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[Extended Abstract]

Condensation of rotational speed-dependent bladed disk models to nonlinear degrees of freedom

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Introduction

In turbomachinery, it is common practice to reduce extensive models to guarantee temporal feasibility of solution methods such as the harmonic balance method. Several component mode synthesis (CMS) reduction techniques established exploiting a mode-dominated motion, differing in the assumptions made on the nonlinear interface constraints. Besides applying CMS reduction, the system of equations of motion of nonlinear bladed disks can be partitioned into degrees of freedom (DOF) subject to nonlinear contact forces and remaining linear DOF. Such a set of equations can be condensed to the nonlinear DOF, due to the algebraic character of the remaining equations [1, 2].

$$\mathbf{U}_n + \mathbf{H}_n \left(\mathbf{F}_{\mathrm{nl},n} - \mathbf{F}_{\mathrm{e},n}\right) = \mathbf{0}, \quad \forall n = 0, \ldots, N_{\mathrm{h}} \tag{1}$$

Problem statement

Bladed disks show an inherent rotational speed-dependency of their structural quantities. Thus, deducing modal properties utilized for the condensation to nonlinear DOF are also rotational speed-dependent. However, during forced response computations, a range of rotational speed is investigated. Therefore, to account for variable speed, the associated eigenvalue problem has to be re-evaluated continually, to provide the solver with the correct mode-shapes and eigenfrequencies at the selected speed. This requires computational effort, diminishing the efficiency of the condensation to the nonlinear DOF.

$$\mathbf{H}_n = \sum_{a=1}^{\mathrm{N}_m} \frac{\boldsymbol{\varphi}_{a,q}(\Omega)\boldsymbol{\varphi}_{a,q}^H(\Omega)}{-(mn\Omega)^2 + \mathrm{i}mn\Omega(\alpha + \beta\omega_a^2(\Omega)) + (1+\mathrm{i}\eta)\omega_a^2(\Omega)} \tag{2}$$

Solution approach

Based on a Taylor series, the modal properties are expanded up to a specific order, using only a set of eigenvalue problems solved in advance [3]. This accelerates the residuals evaluation and performs well during the overall forced response computiation. Within this paper the computational performance of the proposed method will be thoroughly investigated regarding several sensitive parameters such as the ratio of nonlinear/linear DOF, order of series expansion and suchlike.

$$\boldsymbol{\psi}(\Omega) = \boldsymbol{\psi}(\Omega^*) + \left.\frac{\mathrm{d}\boldsymbol{\psi}(\Omega)}{\mathrm{d}\Omega}\right|_{\Omega=\Omega^*}(\Omega-\Omega^*) + \frac{1}{2}\left.\frac{\mathrm{d}^2\boldsymbol{\psi}(\Omega)}{\mathrm{d}\Omega^2}\right|_{\Omega=\Omega^*}(\Omega-\Omega^*)^2 + O(\Omega^3), \quad \boldsymbol{\psi} = \omega_a^2, \boldsymbol{\varphi}_{a,q} \quad (3)$$

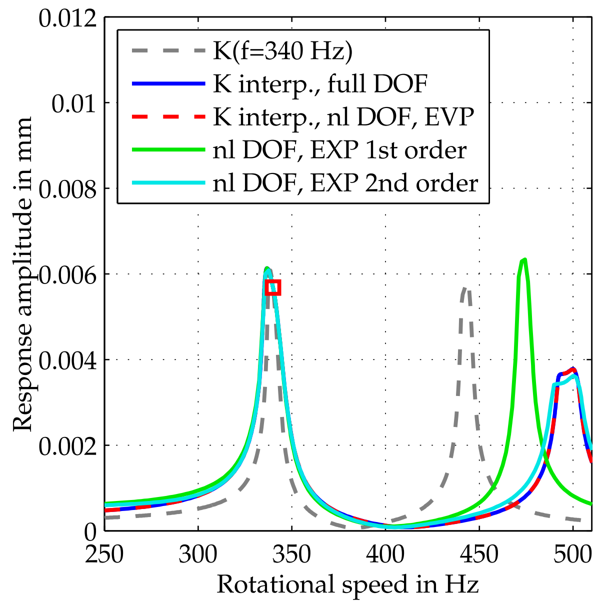

Figure 1. Expansion capabilities

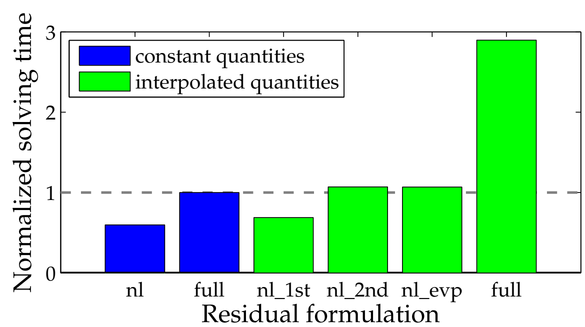

Figure 2. Computational performance

References

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[3] Torsten Heinze, Lars Panning-von Scheidt, Jörg Wallaschek, and Andreas Hartung. A Taylor Series Expansion Approach for Nonlinear Blade Forced Response Prediction considering Variable Rotational Speed. In *Proceedings of ASME Turbo Expo 2016*. 2016.