DUTCH COMPUTATIONAL SCIENCE DAY - 10/11/2023
FOR A SUSTAINABLE FUTURE

Spline Modeling Techniques for Industrial Applications

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Introduction

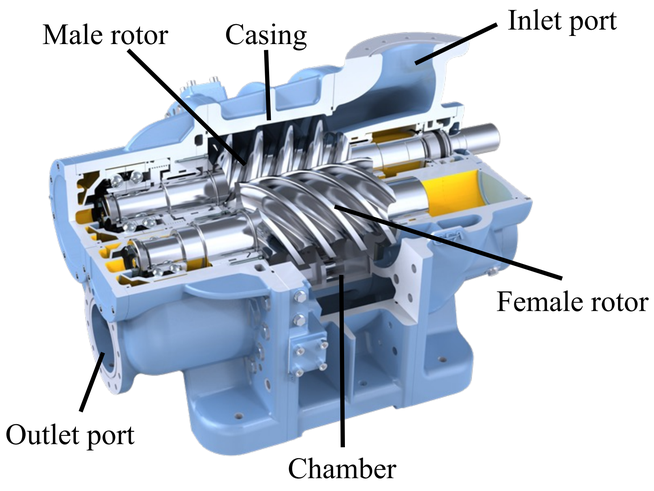
Geometry modeling using splines demonstrates significant promise across various applications. This poster specifically examines its effectiveness in:

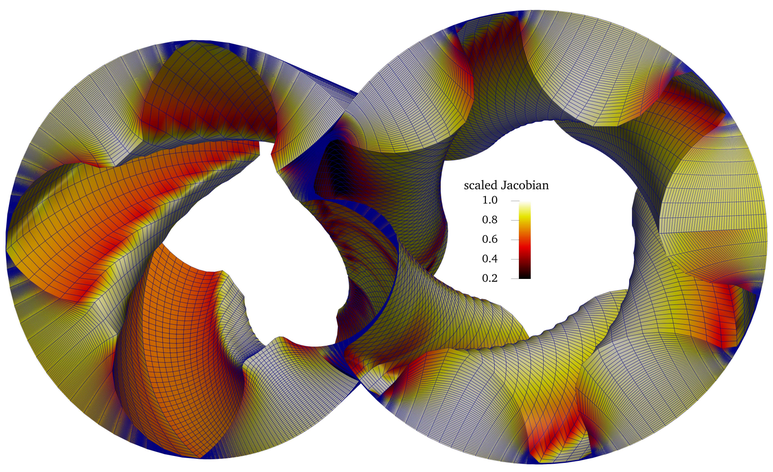
- improving the quality and efficiency of mesh generation for **twin-screw compressors**;
- boosting precision in contact modeling for **wheel/rail interaction problem**.

Mesh Generation for Twin-Screw Compressors

Background:

- Rotary-type positive displacement machines (PDMs) are vital in industrial applications for producing high-pressure air and gases, consuming 15% of the total industrial electricity;
- Even a slight improvement in efficiency can translate to substantial energy and cost savings;
- We generate simulation-suitable mesh using spline-based parameterization technique [1].





Method:

- To compute a quasi-harmonic mapping $\boldsymbol{x}: \hat{\Omega} \rightarrow \Omega$ by solving:

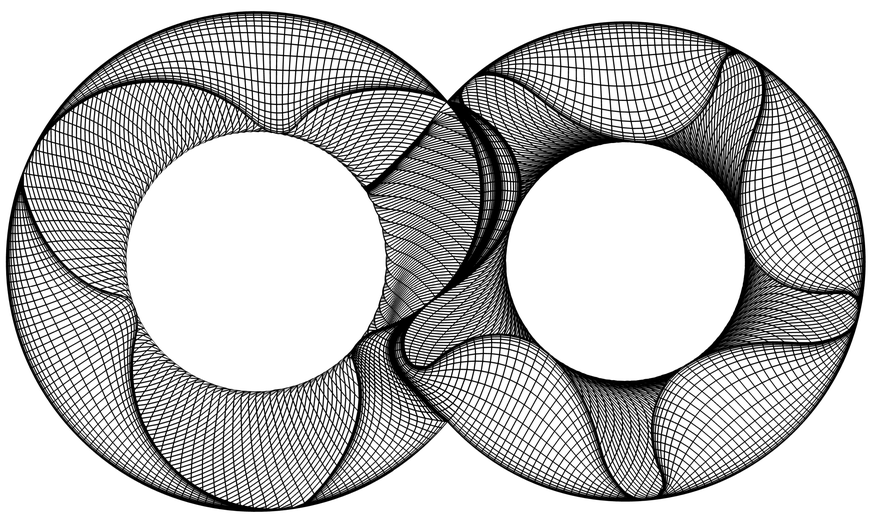
$$\begin{cases} \nabla \cdot (\mathbb{A}(\boldsymbol{x}) \nabla \xi(\boldsymbol{x})) = 0 \\ \nabla \cdot (\mathbb{A}(\boldsymbol{x}) \nabla \eta(\boldsymbol{x})) = 0 \end{cases} \quad \text{s.t. } \boldsymbol{x}^{-1}|_{\partial\Omega} = \partial\hat{\Omega}.$$

