Contribution ID: **26** Type: **Poster**

Insights into squealing disk brakes through explainable machine learning for time series data

Thursday, July 30, 2020 1:00 PM (1 hour)

Friction brakes can exhibit high-intensity vibrations in the frequency range above 1 kHz, which is typically known as squeal. Those vibrations are self-excited due to the friction-interface between brake pads and disk. Decades of research have been spent on modelling this phenomenon, but even today predictive modelling is out of reach. The root causes, amongst others, are considered to be the multi-scale temporal effects, multi-physic interactions involving mechanics, thermodynamics and chemistry, unknown system parameters and emergent behaviour. Continuing recent works, we present a machine learning approach to predict the dynamic instability from multiple complex loading conditions using recurrent neural networks and a large experimental database. In order to generate new designs that are less prone to self-excited vibrations, the trained networks are exposed to model-agnostic explainers, that can disaggregate the complex nonlinear relations that were learned during the training phase. Importance values are assigned to loading sequences and are visualized by colour mappings. The validated models are virtual twins for the actual brake system and can serve as a reduce-order model. Furthermore, classical analytical models are compared and updated using the virtual twins for generating low-dimensional representations of complex dynamical systems.

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Session Classification: Posters 3