POLITECNICO DI TORINO

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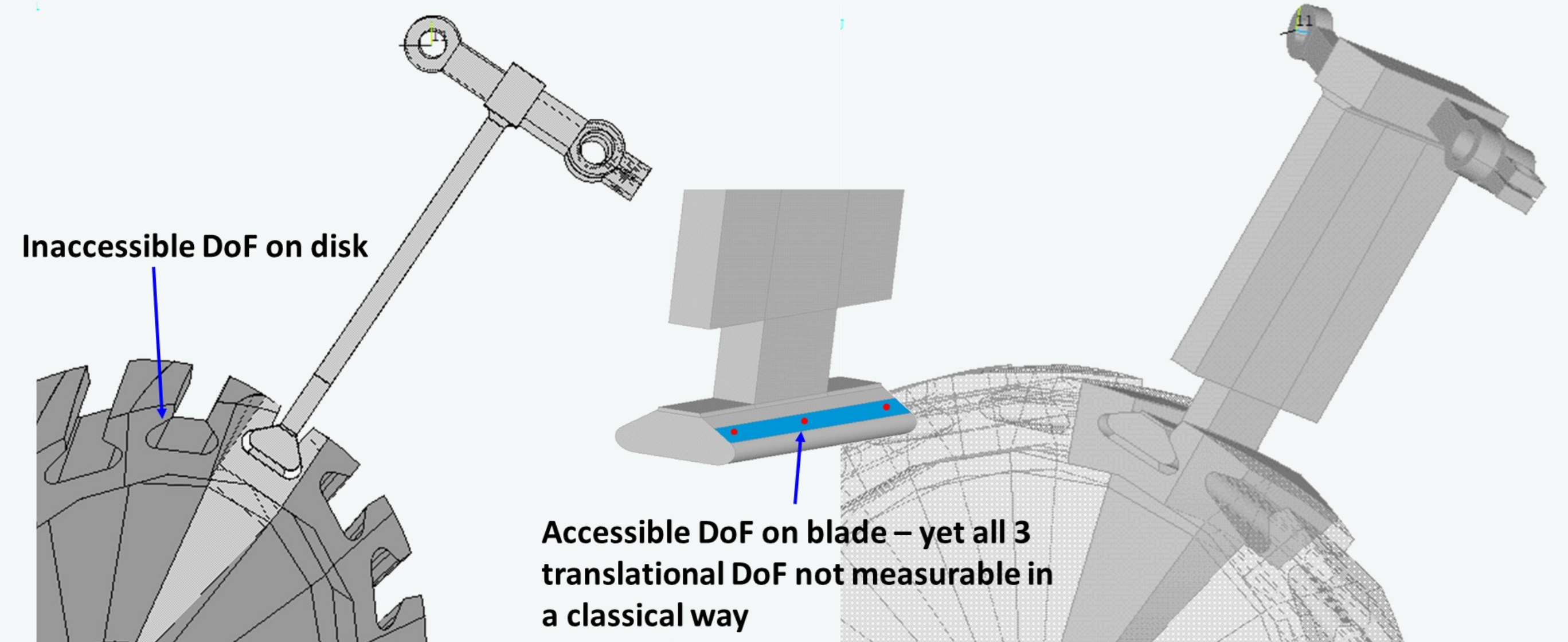**Prof. Christian Firrone**

EXPERTISE

Experimental Joint Identification by SEMM Decoupling in A Bladed-Disk

RESEARCH OBJECTIVE

To *experimentally identify and characterize* the blade-root joints of a bladed-disk
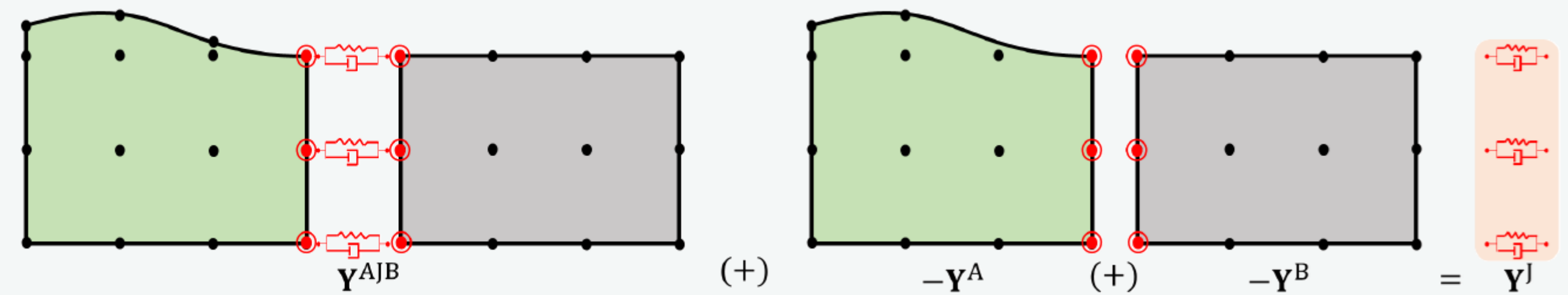
KEY CHALLENGES

