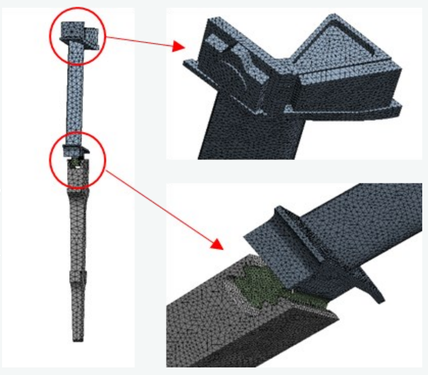
POLITECNICO DI TORINO

Substructuring in Bladed-disks for Mistuning Parameters Identification

INTRODUCTION:

Bladed-disks are an essential component of a turbomachine that experience a very harsh environment and undergo high cycle fatigue due to large vibration amplitudes. Although these are made of nominally identical sectors, the presence of imperfections / misalignment / in-homogeneity (in a single word: ***mistuning***) produces a large amplification of the forced response, thereby, making the situation even worse. Therefore, damping is needed to lower the amplitudes. However, identification and modelling of damping is always a challenging task especially when it comes from contact friction which is highly non-linear.

In case of bladed-disks, the main damping sources are the joints between blade to blade (shrouds) or blade to disk (***blade-root*** or under platform dampers).



FREQUENCY-BASED SUBSTRUCTURING (FBS)

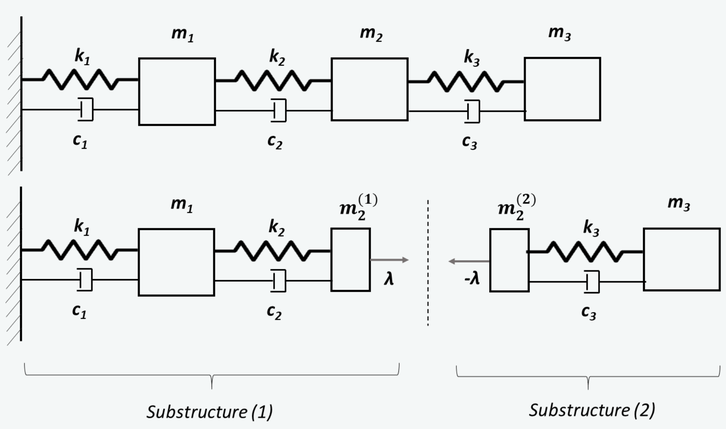
Structures can be sub divided in different domains. In the context of experimental methods, FBS is quite useful.

Example

$$\begin{cases} Z\bar{\boldsymbol{u}} + B^T\lambda = \bar{\boldsymbol{f}} \\ B\,\bar{\boldsymbol{u}} = 0 \end{cases}$$

$$Z = \begin{bmatrix} Z^{(1)} & 0 \\ 0 & Z^{(2)} \end{bmatrix}$$ Impedance matrix

B is the signed Boolean interface compatibility matrix



Experimentally

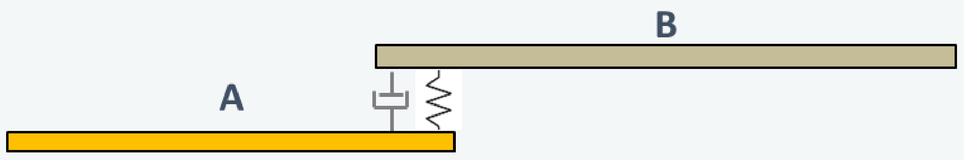
$$Y = Z^{-1}$$ Flexibility matrix or FRF

$$\boldsymbol{Y}_{g,dual} = \underbrace{\boldsymbol{Y}}_{\text{uncoupled}} - \underbrace{\boldsymbol{Y}\,\boldsymbol{B}^T\left(\boldsymbol{B}\,\boldsymbol{Y}\,\boldsymbol{B}^T\right)^{-1}\underbrace{\boldsymbol{B}\,\boldsymbol{Y}}_{\Delta}}_{\lambda}$$

(coupled)

INTERFACE FLEXIBILITY BY THEORY OF DECOUPLING

$$\boldsymbol{K}^* = \left(\boldsymbol{Y}_{ic}^{(1)} \cdot \left(\boldsymbol{Y}_{oi}^{C}\right)^{-1} \boldsymbol{Y}_{oc}^{(2)} - \boldsymbol{Y}_{cc}^{(1)} - \boldsymbol{Y}_{cc}^{(2)}\right)^{-1}$$

