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AERO ELASTIC ANALYSIS OF ROTATING MACHINERY

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ABSTRACT

Aero elastic analysis used in design of turbo machineries. A coupled time domain analysis, involving flow and structural domains, using 3D Navier Stokes solver is to be performed. This results in accurate plotting of flow-body interactions at different conditions. Blade structural response is modeled using a modal representation of the blade and the work per cycle method is used to evaluate the stability characteristics. Non zero inter blade phase angle is modeled using phase lagged boundary conditions. Results are presented for a flat plate helical fan, a turbine cascade and a high speed fan, to highlight the aero elastic analysis method, and its capability and accuracy. Obtained results showed good correlation with existing experimental, analytical and numerical results. Numerical analysis also showed that given the computational resources available currently, engineering solutions with good accuracy are possible using higher fidelity analysis

Key words: Elastic analysis, Rotating machinery, Blade.

INTRODUCTION

Motivation to the study

An unsteady flow may vary in time either randomly (turbulence) or periodically. It is the latter type that dealing with turbo machinery performances, there are two main aspects associated with unsteady flow effects:

(i) Aero thermal performance due to blade-row interaction and flow instability (stall/surge);

(ii) Blade mechanical integrity due to flow-induced vibrations (forced response and flutter).

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Objective of the present work

To develop a CFD analysis for a 3-D rotor and to predict the unsteady aerodynamic loads acting over it. To couple the rotor blades and to perform structural analysis predicts aero elastic turbo machinery response, air-loads and vibration. This accounts for the near wake flow field. But the far wake effects because of the trailed tip vortices from all the blades have to be included separately. This is achieved by the use of the field velocity approach, which is a method for modeling unsteady flows via apparent grid movement. In this method, the induced velocity field caused by the trailed vortex wake is included by modifying the grid time metrics.

Design and analysis

Tools used in design

CATIA V5 R21

Sketch

Part design

Pad

Multi section solid

Patterns

Fillet & chamfer

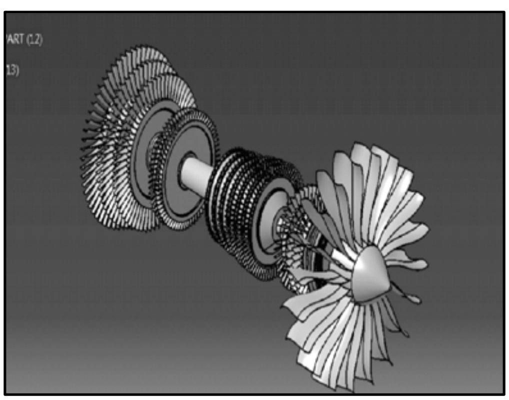

Fig. 1: CATIA modelx

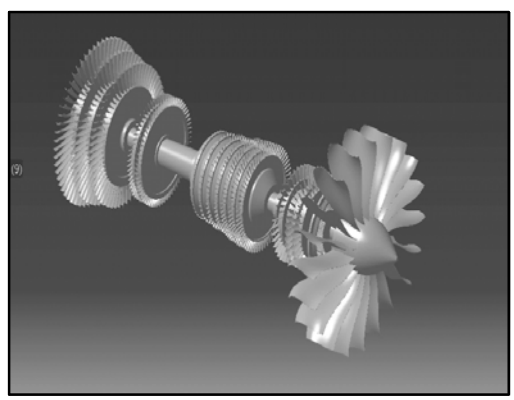

Fig. 2: CATIA Meshing model

Meshing process

Mesh family: Explicit and implicit

Element name: C43R

Total No. of element: 2 Crores

Total No. of nodes: 1.32 Crores

Mesh type: Structured and adaptive meshing by moving method technique

Continue mechanics: Due to nodal point formulation

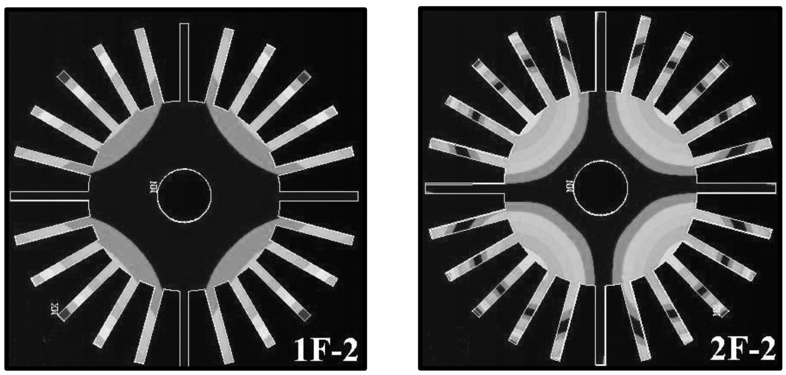

Fig. 3: Natural frequencies of a 24-bladed

Campbell diagram

A Campbell diagram Fig. 4 plot represents a system's response spectrum as a function of its oscillation regime. It is named for Wilfred Campbell, who introduced the concept also called interference diagram.