1. *Inaccessibility of joint degrees-of-freedom (DoF) in assembled system*
2. *Inaccessibility of interface DoF in unassembled subsystems*
3. *Difficulties in collocated DoF set (Drive points FRF)*
4. *Problem in acquiring rotational interface DoF*
5. *Noise polluted FRF inversion*

Inaccessible DoF on disk

Accessible DoF on blade – yet all 3 translational DoF not measurable in a classical way

Joint Identification by Classical Decoupling

In frequency based susbtructuring (FBS), decoupling known subsystems from a coupled subsystem gives the joint flexibility FRF

$$\bar{Y}^J = Y - YB^T(BYB^T)^{-1}BY, \quad \text{with} \quad Y = \begin{bmatrix} Y^{AJB} & & \\ & -Y^A & \\ & & -Y^B \end{bmatrix}$$
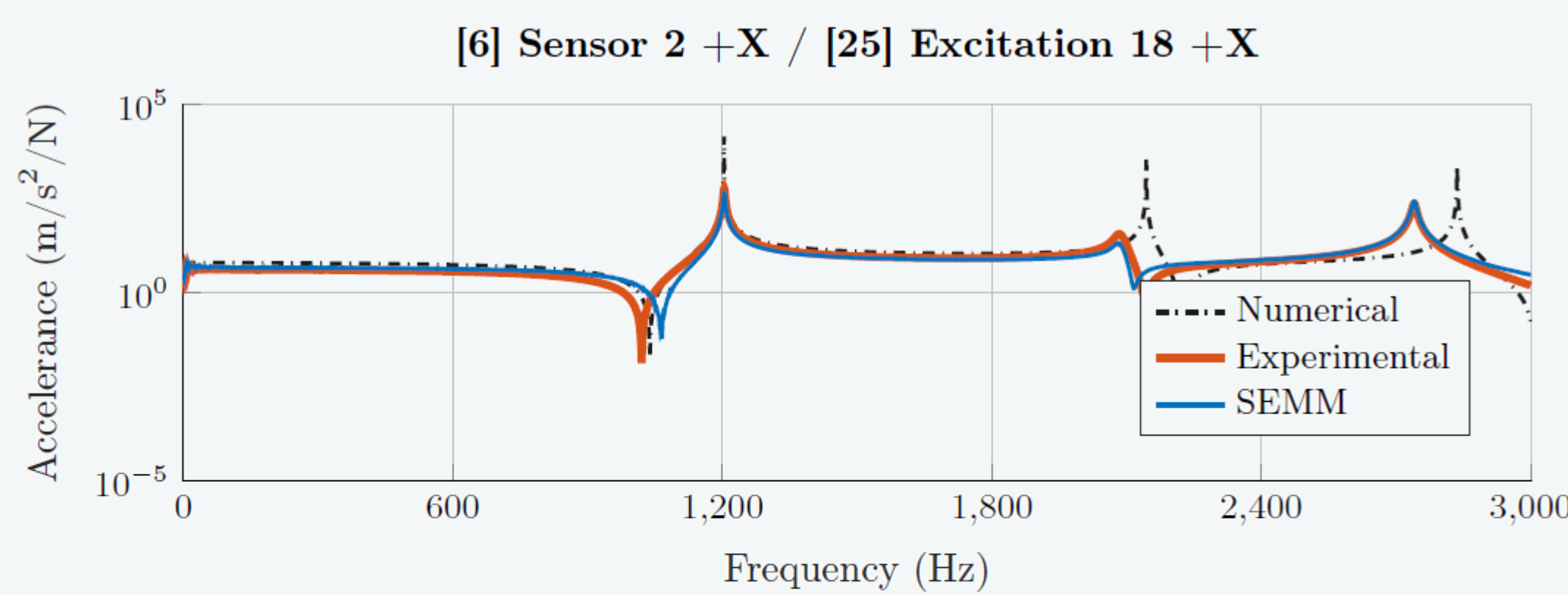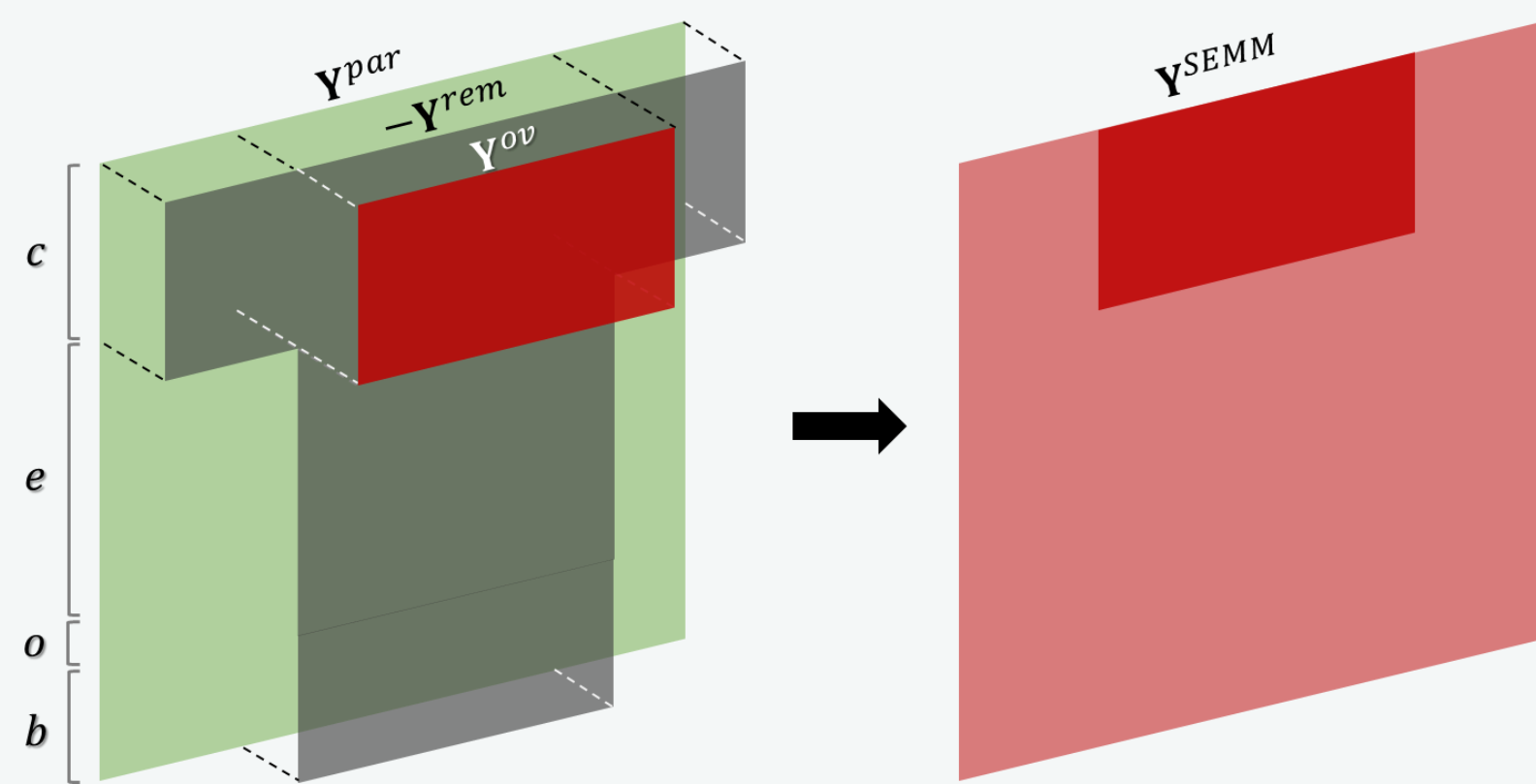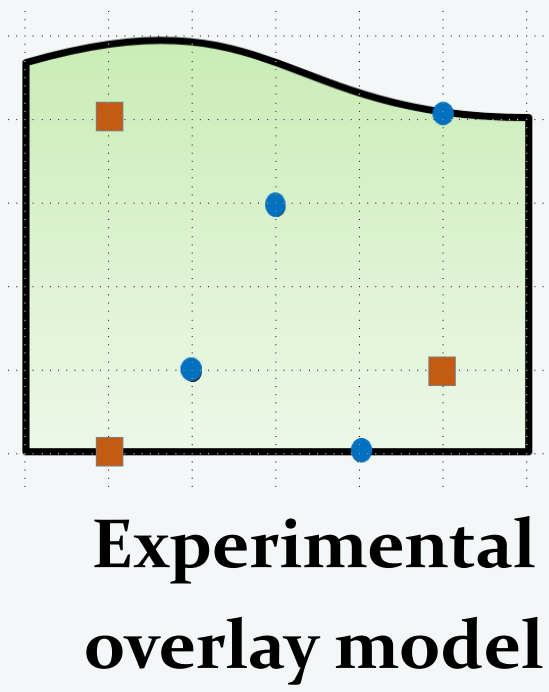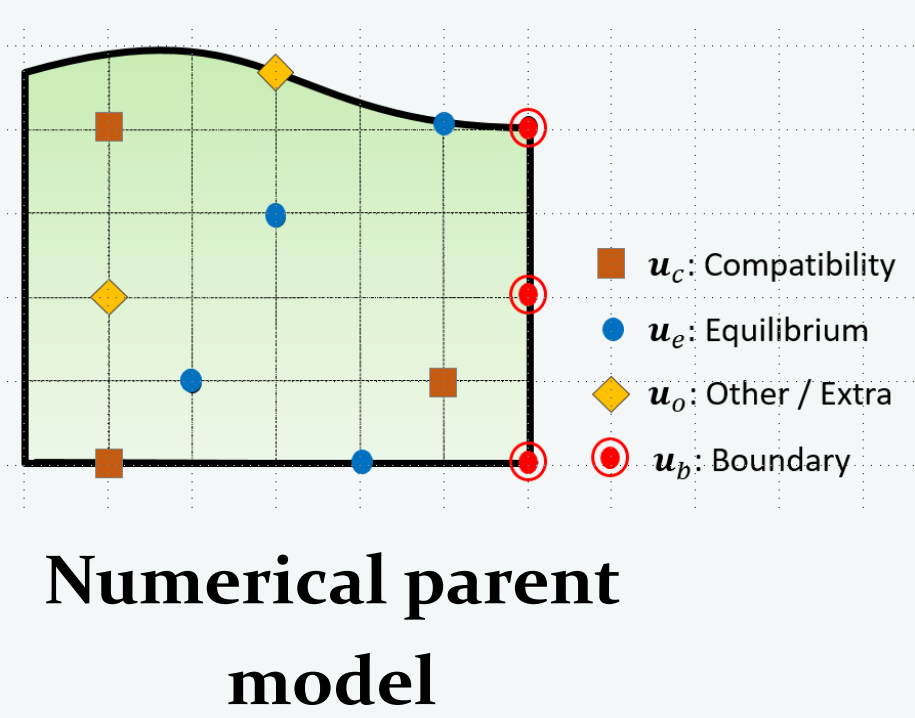