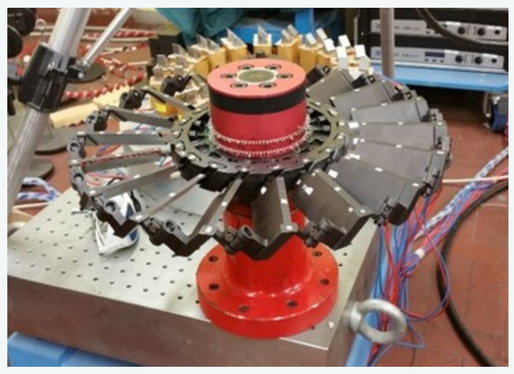


$$K_{ij}^* = k_{ij} + ic_{ij}$$

TEST CASES AND RESULTS:

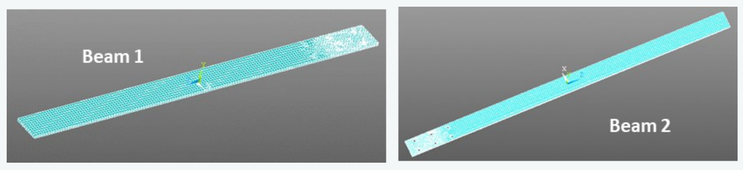
1. Fixed-free beams assembled to make a fixed-fixed assembly

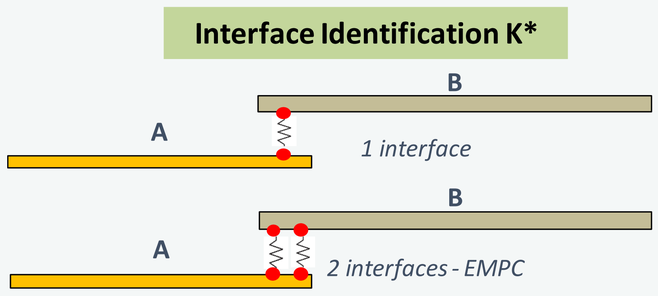
2. Fixed-free disk, free-free blade assembled to make a fixed-free system

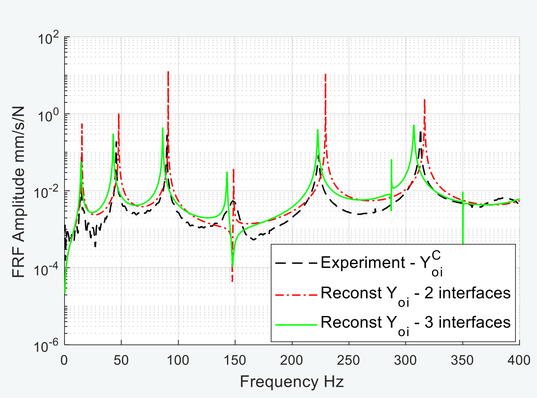


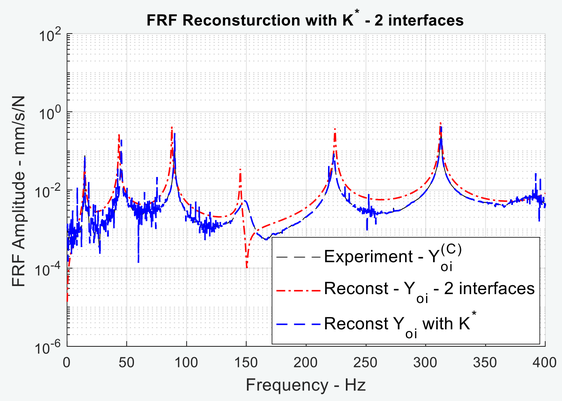
Hybrid method of FBS:

- Experimental FRFs
- Numerical FRFs







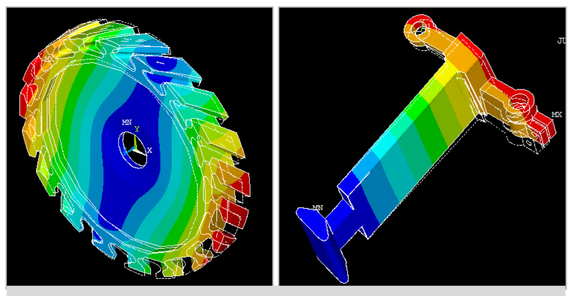


Applying similar method to the bladed-disk as on the beams successively...

Disc + Blade 1

Disc + Blade 2

Experimental FRFs



Numerical FRFs individual components

INTERFACE IDENTIFICATION

Disc+blade1, Disc+blade2, ...

MISTUNING PARAMETER FROM ALL THE CONTACTS ON THE BLADED-DISK ASSEMBLY

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EXPERTISE

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