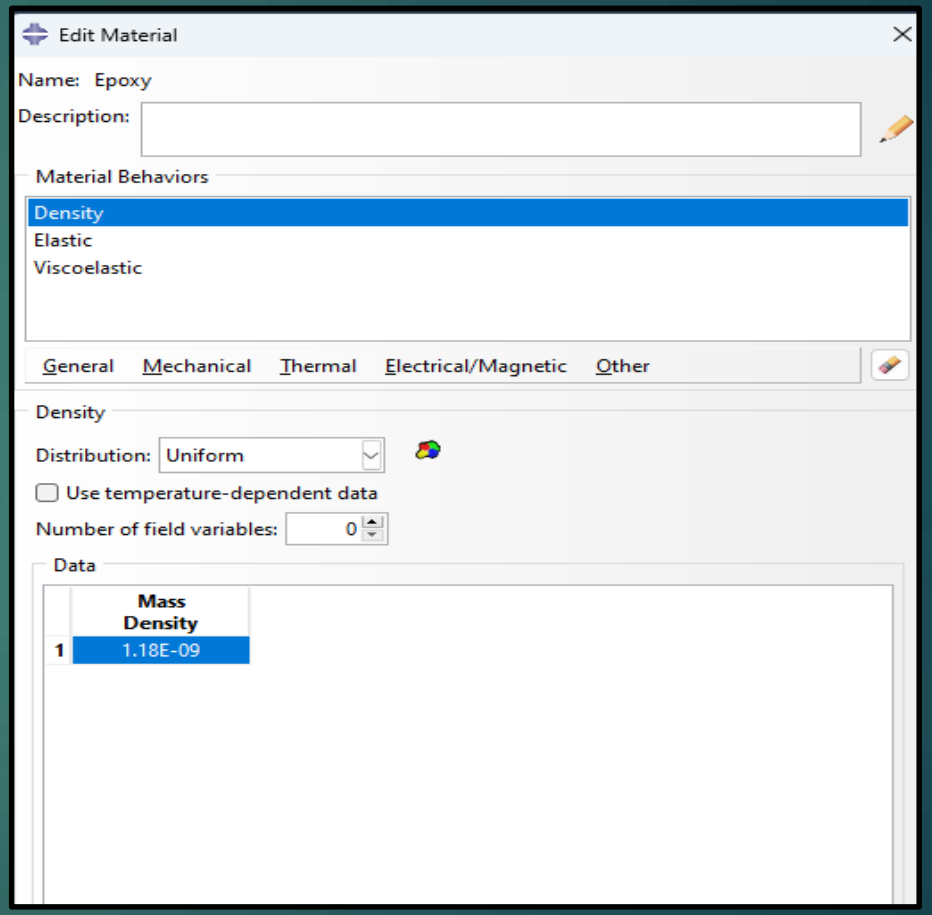


- The details of the strategy for simulating creep cavitation including material properties are defined in ABAQUS CAE.
- The mechanical and thermal properties of epoxy are characterized, by covering elasticity, visco-elasticity, and creep.
- These properties are highly desirable for the realistic simulation of material response to long-term stress and temperature.

RESULTS AND ANALYSIS

- This study briefly highlights the focus of the study as it aims at modelling and simulating creep cavitation damage utilizing ABAQUS CAE.
- It aims to replicate the deformation and failure of material as exposed to high temperature and long-term stress conditions.
- Creep cavitation is amongst the essential parameters that require prediction in an operations environment since its occurrence marks the potential failure of structural components.



