TRC CONTINUATION PROPOSAL 2022-2023

Solid Modeler Rotordynamics: High Fidelity, Shaft Dynamics, Stress and Thermal Modeling (Project # 00071)

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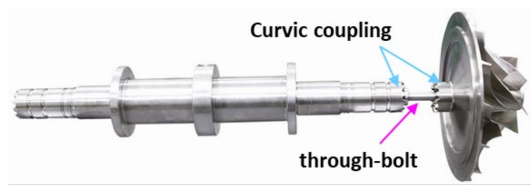
INTRODUCTION AND JUSTIFICATION

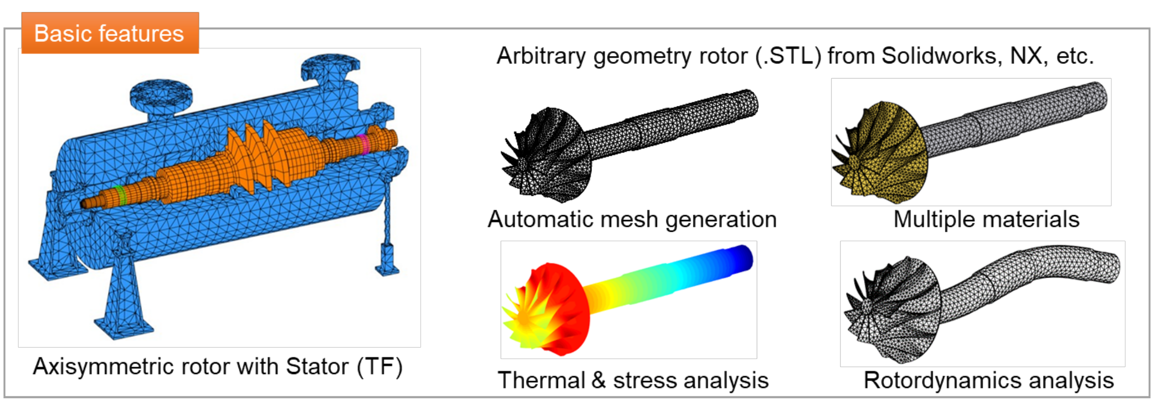


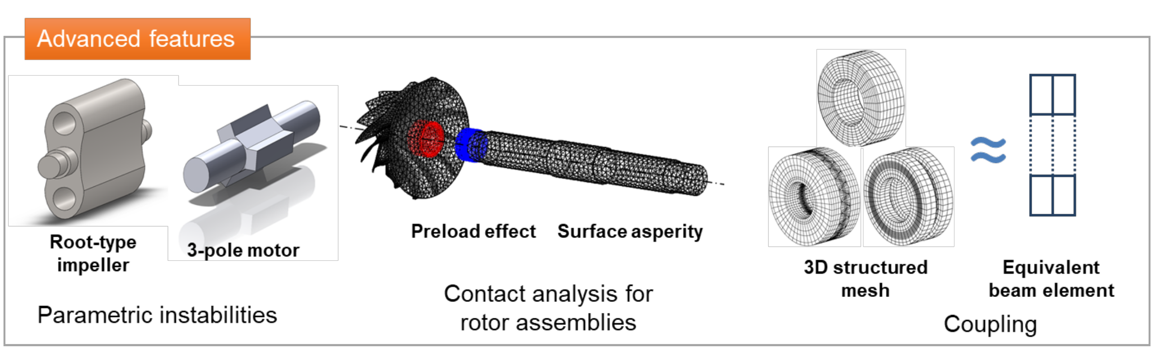
Compressor turbine rotor

This project provides software models of rotating assemblies with non-beam-like behavior, using 3D solid element modeling and solid model inputs. For example, non-beam-like behavior occurs at internal butt, Hirth, or Curvic coupling of a rotor fastened together with a preloaded through-bolt. The coupling introduces a local lateral flexibility that can affect critical speed and general rotordynamic response, yielding an inaccuracy problem in a conventional beam model. In these instances, a 3D solid finite element model with accompanying rotordynamic analyses is recommended to produce reliable predictions of critical speed, log dec, parametric instability, etc. In a traditional beam-based rotordynamic model, this can also be done indirectly using equivalent beam properties, which is equivalent Young's modulus and transverse shear effect, obtained from the 3D FEM.

