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Computation of quasi-periodic localised states in nonlinear cyclic and symmetric structures with harmonic balance methods

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The emergence of localised vibrations in cyclic and symmetric rotating structures, such as bladed disks of aircraft engines, has challenged engineers in the past decades. In the linear regime, localised states emerge due to inhomogeneities induced by manufacturing variability, and this phenomenon is well-known in the turbomachinery community as a mistuning problem (see e.g. Ref. [1]). However, the linear behaviour has to be seen as an approximation, and structures may deviate significantly from the linear assumption due to e.g. frictional dampers, impacts, and large displacements. Within this nonlinear regime even perfectly symmetric structures can localise vibrations due to bifurcations (see e.g. [2]).

In this paper we develop a fully numerical methodology based on harmonic balance methods to compute localised vibrations in cyclic and symmetric structures. The main focus is on quasi-periodic states induced by strong engine order excitations. In this case, periodic solutions loose stability due to Neimark-Sacker bifurcations, and localised vibrations detach from homogeneous states. We apply the numerical methodology for two minimal models of bladed disks. The first one investigates the geometrical stiffening effect induced by large deformations, while the second one models impacts induced soft joints. In both cases the methodology is able to identify and trace multiple coexistent quasi-periodic solutions. Future investigations will apply the present methodology in reduced-order models computed from high-fidelity finite element codes. These results should clarify whether bladed disks can localise vibrations in operational conditions due to nonlinearities.

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