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Wave Speed Coincidence in Rotating Machinery

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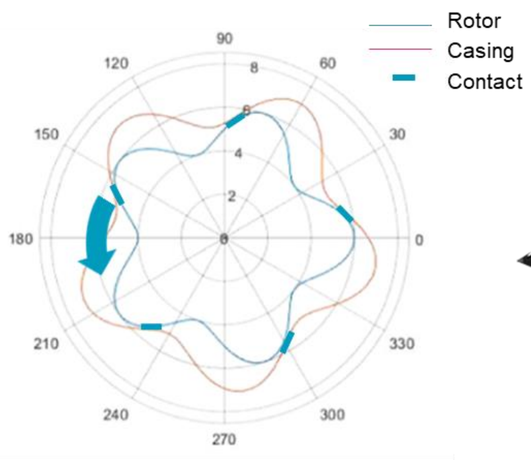
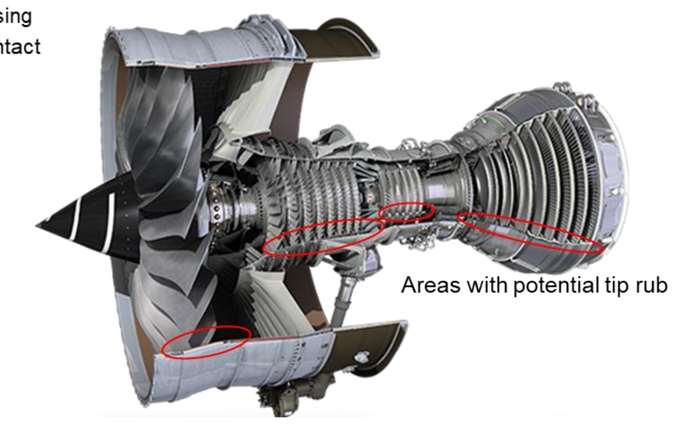
1. Background



Example of Wave Speed Coincidence between two simple ring structures



Cross-section of a Rolls Royce Trent XWB[1]

Wave speed coincidence is a modal interaction, where vibration in two structures characterised as travelling waves interact synchronously. Under certain conditions this has been shown to lead to instability and structural failure.

This research focuses on interaction via tip rub between the casing and the blade tips. Tip clearances are often minimised to maximise efficiency, which makes tip rubs more likely. Other factors such as the casing symmetry and abradable liner properties can also influence the wave speed coincidence phenomenon.

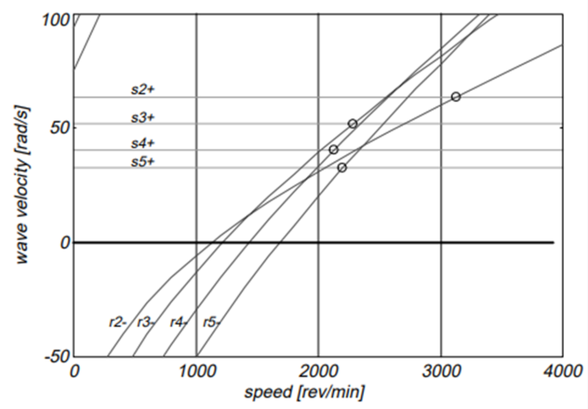
This research aims to establish a prediction and screening method for the design of mainly aero-engines, and to improve understanding of the phenomenon generally.

2. Objectives

- Develop modelling and prediction methodologies to predict the potentially damaging coincidence of travelling waves between rotor blades and casing.
- Identify design parameters that influences the phenomenon.
- Develop screening method(s) to detect wave speed coincidence in design; clarify if all coincidences lead to structural failure.
- Deliver feasible solution(s) for mitigation of wave speed coincidence risk on a gas turbine.

3. Methodology

Wave speed diagrams are used to identify critical speeds at which similar modes in the casing and bladed disk have the same wave velocities[2].



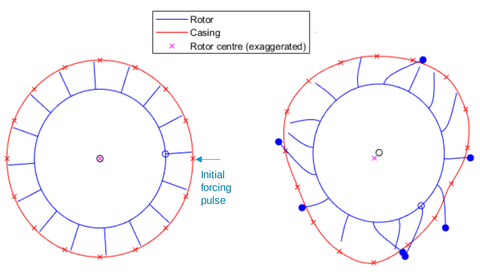
Example of a wave speed diagram to identify critical speeds[2]

This is followed by more time integration analyses to identify additional critical speeds not captured by the wave speed diagrams.

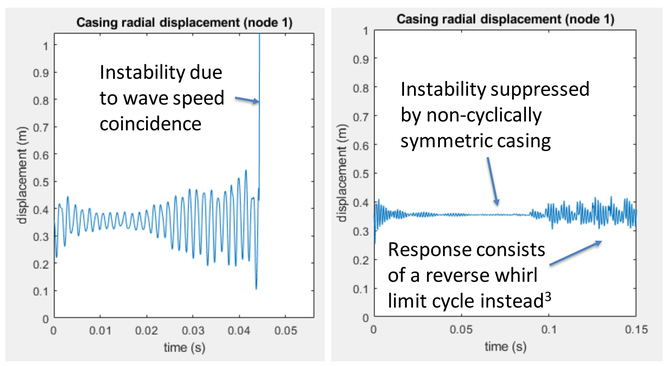
A 2D model including radial contact and tangential friction forces is used. An abradable liner has also been introduced into the model to study its impact.

4. Preliminary Results

- Various studies carried out on a preliminary model with arbitrary properties.
- Instability was found, with a 3 nodal diameter interaction in one of the cases as shown below.
- Effect of casing asymmetry was studied, among other factors such as rotational speed, damping and support stiffnesses.
- Ongoing investigations with the latest non-dimensional model.



3 nodal diameter interaction between casing and bladed disk



Comparison of radial displacement for a selected node between an cyclically symmetry casing and a non-cyclically symmetry casing

5. Conclusion and Future Work

The latest structural model can now study the factors influencing wave speed coincidence more comprehensively than previous models. Preliminary analyses has shown the onset of instability is highly sensitive to factors such as casing symmetry. Further parametric studies around the design space representative of a real aero-engine is to be conducted to establish a screening method.

References

1. https://www.rolls-royce.com/products-and-services/civil-aerospace/airlines/trent-xwb.aspx#/
2. Schmiechen, P. (1997), `Travelling Wave Speed Coincidence ', PhD thesis, Imperial College London.
3. Williams, R. J. (2004), `Parametric Characterisation of Rub Induced Whirl Instability using an Instrumented Rotordynamics Test Rig'.

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