On the Role of Damping on the Dynamics of Rotating Blades

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ABSTRACT

The role of damping in rotordynamics is well known since more than half a century: all damping which can be associated to the nonrotating parts of the machine have the usual stabilizing role as in structural dynamics, but damping of rotating elements can trigger instability in the supercritical range. What actually happens is that rotating damping couples rotational motion and vibration, causing energy to be transferred from the former to the latter.

Rotor damping is not the only cause of instability, since there are cases in which even an undamped rotating system can become unstable. In the instability of propellers and of rotors partially filled with fluid instability is linked with a wave propagating in the rotor in forward direction with respect with a nonrotating frame while it propagates in a backward direction in a rotor-fixed frame.

The interaction between the dynamics of a row of blades and that of the rotor is studied using the simplest model, an array of rotating pendulums. The closed form solution so obtained is then checked against a more realistic FEM model in which the blades are modeled as beams. The simple models here studied yielded the following conclusions:

- If the pendulums are 'long', an instability range is found where the line related with an in-plane wave which travels backward with respect to the rotor but forward in a fixed frame crosses the line related with the vibration of the supporting disc.
- If the pendulums are short all backward travelling waves do the same also in the fixed frame and no instability range is present
- Out-of-plane motion never become unstable
- The presence of dampers, either between the disc and the blades or between the latter has no unstabilizing effect. Although rotating, their effect is similar to that of non-rotating dampers.

Some numerical experiments performed on FEM models in which the blades are modeled as prismatic beams essentially confirm the applicability of the results obtained on the pendulums to actual blades.

A simple heuristic explanation of the lack of instability due to blade damping can be given: the slope on the Campbell diagram of the lines related with blade vibration is higher than that of the bisector of the first quadrant or, in other words, the natural frequencies of the blades increase with the speed in such a way that they work in subcritical conditions even when the rotor as a whole is supercritical. This causes their damping to have no unstabilizing effect, since it works 'locally' in subcritical conditions. This is likely to occur also in other cases, like the vibration of flexible discs or membranes, whose natural frequencies grow quickly with the speed.