COMPUTATIONAL MECHANICS 2018
34th conference with international participation
Srní
October 31 - November 2, 2018

Non-linear vibration of planar case of three-blade bundle with dry friction contacts

P. Šnábl[a], L. Pešek[a], L. Půst[a]

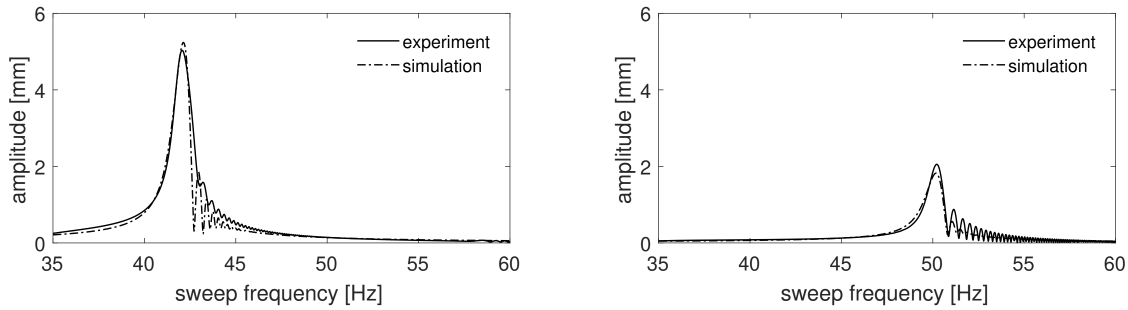
[a] *Institute of Thermomechanics of the Czech Academy of Sciences, Dolejškova 5, 18200 Prague, Czech Republic*

Using dry friction couplings (so called tie-bosses) between the blades in turbine rotors can be used to suppress dangerous resonant vibrations of turbine blades and it has been studied on our institute on various models [1, 3].

Experimental setup of three-blade bundle was built along with bladed wheel [2]. The first set-up of the bundle was with blades turned 45 degrees to the disc plane. In that case the deformation of the blades causes turning of the ends of tie-bosses and edge contact together with multi-directional slip occurs. The experimental set-up was simplified herein so that the blades are parallel to the disc plane and in-line slip occurs. Although single electromagnet was used to excite the system, the first mode of vibration with no slip in tie-bosses just occurred. In case of bladed wheel, all blades have coupling through tie-bosses with neighbouring blades which stiffen them and raise their eigenfrequency. In our case, a mistuning by reducing mass of side blades caused similar behaviour. Steel to steel contact pair was used for the first tests.

Analytical non-linear model of three-blade bundle has been created in Simulink to study the effect of dry friction on system damping. Each blade is represented by single-DOF element connected with Kelvin-Voigt element to another single-DOF element representing part of the disc. That part of the disc is connected to the frame and neighbouring disc parts also with Kelvin-Voigt elements. Between neighbouring blades a friction coupling consisting of serially connected dry friction element and spring was used [3].

Parameters of the Simulink model were tuned so that the resonance amplitudes of the middle blade during sweep excitation from 30 to 70 Hz for 60 s with measured peak of excitation force 3.8 N with open tie-bosses (with no friction force) and closed tie-bosses (with high friction force so that no slip occurs) match with the experiment as can be seen on Fig. 1.



(a) open tie-bosses (b) closed tie-bosses

Fig. 1. Comparison of resonances during sweep excitation from experiment and simulation

Parameters are following: mass of the side blades 0.473 kg, mass of the middle blade 0.908 kg, stiffness of the blades (measured on experimental set-up) 6 300 N/m, damping coefficient of the blades 2.2 Ns/m, mass of the disc parts 0.7 kg, stiffness of the disc part to the frame 2×10^6 N/m and to the neighbouring disc part 4×10^6 N/m, damping coefficient of the disc parts 0 Ns/m and stiffness of the spring serial to the friction element 2×10^5 N/m. Coulomb friction law was used in the friction element.

Simulation responses on sweep excitation with various friction forces is shown on Fig. 2. Dashed line shows resonance peak of the system with closed tie-bosses. Allowing system to slip by reducing friction force, the resonance peak is being cut off till the amplitude of the middle blade reaches it's minimum for friction force around 2 N and by further reduction of the friction force the open-contact resonance arises.

Dash-dotted line on Fig. 3 shows measured data from the experiment with pre-stressed contacts. It corresponds with the simulation data with friction force 2.4 N.

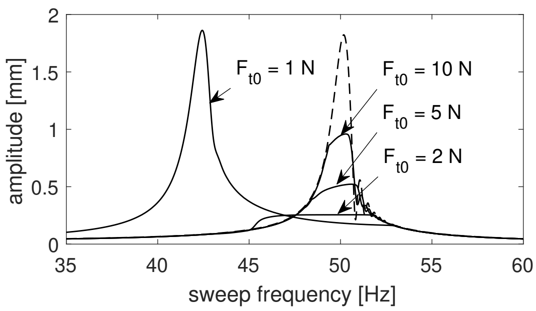


Fig. 2. Change of amplitude with varying friction force

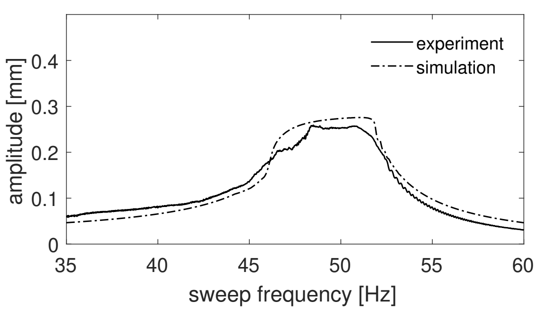


Fig. 3. Comparison of experimental and simulation results for $F_{t0} = 2.4$ N

The first results show very good agreement between experimental results and those from analytical model. According to the simulation, ideal friction force for this setup is 2 N and for excitation force 3.8 N it reduced the maximal amplitude 20x (from 5.24 to 0.26 mm) compared to open-contact resonance and 7x (from 1.82 to 0.26 mm) compared to close-contact resonance.

Acknowledgement

This work was supported by the research project of the Czech Science Foundation No. 16-04546S "Aero-elastic couplings and dynamic behaviour of rotational periodic bodies".

References

[1] Pešek, L., Bula, V., Šnábl, P., Cibulka, J., Experimental analysis of bladed wheel model with tie-boss couplings – steady and rotational states. Proceedings of the conference DYMAMESI 2018, Prague, Institute of Thermomechanics of the CAS, 2018, pp. 47-50.

[2] Pešek, L., Půst, L., Šulc, P., Šnábl, P., Bula, V., Stiffening effect and dry-friction damping of bladed wheel model with tie-boss couplings – Numerical and experimental investigation. Proceedings of the 10th International Conference on Rotor Dynamics – IFToMM, Cham, Springer International Publishing, 2019, pp. 148-162, doi: 10.1007/978-3-319-99270-9_11.

[3] Půst, L., Pešek, L., Radolfová, A., Blade couple with dry friction connection, Applied and Computational Mechanics 9 (1) (2015) 31-40.