Y^{AJB} (+) $-Y^A$ (+) $-Y^B$ = Y^J

Because of the stated challenges, especially the interface DoF inaccessibility, we use an expansion technique called System Equivalent Model Mixing (SEMM)
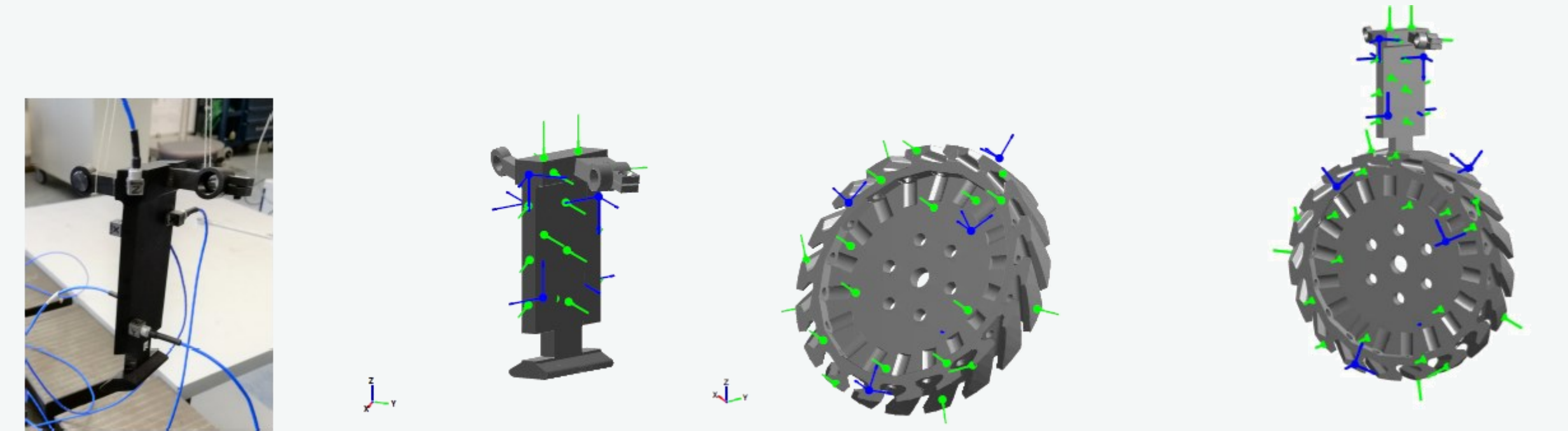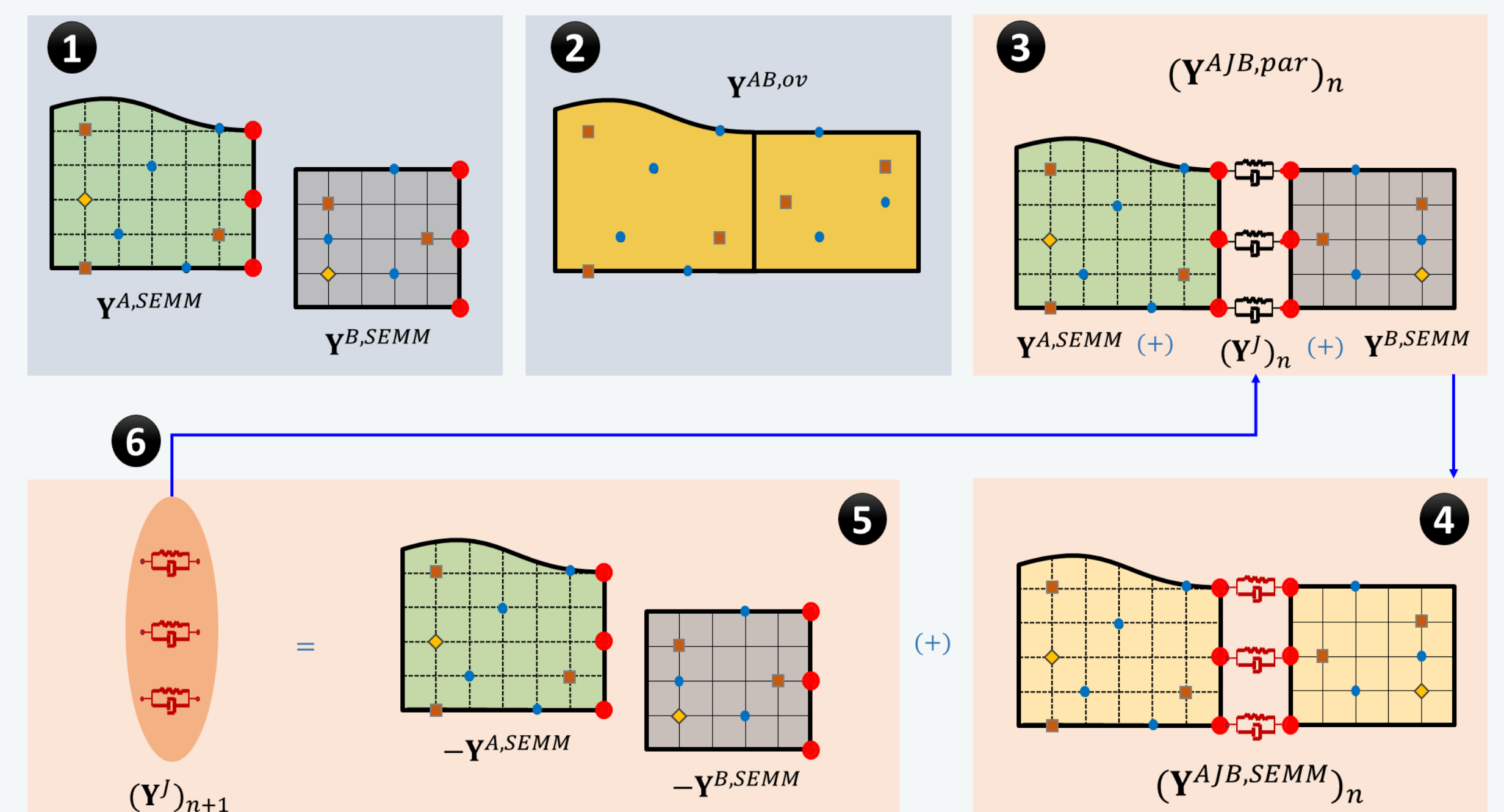
SEMM

A method to mix different equivalent models of a structure that expands dynamics of an overlay model onto a parent model by a simultaneous coupling and decoupling of a removed model.

$$\bar{Y}^{SEMM} = Y_{gg}^{par} - Y_{gg}^{par}(Y_{cg}^{par})^+(Y_{ce}^{par} - Y_{ce}^{ov})(Y_{ge}^{par})^+ Y_{gg}^{par}$$

Numerical parent model

- u_c: Compatibility
- u_e: Equilibrium
- u_o: Other / Extra
- u_b: Boundary

Experimental overlay model

[6] Sensor 2 +X / [25] Excitation 18 +X

Accelerance (m/s²/ N)

