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Prediction of the non-linear dynamic behavior of on-board rotors under extreme solicitations

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1. Introduction

Problem statement: In the transportation domain and power plants, rotors in bending are subjected not only to rotating mass unbalance but also to several motions of their support.

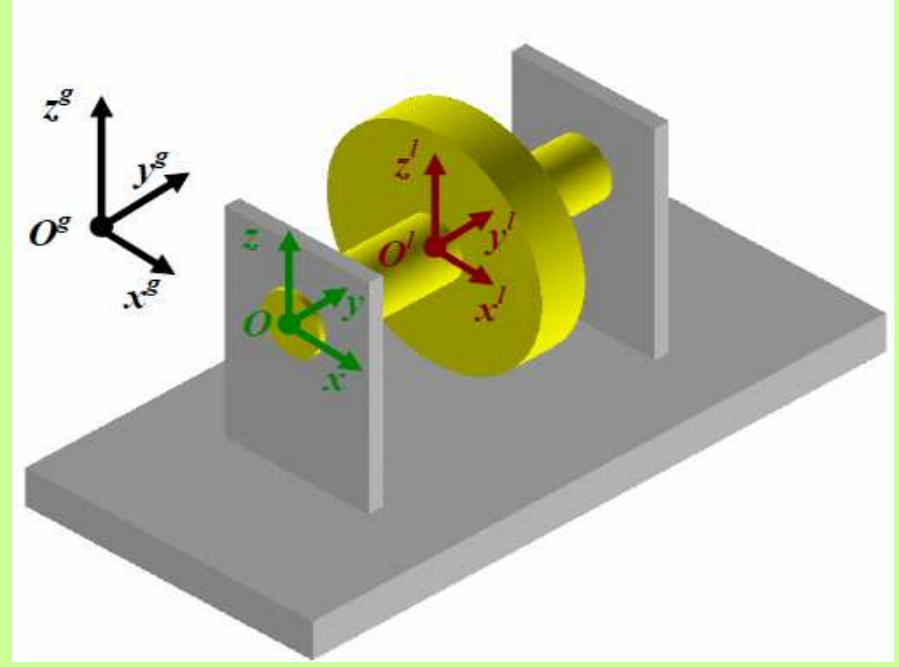
Objective: Investigation of the dynamics of an on-board rotor mounted on hydrodynamic journal bearings in the presence of rigid support excitations.

Support-excited rotor systems in the literature:

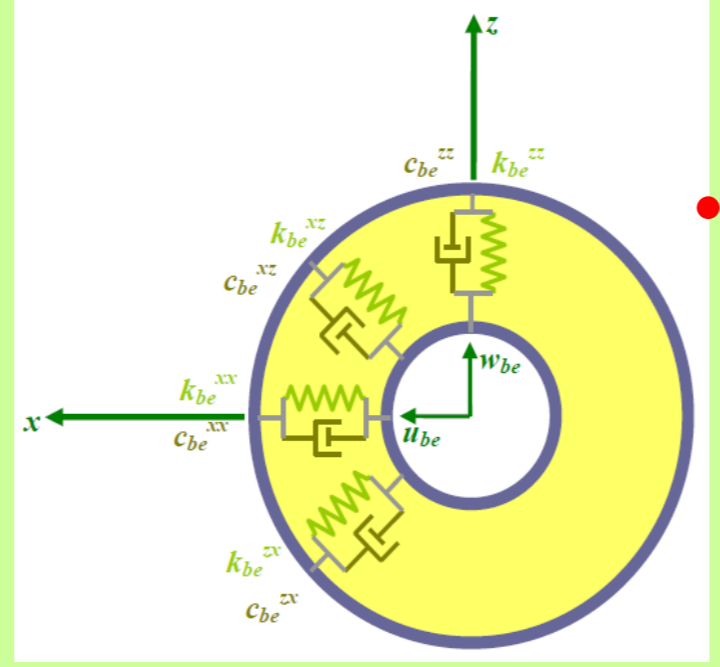
- Simple rotors (Jeffcott rotor, Rayleigh-Ritz method),
- Rotors on flexible bearings with constant coefficients,
- Rotors excited by simple motions of their support.

Improvements: Finite elements, Non-linear hydrodynamic bearings, Combined motions of the support.

