# Optimizing Structural Analysis: Stress Field Prediction in Plates with Holes using Graph Neural Networks


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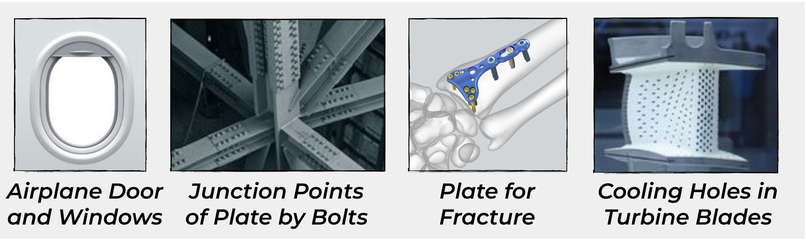
**MIT Portugal** 2023 Annual Conference


## Motivation

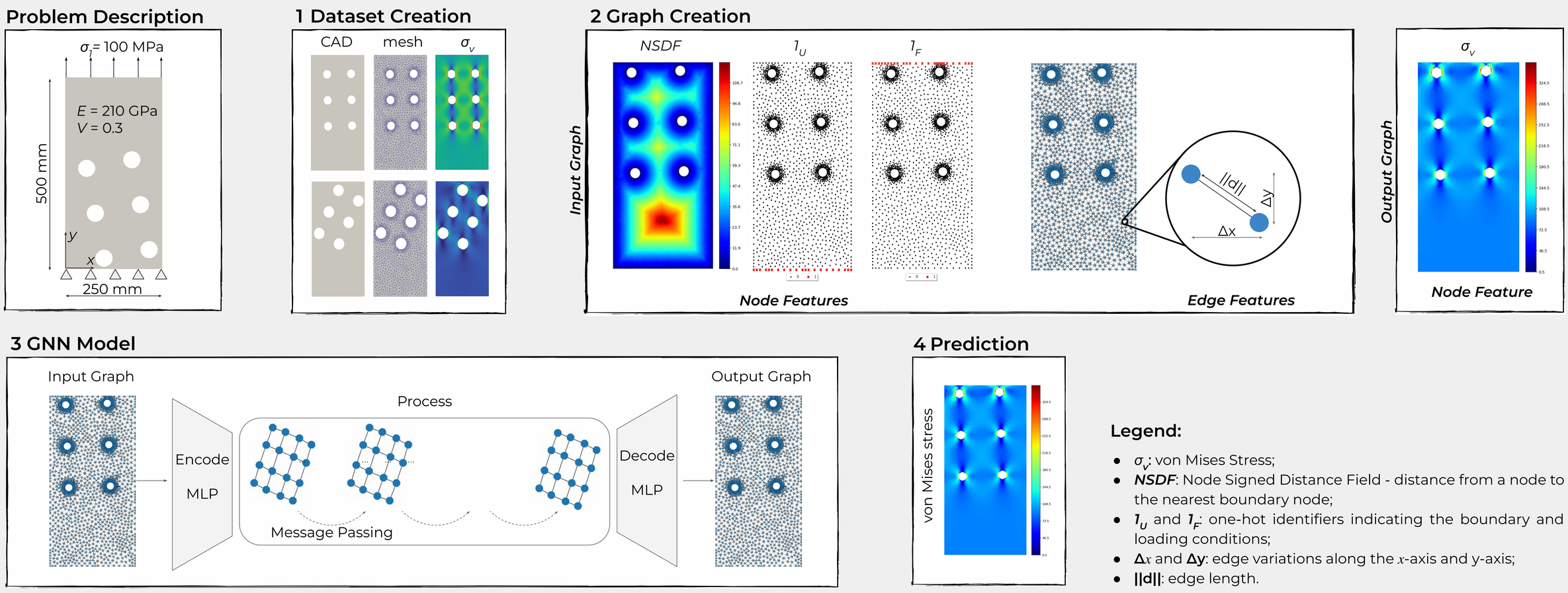
**Accurate stress-strain prediction** is **crucial in mechanical engineering and materials science** for aerospace, energy, and biomedical applications. Traditional methods like **Finite Element Method** (FEM) **are accurate but computationally intensive**, while Deep Learning techniques, particularly **Graph Neural Networks (GNNs)**, **show promise in stress field prediction. GNNs handle complex geometries and loading conditions**, offering **accurate local predictions with reduced computational power**. Their integration presents an **innovative approach with potential benefits for engineering analysis and design optimization.**

## Plate with Holes

The **plate with holes** holds **significant importance as a structural element** in engineering applications. **Accurate stress field prediction is essential for ensuring integrity and safety in components** like aircraft parts, mechanical elements, and civil structures. **Analyzing stress distribution around the holes enables informed decisions and optimized designs**, leading to enhanced reliability and safety standards, making it **a valuable investment in various industries**.