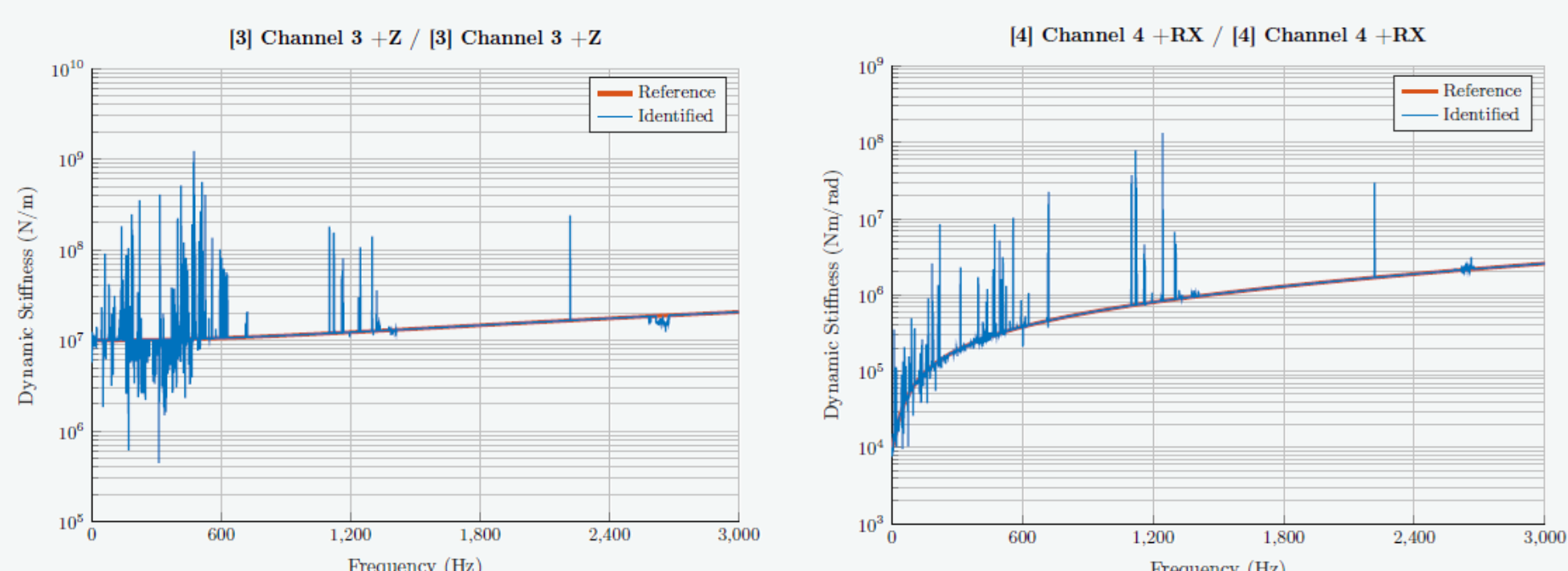- Numerical
- Experimental
- SEMM

Frequency (Hz)

Joint Identification by SEMM Decoupling

In order to identify the joint by SEMM, the decoupling is performed iteratively until the expansion error $\varepsilon = || (Y^{AJB,par})_n - Y^{AB,ov} ||$ is minimized.
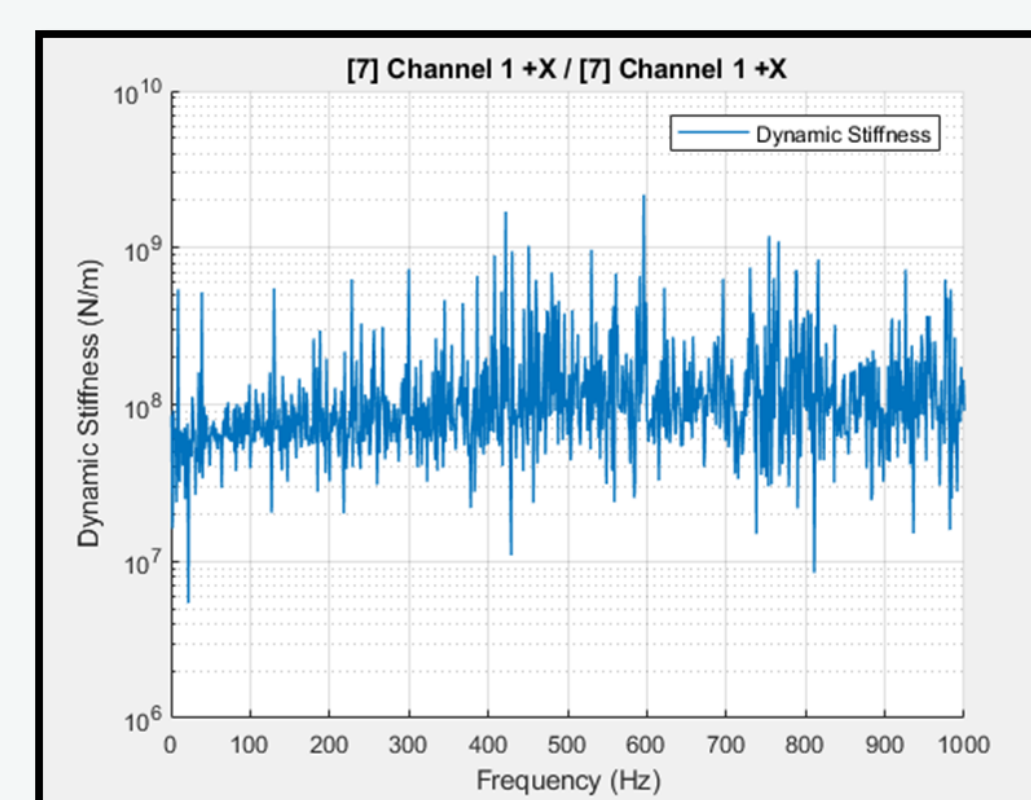