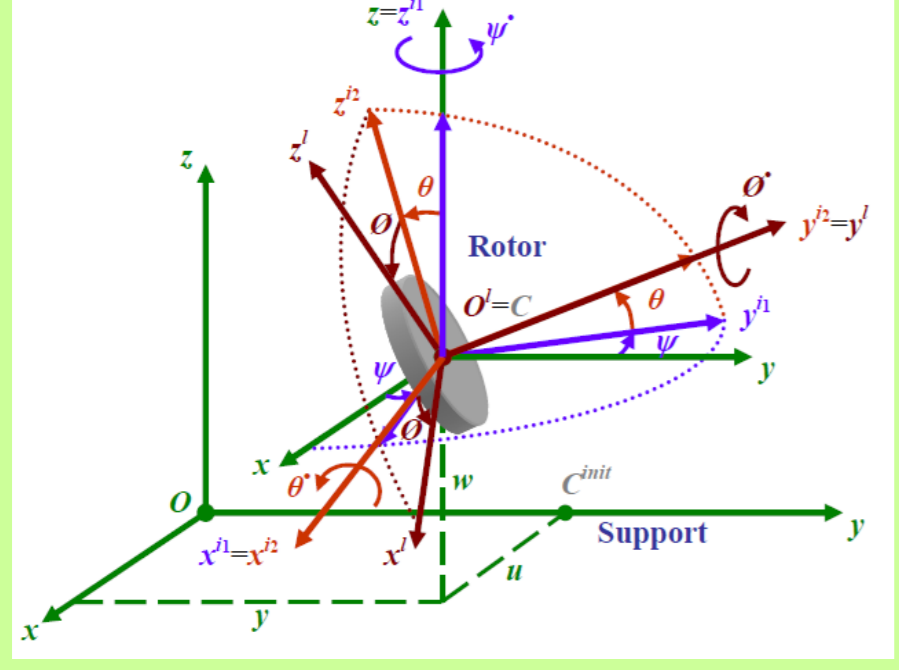
2. Basic description



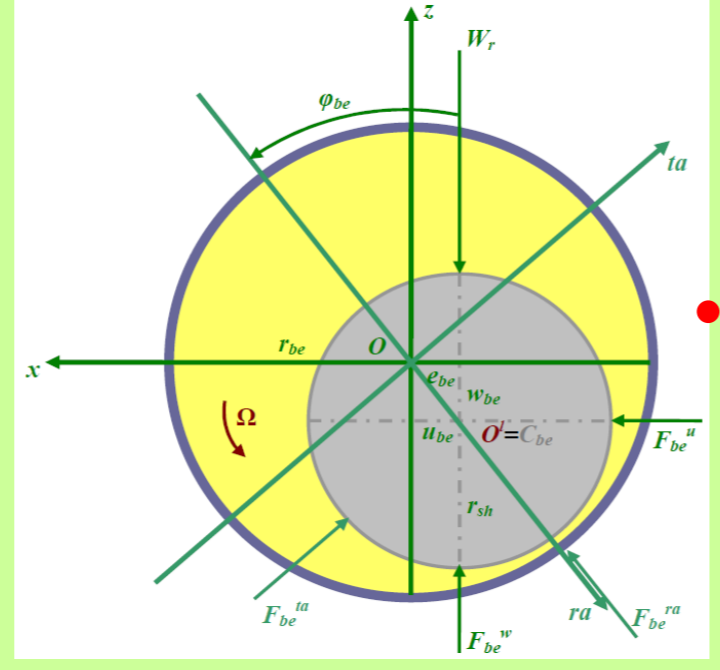
Frames of reference of the on-board rotor



Linearized bearing model



Euler angles for the transformation between the frames



Non-linear hydrodynamic bearing

3. Equations of motion

$$\mathbf{M}(t)\ddot{\delta} + (\mathbf{C}(t) + \Omega\mathbf{G}(t))\dot{\delta} + \mathbf{K}(t)\delta = \mathbf{F}(t) + \mathbf{F}_{be}(\delta, \dot{\delta})$$

$\mathbf{M}(t)$, $\mathbf{C}(t)$, $\mathbf{G}(t)$, $\mathbf{K}(t)$: Mass, damping, gyroscopic and stiffness matrices with **periodic and time-varying parametric coefficients** due to the **geometric asymmetry** of the rotor and the **rotational motions** of the support.