## Methodology

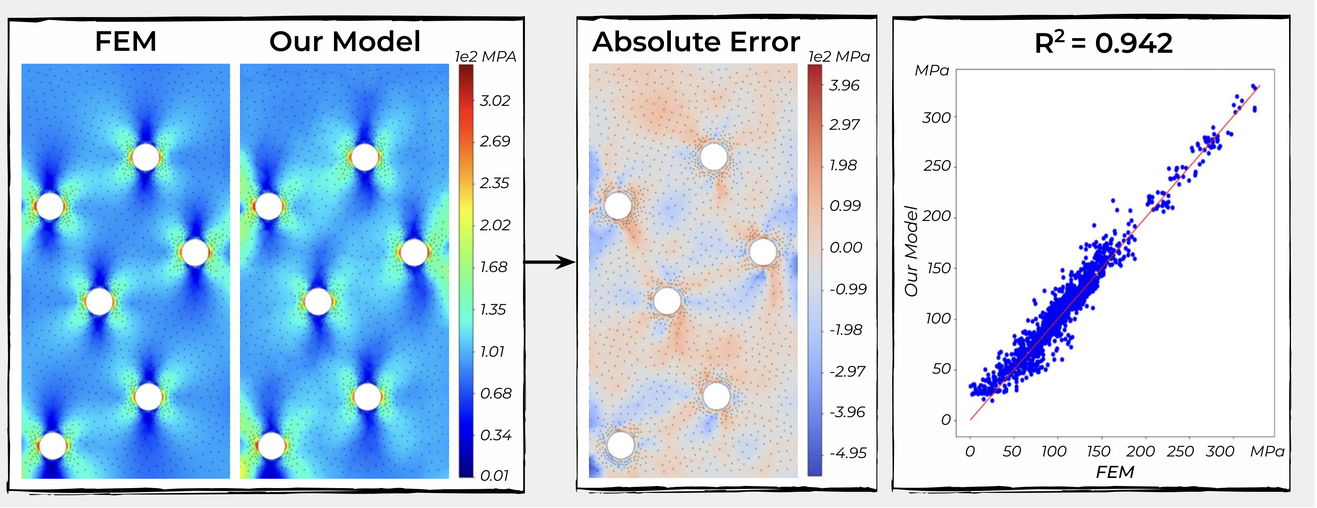



**Legend:**

- $\sigma_v$: von Mises Stress;
- ***NSDF***: Node Signed Distance Field - distance from a node to the nearest boundary node;
- $l_1^U$ and $l_1^F$: one-hot identifiers indicating the boundary and loading conditions;
- $\Delta x$ and $\Delta y$: edge variations along the $x$-axis and y-axis;
- $||d||$: edge length.

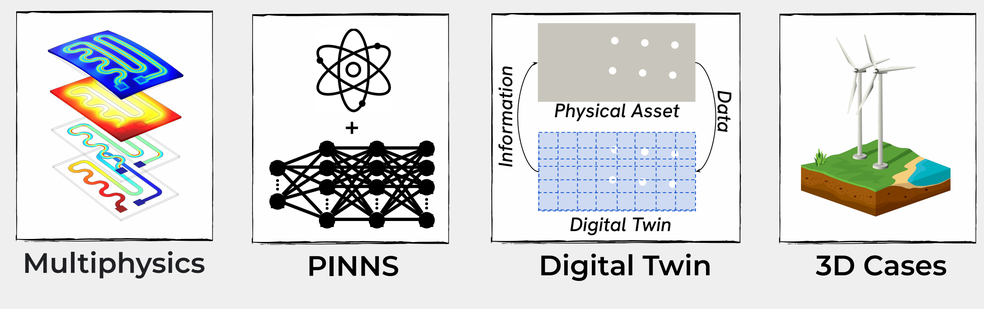
## Application

The research **goal** is **to predict the von Mises stress field.**




## Future Work

Future work involves **evaluating the model's generalization for intricate geometries, diverse conditions, and materials**. It will strive **to make the model more robust, adaptable, and capable of accurately simulating complex scenarios**, enabling transformative applications in various industries.




## Conclusion

**Our GNN model** demonstrates great promise in **accurately predicting the von Mises stress field for both linear and elastic cases**, achieving **high predictive performance** ($R^2 \approx 0.9$). Its versatile capabilities pave the way for disruptive **applications in real-time simulations** and **precise control of large structures, revolutionizing stress analysis and engineering simulations.**


Funded by:

Fundação para a Ciência e a Tecnologia

MIT Portugal

under the Doctoral Grant SFRH/BD/151364/2021 | Digital Transformation in Manufacturing