  Here, we set the metric tensor $\mathbb{A}(\boldsymbol{x}) = \text{diag}\,(1/|\mathcal{J}|, 1/|\mathcal{J}|)$.
- Our approach enhances computational efficiency using a novel **dynamic preconditioned Anderson acceleration method**

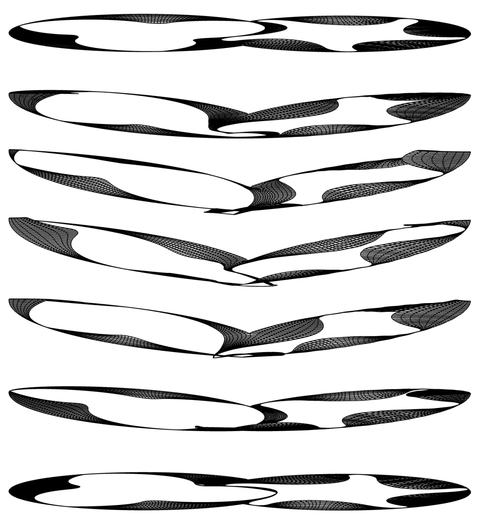
$$\boldsymbol{u}_{k+1} = \boldsymbol{u}_k - \mathcal{M}_k{}^{-1} \mathcal{F}_k, \tag{1}$$

  where $\mathcal{M}_k$ is a non-singular matrix, known as the preconditioner at iteration k.

Conversion to Traditional Mesh:

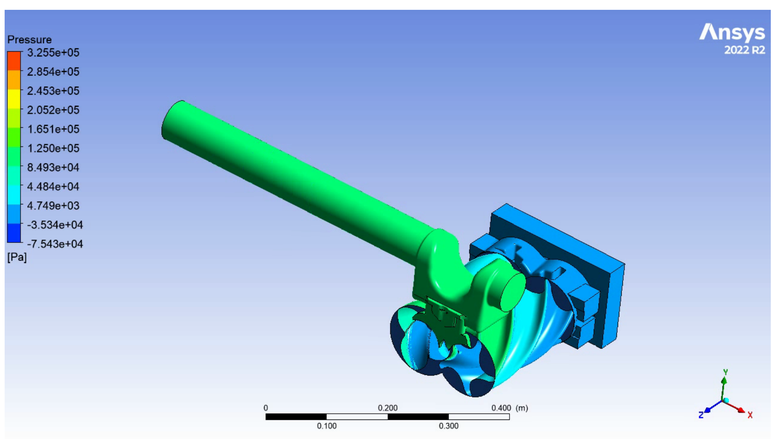


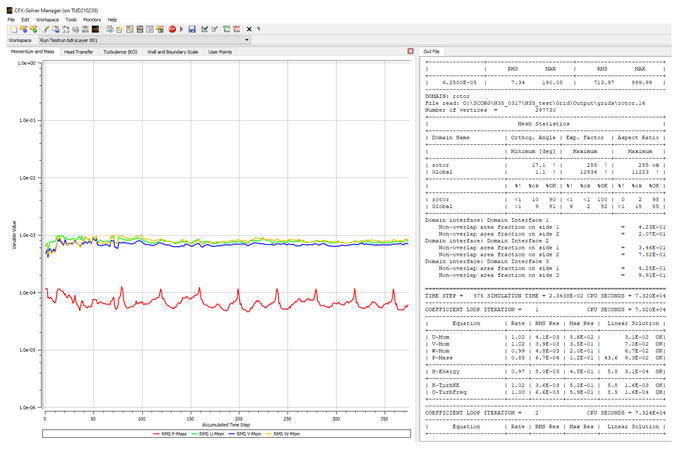
Boundary Layer Mesh



Flow-aligned Mesh

Simulation using ANSYS CFX ™:





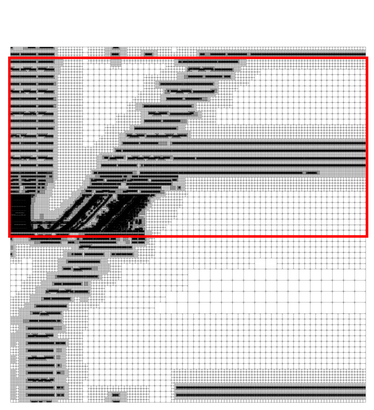
Wheel/Rail Interaction Problem

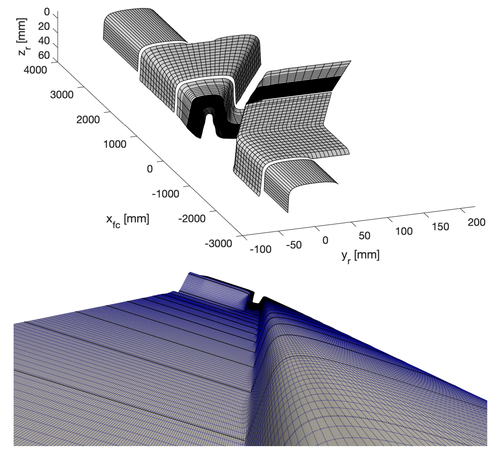
Background:

- Wheel/rail interaction plays an essential role in rail vehicle systems, carrying the vehicle load, guiding the vehicle along the track curve, and allowing for traction and braking [2];
- The accuracy of geometric modelling plays a crucial role in ensuring precise interaction analyses;
- Our approach utilizes spline techniques for optimal surface reconstruction and interface detection.

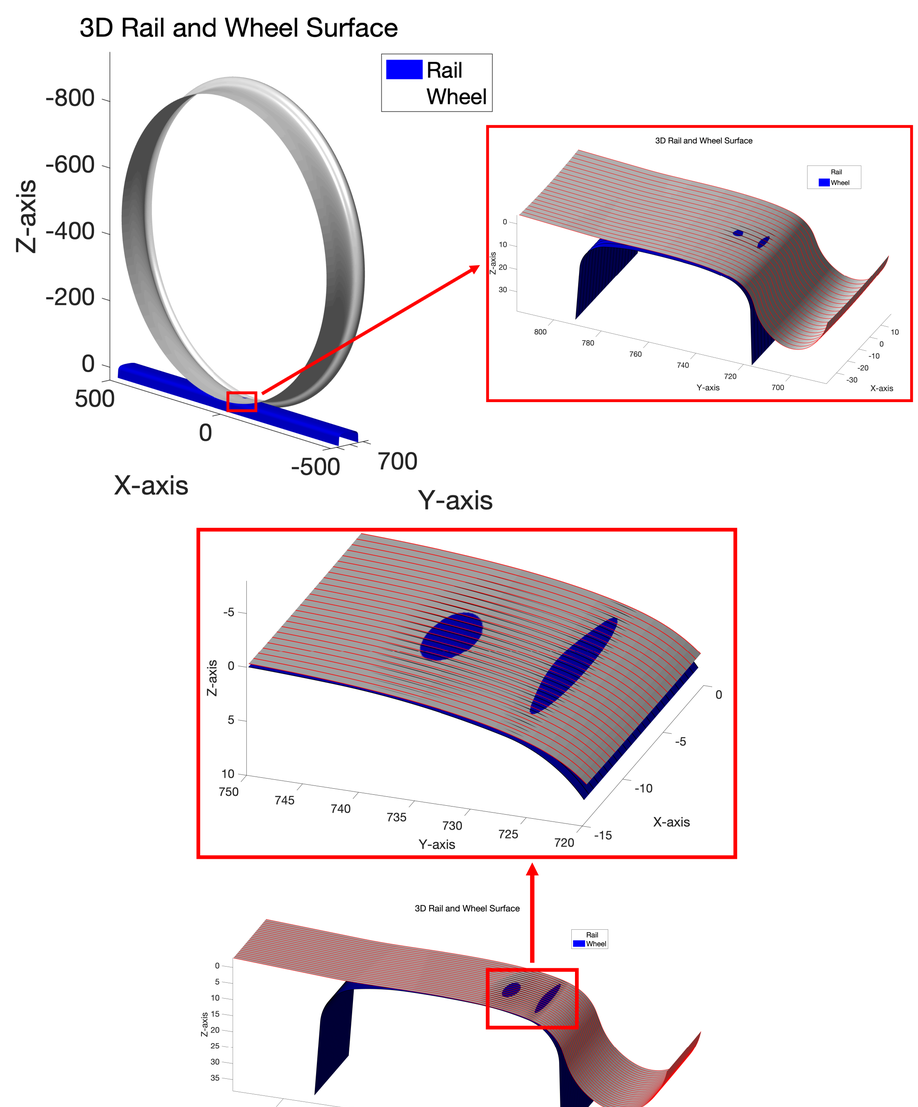
Contributions:

- Employ advanced Truncated Hierarchical B-spline (THB-spline) for precise surface reconstruction.





- Introduce a curve-by-curve scanning approach for efficient surface-surface intersections.



References & Contact

[1] Ji, Y., Chen, K., Möller, M., & Vuik, C. (2023). On an improved PDE-based elliptic parameterization method for isogeometric analysis using preconditioned Anderson acceleration. Computer Aided Geometric Design, 102, 102191.
[2] Vollebregt, E. (2021). Detailed wheel/rail geometry processing with the conformal contact approach. Multibody System Dynamics, 52(2), 135–167.

Please feel free to contact me! ;-)
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