Model Fusion approach for estimating bearing loads

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Health & Condition monitoring

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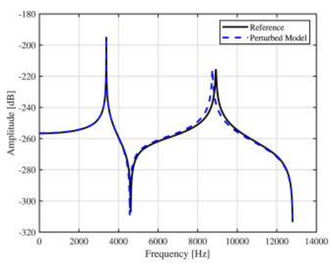
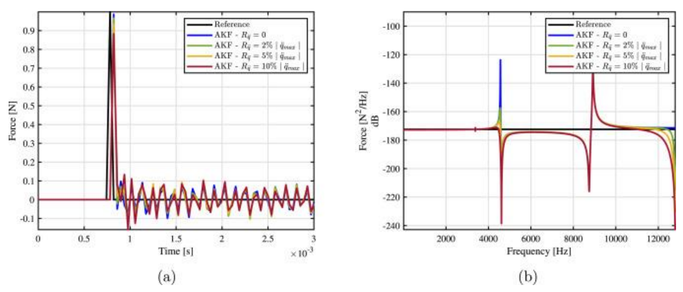
Goal

To improve the accuracy of inverse problems, such as force reconstruction in ball bearings, through simultaneous usage of multiple models of the same system.

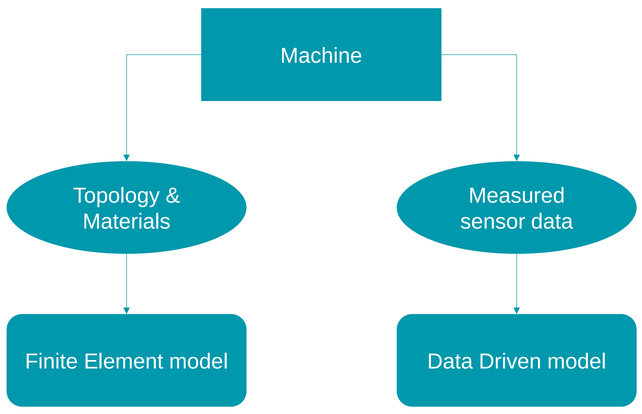
Motivation

- Force *measurements* are often expensive or impractical to obtain. Force *estimations* are then interesting alternatives.
- Models are imperfect. And inverse problems are known to be very sensitive to modelling errors: [1]





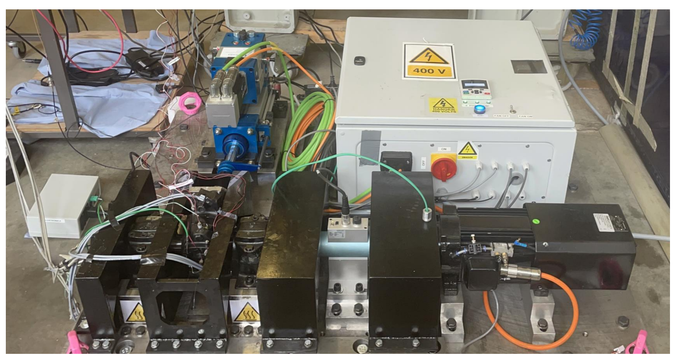
- Multiple models are often available:



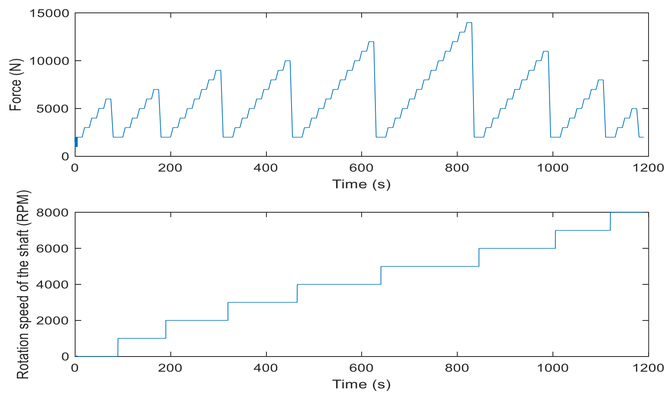
- FE models better capture low frequency behaviour and DD models better capture high frequencies.
- Using both models together, each in their accurate frequency range, improved the accuracy in past academic test cases.
- A more realistic test case, in the form of frequency domain force estimation on a ball bearing, is proposed.

Setup

- Bearing degradation setup:

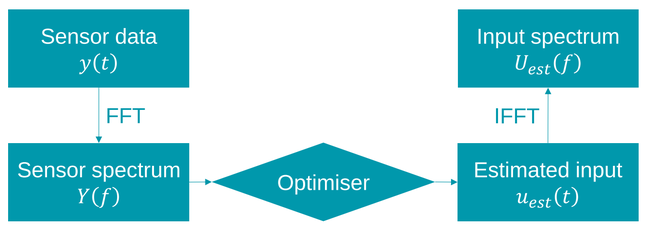


- Force input: stepwise constant



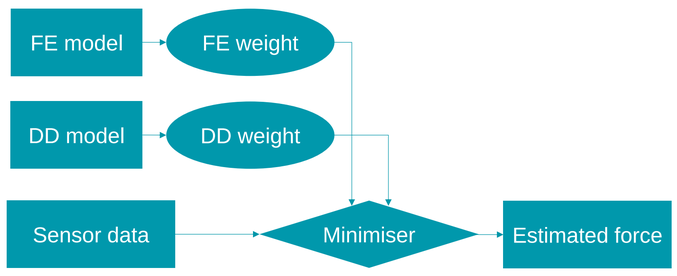
Approach

- Move sensor data to frequency domain, optimize input spectrum and return to time domain:

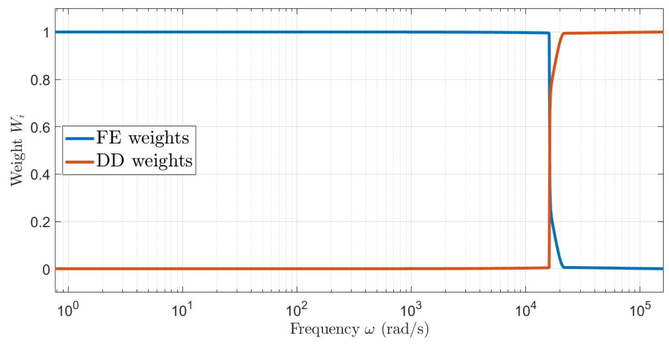


- Optimiser: Minimise weighted output error, summed over both models:

$$\min_{U_{est,f}} \sum_{m} W_f^m \left\| \left(Y_f - H_f^m U_{est,f} \right) \right\|_2^2$$



- Weights need to be chosen. Done by optimizing with training data:



Results

- Using very noisy measured data to make a useful data driven model is harder than in more trivial test cases.
- Near-constant force input has a high DC component. All other frequencies have low S/N.
- Resulting errors are larger than 100% for some data driven models.
- Still, most of the time, the error is smaller when simultaneously using both models than when using either model alone.

Key take-aways

- Small modelling errors allow for large errors in inverse problems.
- Multiple models are available.
- Simultaneous usage of different models limits the inverse problem sensitivity errors.
- The considered frequency domain input estimation method works better in some applications than others.

Further reading

- [1]: Zapata L., Patalong M., Teufelhart S., Desmet W. & Naets F. (2022). Combined impulse-response/Kalman filtering (CIRKF) for input/state estimation https://doi.org/10.1016/j.ymssp.2022.109527
- Geutjens B., Meerbergen K. & Naets F., “A spectral model fusion approach for force input estimation” (Future journal publication, working title)

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