① $Y^{A,SEMM}$ $Y^{B,SEMM}$
② $Y^{AB,ov}$
③ $(Y^{AJB,par})_n$ — $Y^{A,SEMM}$ (+) $(Y^J)_n$ (+) $Y^{B,SEMM}$
④ $(Y^{AJB,SEMM})_n$
⑤ $-Y^{A,SEMM}$ $-Y^{B,SEMM}$
⑥ $(Y^J)_{n+1}$ =

Validation of Identification by A Simulated Joint
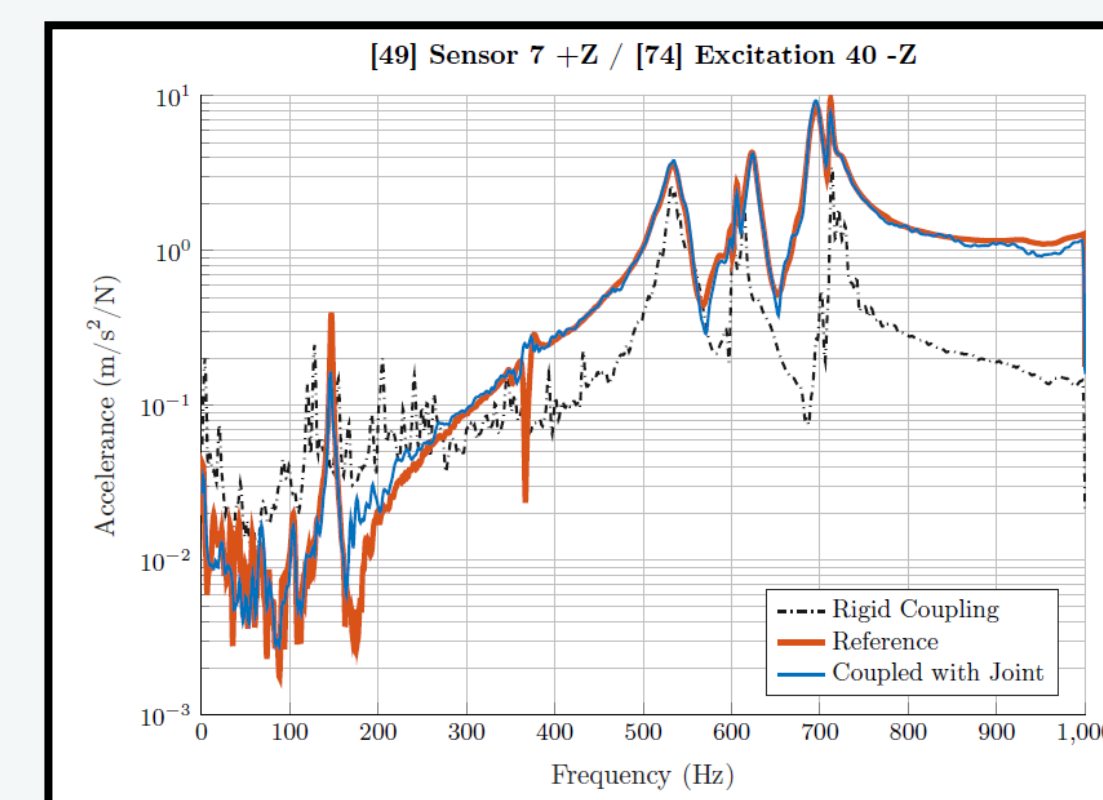
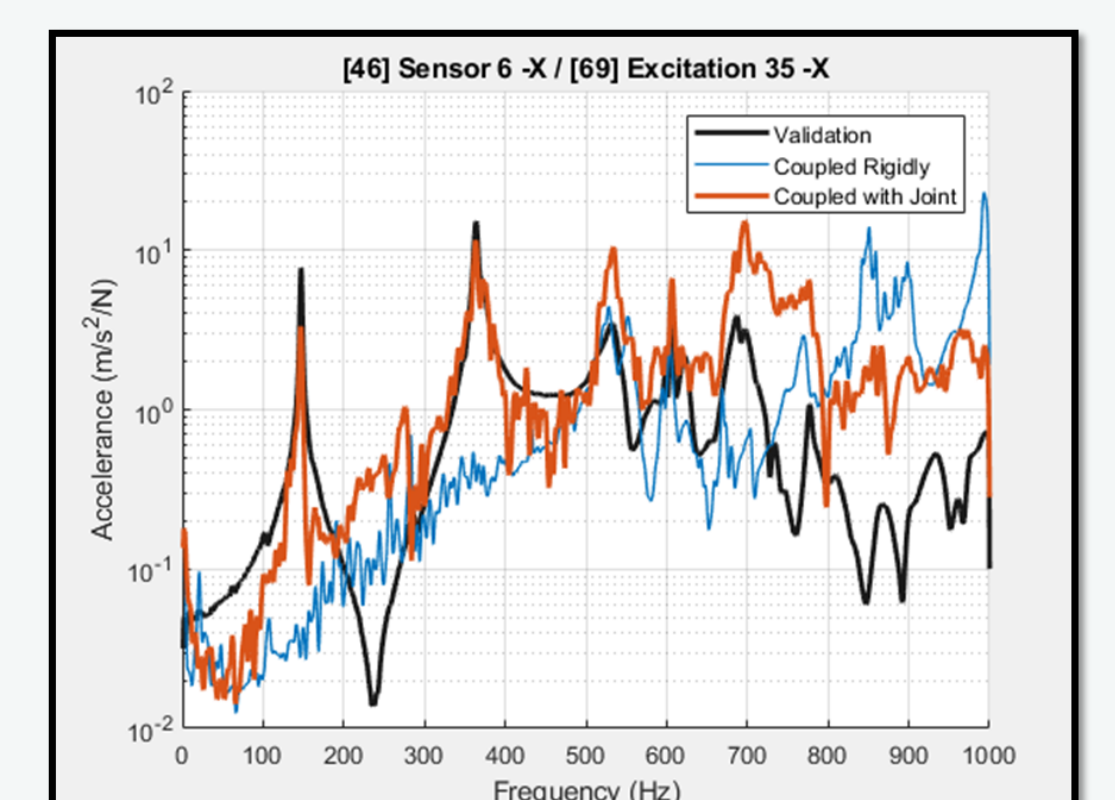|	Translational	Rotational
Stiffness Coefficient	1×10^7 N/m	1×10^4 Nm/rad
Damping Coefficient	1×10^3 Ns/m	1×10^2 Nms/rad
Mass Coefficient	5 g	5 gm²/rad

[3] Channel 3 +Z / [3] Channel 3 +Z
- Reference
- Identified

[4] Channel 4 +RX / [4] Channel 4 +RX
- Reference
- Identified

The Actual Joint Identification

[7] Channel 1 +X / [7] Channel 1 +X
- Dynamic Stiffness

Translational DoF

[49] Sensor 7 +Z / [74] Excitation 40 -Z
- Rigid Coupling
- Reference
- Coupled with Joint

Agreement—all measurement channels included in the decoupling

[46] Sensor 6 -X / [69] Excitation 35 -X
- Validation
- Coupled Rigidly
- Coupled with Joint

In-situ Validation—excluded one response and one reference measurement channels included in the decoupling

Future Work

. Improve observability as well as expansion

. Identify all the blade-root joints—

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Publications

I. Saeed, Z., Klaassen, S. W. B., Firrone, C. M., Berruti, T. M., "Experimental Joint Identification Using System Equivalent Model Mixing in A Bladed-Disk" - Under Review

II. Saeed, Z., C. M. Firrone, and T. M. Berruti. "Substructuring for Contact Parameters Identification in Bladed-disks." *Journal of Physics: Conference Series*. Vol. 1264. No. 1. IOP Publishing, 2019.

III. Saeed, Z., et al. "A Test-Case on Continuation Methods for Bladed-Disk Vibration with Contact and Friction." *Nonlinear Structures and Systems, Volume 1*. Springer, Cham, 2020. 209-212.