DELIVERABLES

- Standalone 3D Solid Finite Element Rotordynamics software which runs under the EXCEL system umbrella without any other software (ANSYS, Fortran …) required.
- Geometric input obtained from any solid model software outputs (SolidWorks, Catia, …) or by users.
- Multiphysics solid finite element analysis (thermal/structural/rotordynamics), such as predictions of natural frequency, critical speed, mode shape, parametric instability, with arbitrary shape geometries with multiple materials and connections (butt joint, Hirth, Curvic coupling) using GW contact theory.
- Calculating equivalent Young's modulus and equivalent transverse shear effect at mating surface that can be used for the equivalent beam model.





PROPOSED WORK

Fig. 1 Fetter ring

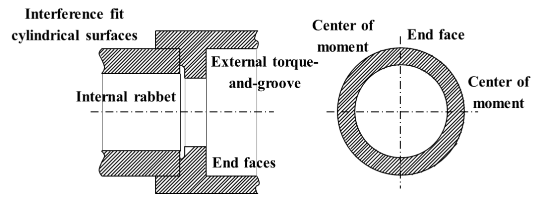


Fig. 2 Rabbet joint

1) **Fetter rings radial contact**
   (Holding discs onto shaft)
   a. Natural frequency, critical speed prediction
   b. Validation with the test data
2) **Rabbet joint**
   a. radial contact + axial contact
3) **Asymmetric temperature distribution on shafts**
   a. Simulation / Exp. for vibration analysis due to temperature asymmetry (bifurcation of natural frequency expected)

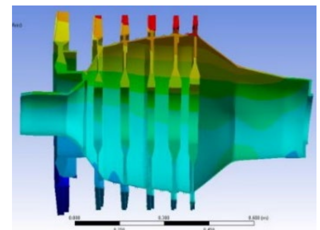


Fig. 3 Asymmetric Temp.

4) **Micro slip modeling, internal friction effect modeling, rub**
   a. Friction due to relative motion from shrink fit
   b. Relationship between microslip and internal friction
   c. Self-excitation instability
5) **Shaft with composite material**
   a. Compare ANSYS penalty method with current SFER GW method
6) **Combination with Machine Learning $\mathbf{E_{coupling}}$ & $\mathbf{\Phi_{coupling}}$**
7) **Newkirk effect**
8) **Improve software computational efficiency and Excel user interface**
   a. Develop a user interface for interacting with $XLTRC^2$ rotor input

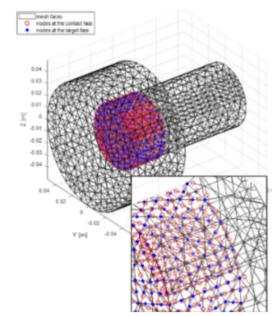


Fig. 4 Micro slip

STATUS OF CURRENT WORK

Standalone Solid Modeler TRC Software

- A user-friendly EXCEL User Interface based simulation environment
- Axisymmetric 2D element/10-node quadratic tetrahedron/8-node hexahedron finite element rotor modeling capability
- Multiphysics analysis for thermal/structural/high-fidelity-rotordynamic analysis (natural frequency, log dec, parametric instability and etc.)

Fig. 5 Composite shaft

- Parametric instability evaluation algorithm
- Butt-joint modeling capability with different levels of surface roughness and preload
- Butt-joint experimental test data
- Hirth / Curvic coupling modeling capability with different parameters, levels of surface roughness, and preload
- Hirth / Curvic coupling experimental test data
- $\mathbf{E_{coupling}}$ & $\mathbf{\Phi_{coupling}}$ of Butt-joint, Hirth and Curvic coupling for Equivalent beam model

BUDGET FOR 2020-2021

1 PhD student ($2,250/mo. Salary + $300 insurance) × 12 months, tuition and fees $18,000, machining cost and supplies $1,400, **Total Cost: $ 50,000**