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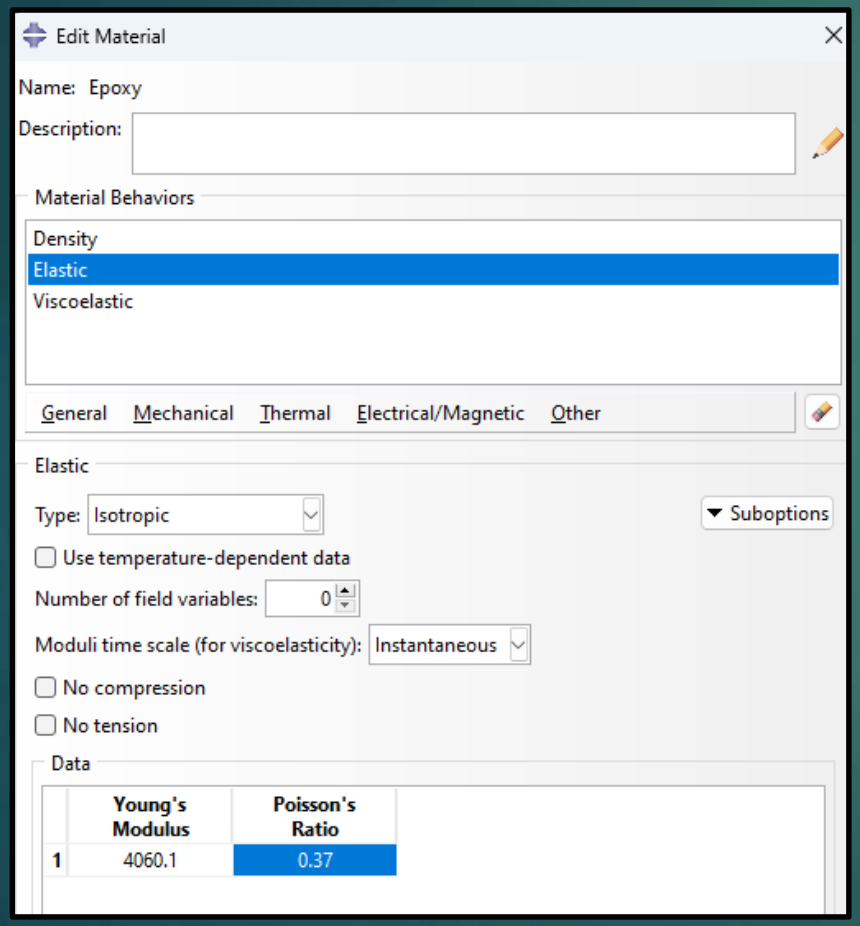

- The model established in ABAQUS CAE to be involved by the geometrical buildup of the material to be analyzed is depicted which is shown in the above figure.
- It allows modelling of creep cavitation which is an essential factor related to the deformation and rupture of materials, particularly under conditions of elevated temperature and persistent loading.
- It is shown in the figure, where the sample region of the material under study is outlined and measured for further investigation in the model.

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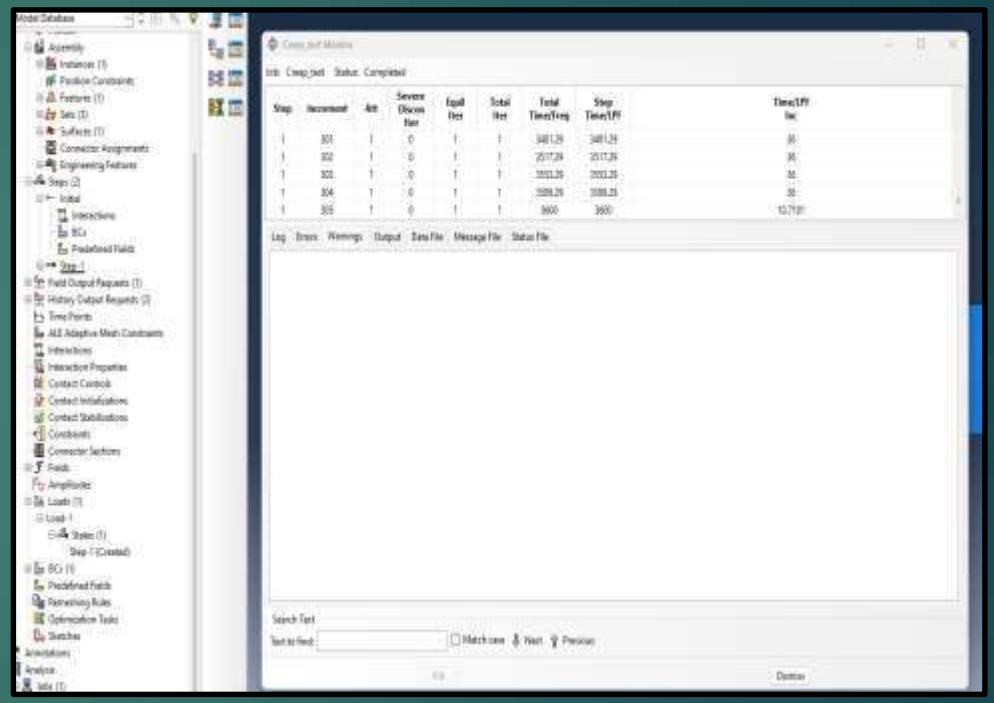
- In this figure representing Epoxy material constants, the following elastic properties are provided.
- The Young's modulus is given as 4060. 1 MPa, While the Poisson's ratio is fixed at 0. 37.
- These values are very crucial in identifying the first stiffness state of the material under stress.
- The elastic properties are given as isotropic, meaning the material properties are the same in any orientation.