$\mathbf{F}(t)$: External force vector due to the **mass unbalance** and the **rotational and translational motions** of the support.

\mathbf{F}_{be} : External **non-linear hydrodynamic force** vector of the bearing.

	Rotation of the support		Translation of the support	
	Symmetric	Asymmetric	Symmetric	Asymmetric
Parametric terms (Instability sources)	Yes	Yes	No	No
External terms	Yes	Yes	Yes	No

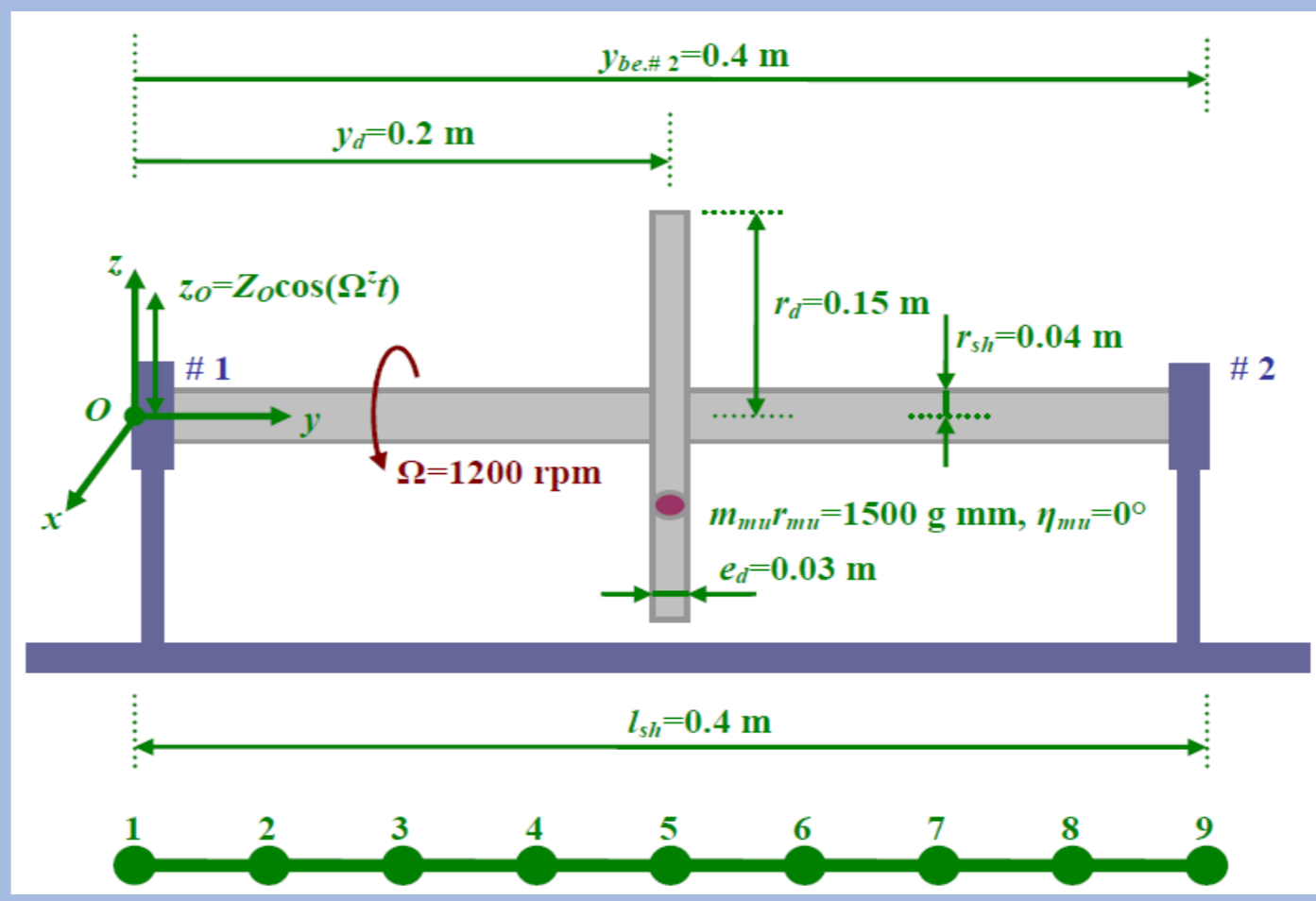
4. Dynamic analysis

The implicit **Newmark** time-step integration algorithm combined with the **Newton-Raphson** iterative technique is used to solve the equations of motion.

