There are three files in this repository

**I) von\_mises\_cyclic\_strain\_increased\_amplitude\_dataset\_preparation.ipynb**

This Jupyter Notebook is focused on **generating a dataset for cyclic strain behavior with increasing amplitude** using the Von Mises yield criterion. Applied strain values, change in plastic strain values, total plastic strain values & hysterisis curves resulting from the von mises yield crieteria are plotted for visual assesment.

Below is a breakdown of its functionality:

**Key Functions and Steps:**

### ****1. Imports and Setup****

* Uses **NumPy, Pandas, SciPy, TensorFlow, and Matplotlib**.
* Ensures **reproducibility** by setting random seeds.

### ****2. Material Properties Definition****

* Defines **material constants**:
  + **E = 19,300 MPa (Young’s modulus)** → Governs elasticity.
  + **σ\_y = 150 MPa (Yield stress)** → Threshold for plastic deformation.
  + **h = 100 (Isotropic hardening rate)** → Governs material hardening.

### ****3. Cyclic Strain History Generation****

* Generates a **cyclic strain history** over **3,900 time steps** with:
  1. **Small incremental strain increases (elastic phase).**
  2. **Alternating strain decreases and increases to induce cyclic behavior.**
  3. **Randomized strain increments in later cycles to increase amplitude.**
  4. **Final cycles introduce even larger strain variations, mimicking real-world material fatigue.**

### ****4. Elastic and Plastic Behavior Calculation****

* Implements **Hooke’s Law (Elastic Predictor)** to compute trial stress.
* Uses **Von Mises Return Mapping Algorithm** to determine:
  + If material remains **elastic** (Hooke’s law applies).
  + If material **yields and deforms plastically**, updating plastic strain and stress.

### ****5. Dataset Generation and Saving****

* Generates a dataset containing:
  + **Material properties (E, σ\_y, h)**
  + **Strain history (including increasing amplitude)**
  + **Stress-strain relationships**
  + **Plastic strain evolution**
  + **Yield function values**

### ****6. Training and Testing Dataset Preparation****

* Creates **three datasets**:
  + **Training set:** Strain range **(0.0001 - 0.0002)** with **2,100 samples**.
  + **Test set 1:** Strain range **(0 - 0.0001)** with **1,500 samples**.
  + **Test set 2:** Strain range **(0.0002 - 0.0004)** with **1,500 samples**.

****II) von\_Mises\_Neural\_Network\_Implementation\_cyclic\_strain\_increased\_amplitude.ipynb****

**This Jupyter Notebook is focused on training a neural network to predict the change in plastic strain values under cyclic loading with increasing amplitude. The trained neural network along with the min\_max\_scaler are stored after training. Below is a breakdown of its key functions:**

### ****1. Imports and Setup****

* Uses **NumPy, Pandas, SciPy, TensorFlow, and Matplotlib**.
* Implements **Latin Hypercube Sampling (LHS)** to generate material property variations.
* Ensures **reproducibility** by setting random seeds.

### ****2. Material Properties and Strain History****

* Defines **ranges for material constants**:
  + **E (Young’s modulus):** 191,000 MPa - 195,000 MPa.
  + **σ\_y (Yield stress):** 90 MPa - 120 MPa.
  + **h (Isotropic hardening rate):** 5 - 10.
* **Generates cyclic strain history** (3,900 steps) with:
  + **Small incremental strain increases (elastic phase).**
  + **Alternating strain decreases and increases (cyclic loading).**
  + **Increasing strain amplitude in later cycles** to mimic material fatigue.

### ****3. Elastic and Plastic Behavior Calculation****

* Implements **Hooke’s Law (Elastic Predictor)** to compute trial stress.
* Uses **Von Mises Return Mapping Algorithm** to determine:
  + If material remains **elastic** (Hooke’s law applies).
  + If material **yields and deforms plastically**, updating plastic strain and stress.

### ****4. Dataset Generation****

* **Generates a dataset** with:
  + **Material properties (E, σ\_y, h)**
  + **Strain history with increasing amplitude**
  + **Stress-strain relationships**
  + **Plastic strain evolution**
  + **Yield function values**

### ****5**. **Data Normalization****

* Uses **MinMax Scaling** to normalize dataset values between **0 and 1** for neural network training.

### ****6. Neural Network Training****

* **Defines and trains a neural network** using tensorflow.keras:
  + **Sequential model** with fully connected layers.
  + Uses **ReLU activation functions** for learning stress-strain relationships.
  + Implements **Early Stopping** to prevent overfitting.
  + Trains on **strain-stress dataset**.

### ****7. Visualization****

* **Plots training and validation loss** to evaluate model performance.
* **Compares predicted vs actual plastic strain values** for accuracy.

**III) von\_mises\_hysterisis\_loops\_cyclic\_applied\_strain\_increased\_amplitude.ipynb**

This Jupyter Notebook is focused on **modeling hysteresis loops for cyclic applied strain with increasing amplitude** using the **Von Mises yield criterion and Neural Networks**. The min\_max\_scalers and trained neural network resulting from the file II is called here to predict the change in plastic strain values. Hysterisis loops resulting from von mises yield criterion and neural network prediction are plotted against each other for accuracy assesment. Below is an explanation of what it does:

### ****1. Imports and Setup****

* Uses **NumPy, Pandas, SciPy, TensorFlow, and Matplotlib**.
* Implements **Latin Hypercube Sampling (LHS)** for generating material properties.
* Ensures **reproducibility** by setting random seeds.

### ****2. Material Properties and Strain History****

* Defines **material constants**:
  + **E = 192,000 MPa (Young’s modulus)** – Governs elasticity.
  + **σ\_y = 110 MPa (Yield stress)** – Defines the stress threshold for plastic deformation.
  + **h = 7 (Isotropic hardening rate)** – Governs material strengthening under cyclic loading.
* **Generates cyclic strain history** (3,900 steps) with:
  + **Small incremental strain increases (elastic behavior).**
  + **Alternating positive and negative strain cycles (cyclic loading).**
  + **Gradually increasing strain amplitude** in later cycles, mimicking material fatigue effects.

### ****3. Elastic and Plastic Behavior Calculation****

* Implements **Hooke’s Law (Elastic Predictor)** to compute trial stress.
* Uses **Von Mises Return Mapping Algorithm**:
  + Determines if the material behaves **elastically** or **plastically**.
  + Updates **plastic strain, stress values, and hardening parameters** accordingly.

### ****4. Dataset Generation****

### Generates a dataset containing:

* **Material properties (E, σ\_y, h)**
* **Strain and stress values**
* **Plastic strain evolution**
* **Hysteresis loop behavior**

### ****5. Machine Learning and Visualization****

* **Trains a Neural Network** to predict stress-strain behavior.
* **Compares predicted vs actual plastic strain values** for accuracy assessment.
* Uses **Matplotlib** to visualize **hysteresis loops**.