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- This figure shows the Shear damage parameters such as fracture strain, shear stress ratio, strain rate, etc. for the creep cavitation model.
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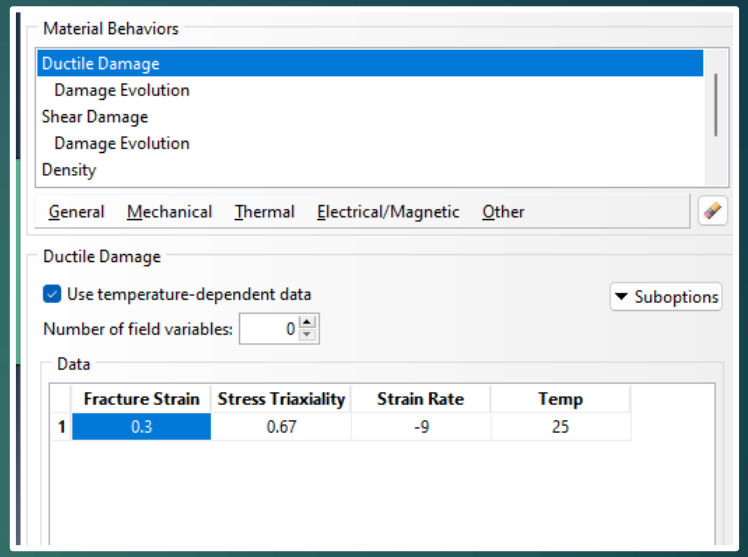

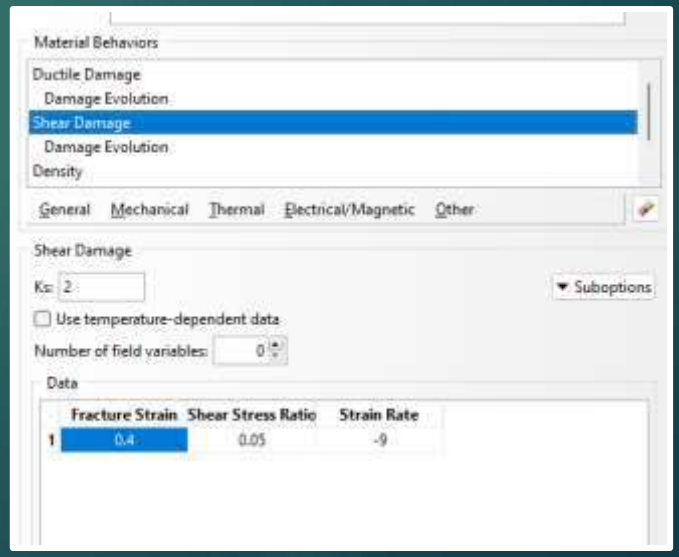

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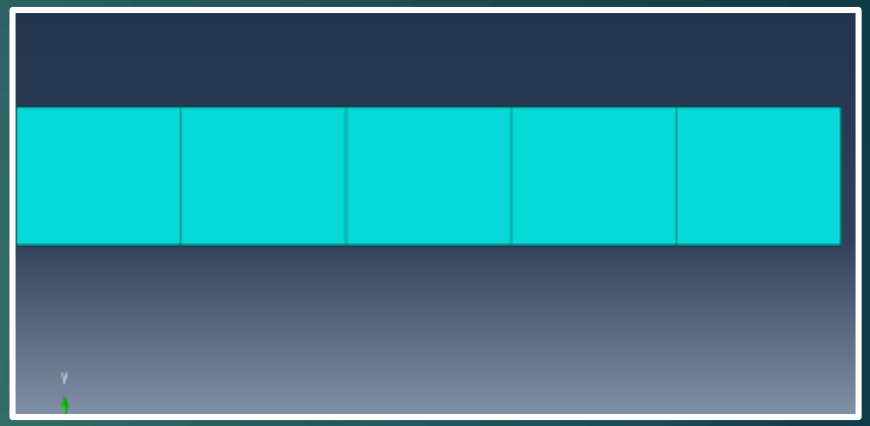
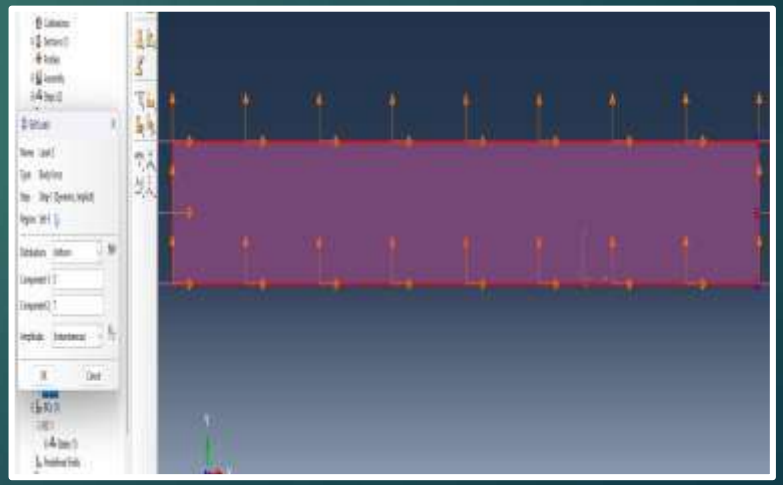
- This figure shows the optimized mesh with the 5 elements based on the damage properties of the Creep Cavitation model.
- This figure shows the assignment of the body force on the cavitation model as the load specification with the values of two components 5 and 7 N respectively.