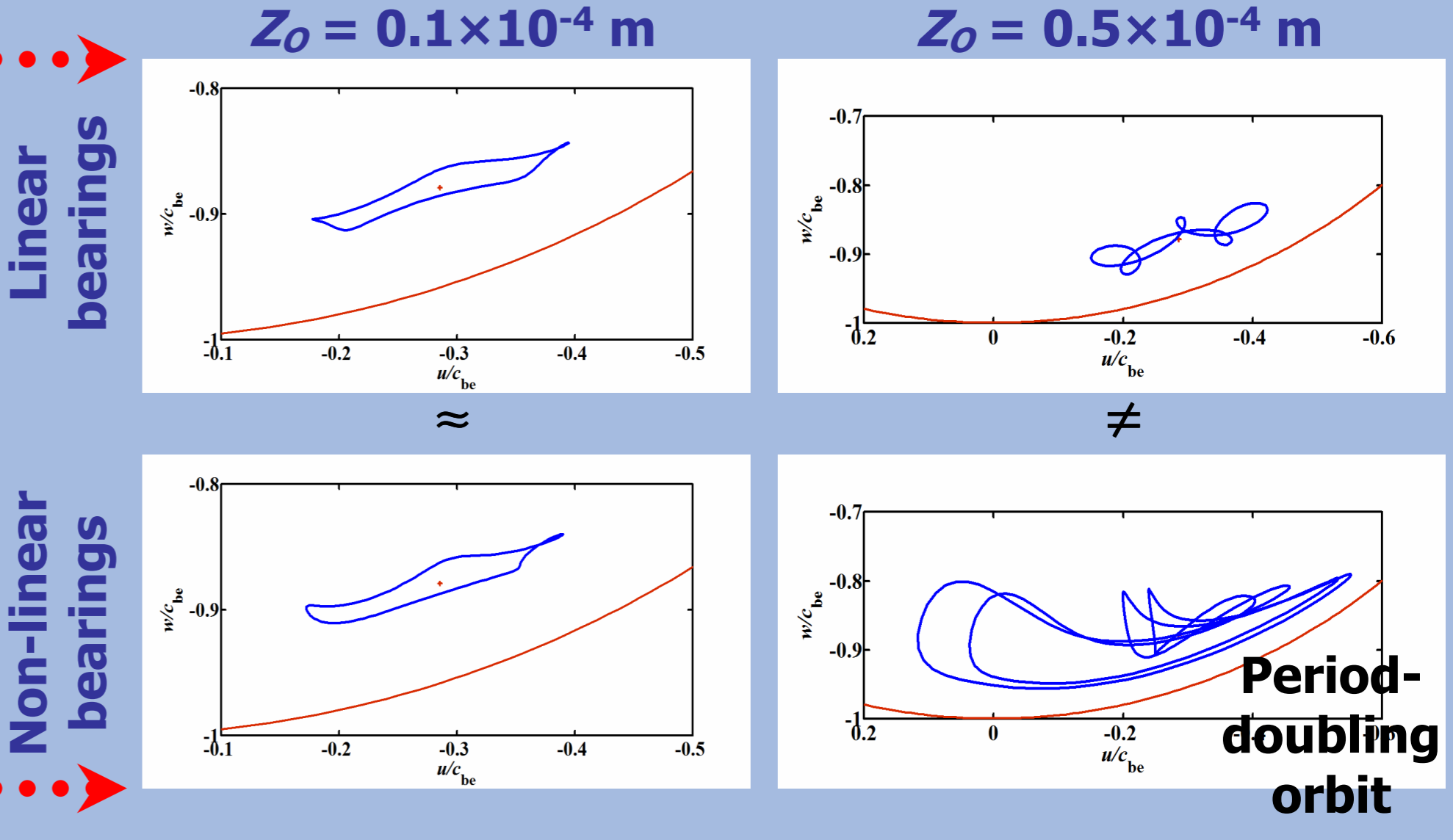
When sinusoidal motions of the support lead to **periodic (harmonic and sub-harmonic) responses** of the rotor, the **shooting method** is optimized and employed to solve the equations of motion.