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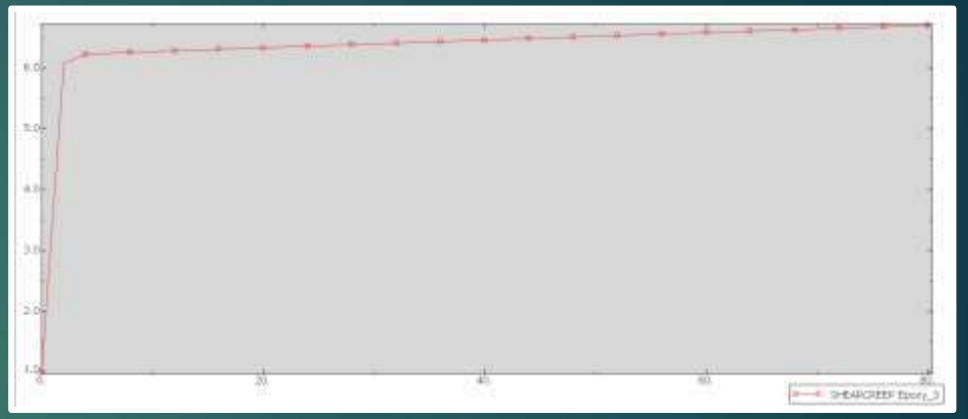
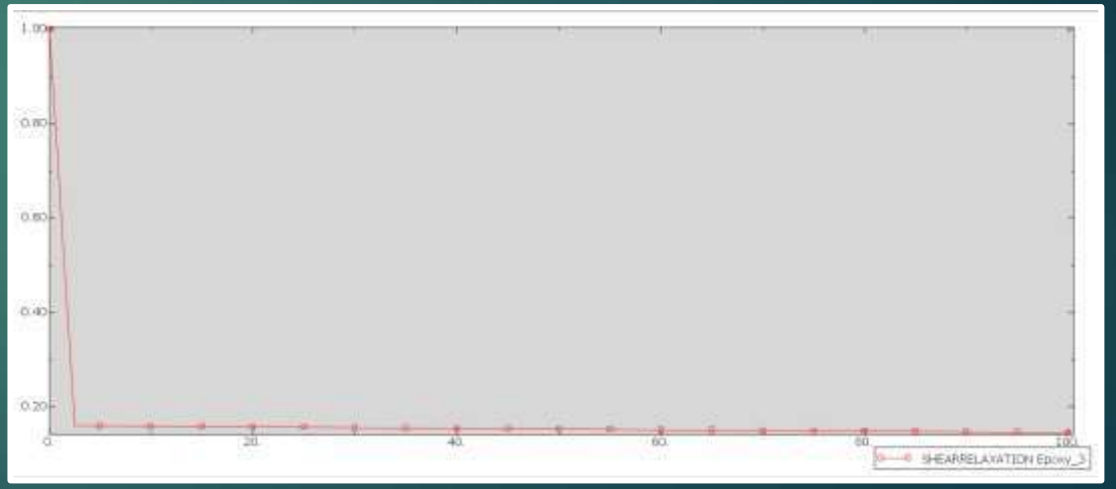
- This figure shows the shear stress curve of the creep cavitaion model after specifying the damage coefficients.
- This figure shows the shear relaxation curve of the creep cavitaion model after specifying the damage coefficients.





EVALUATION AND CONCLUSION

- The findings of the study while presenting modeling and simulation of creep cavitation damage using ABAQUS CAE have provided an understanding of the material's behavior under high temperature as well as lifetime stress.
- This section presents a critical analysis of the main findings as well as the findings' implications in analyzing creep cavitation in structural materials.
- The simulation results indicate several aspects of creep cavitation behavior that are of paramount importance from the previous sections.
- The formulation through the ABAQUS CAE model has been successful in capturing the deformation and failure characteristics of epoxy material under high temperatures. Some of the important outcomes are the ability to predict creep strain rates, void growth, as well as damage localization.

REFERENCES

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THANK YOU!