5. Simulation results

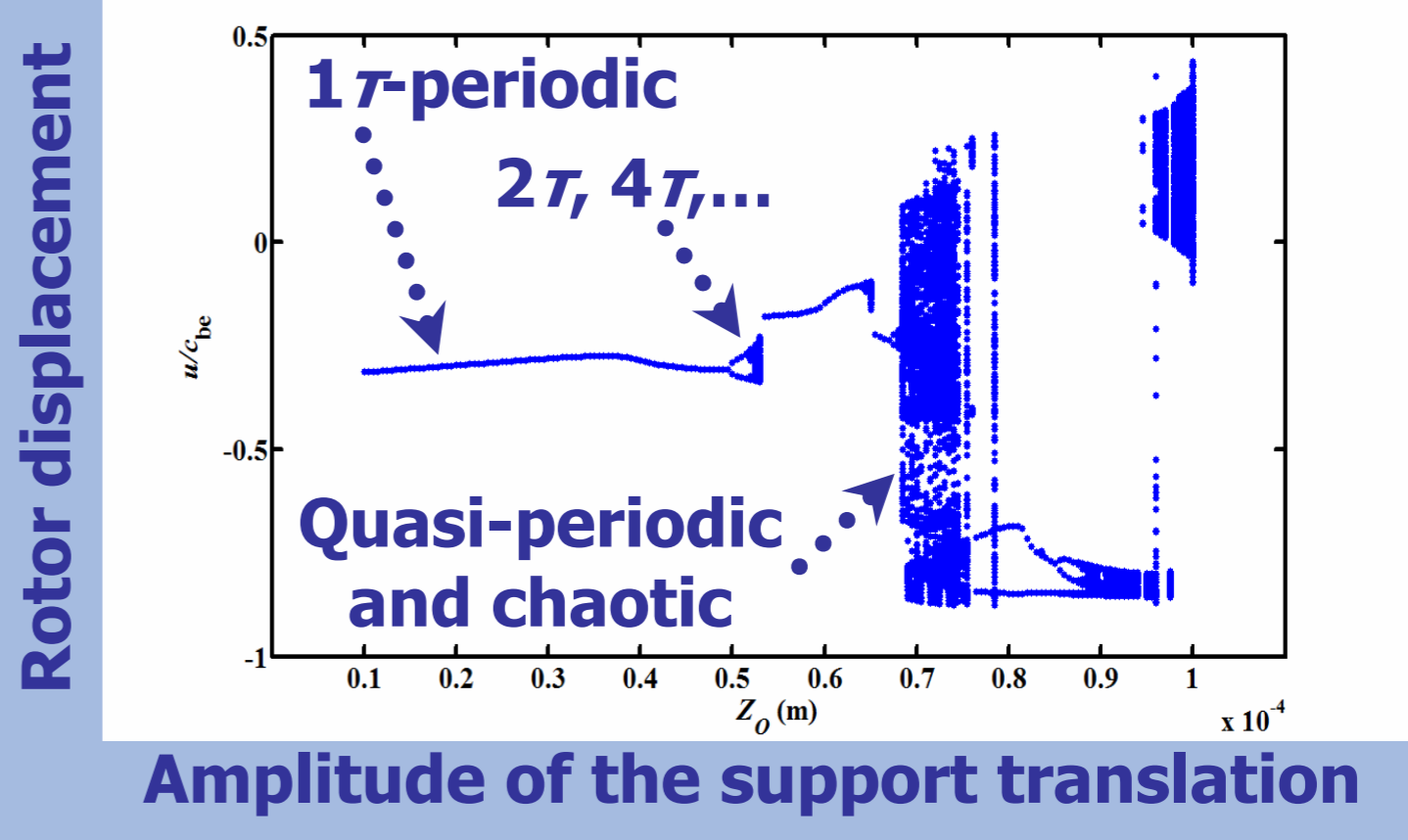
Hydrodynamic bearings + Mass unbalance ($\Omega=20$ Hz) + **Harmonic translation of the support** $z_0 = Z_0 \cos \Omega^z t$, with $\Omega^z = 80$ Hz



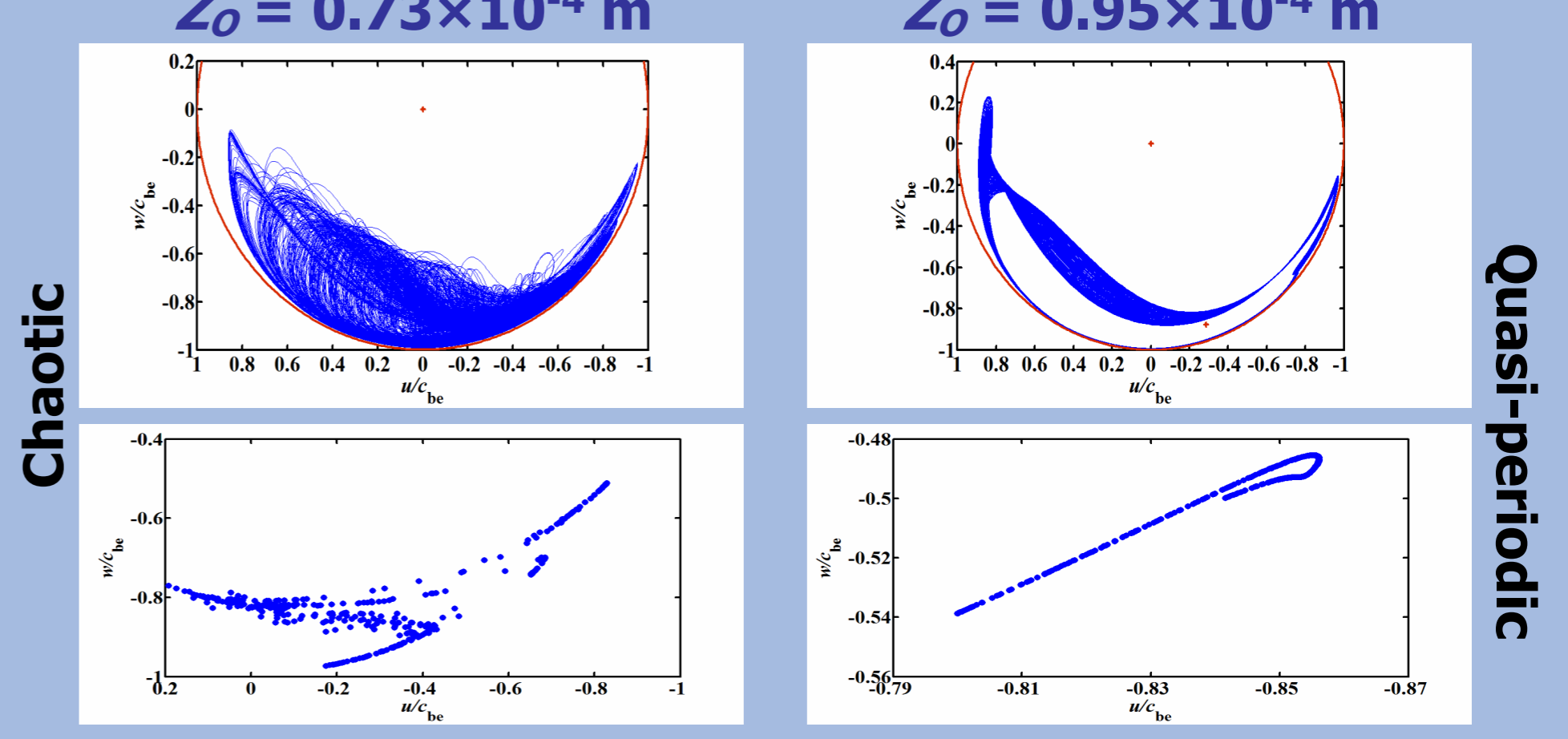
Influence of the bearing model (Linear/Non-Linear)



Bifurcation diagram (control parameter: amplitude Z_0)



Bifurcation responses (orbits and Poincaré maps)



6. Conclusions

- Shape and magnitude of the orbits** can be significantly affected by the amplitude of the **support motion**.
- Bifurcation in the dynamic response** due to the **motions of the support**: periodic, quasi-periodic or chaotic motions.
- This behavior cannot be predicted with the **linearized bearing model**.