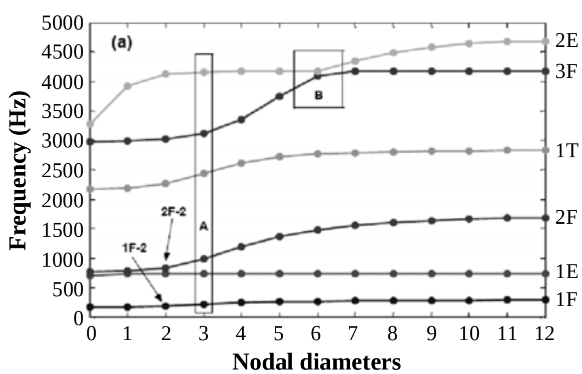

Fig. 4: Frequency vs nodal diameters

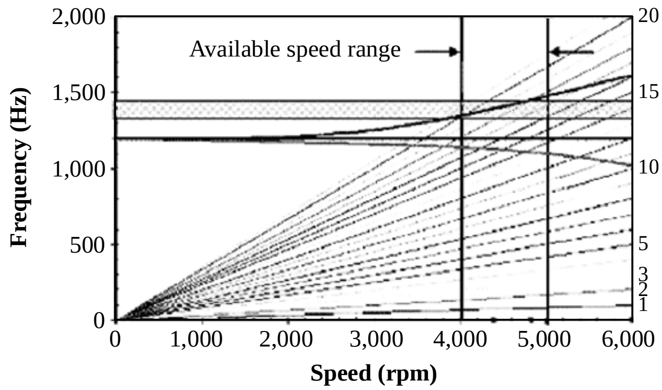

Fig. 5: Campbell diagram for a 24-blade bladed disk

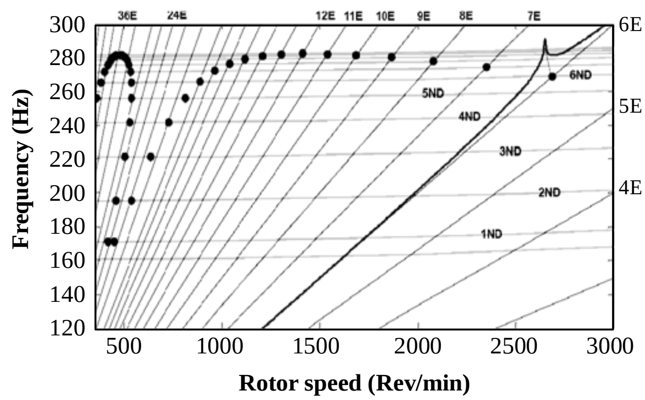

Fig. 6: Frequency vs rotor speed

Material constituent changing

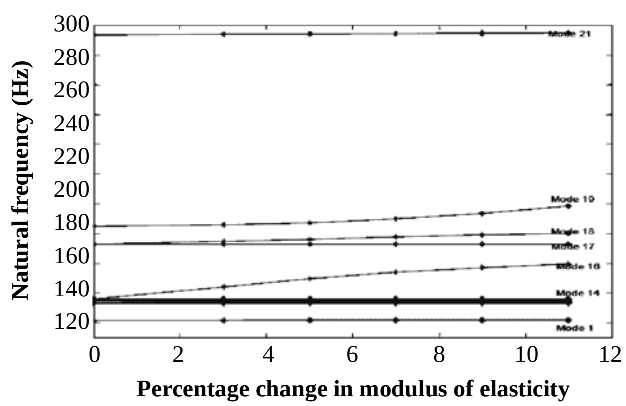

Fig. 7: Natural frequency vs modulus of elasticity

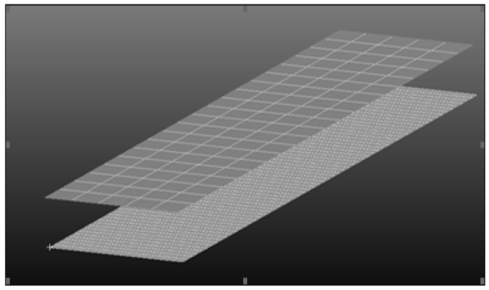

Fig. 8: Aerodynamic surface and structural model of blade

Table 1: Natural frequency with respect to different parameters

Mode No.	Natural frequency	Nodal diameter	Disc thickness sensitivity (%)	Blade thickness sensitivity (%)	Blade trailing edge sensitivity (%)	Blade lending edge sensitivity (%)
1, 2	950.4	2	0.0063	0.0683	-0.0039	0.8498
3, 4	960.6	4	0.0244	0.0855	-0.0017	0.9420
5, 6	960.9	3	0.0186	0.0853	-0.0018	0.9365
7, 8	961.0	5	0.0288	0.0860	-0.0016	0.9450
9, 10	961.9	6	0.0307	0.0867	-0.0015	0.9464
11, 12	962.7	7	0.0310	0.0875	-0.0014	0.9467
13, 14	963.3	8	0.0308	0.0880	-0.0013	0.9467
15, 16	963.6	9	0.0306	0.0883	-0.0013	0.9466
17, 18	999.57	1	-0.0024	0.0999	0.0002	0.9165
19	1011.6	0	-0.0203	0.1084	0.0018	0.8786
20, 21	1156.2	2	-0.1130	0.0090	-0.0123	0.0595
22, 23	1649.7	3	-0.0465	0.0033	-0.0212	-0.1084
24, 25	1952.7	4	0.1024	-0.0041	-0.0450	-0.1278
26	2142.4	0	-0.0827	0.0199	-0.0092	-0.1462
27, 28	2145.3	5	0.1581	-0.0283	-0.0972	-0.0588
29, 30	2207.5	6	0.1082	-0.0347	-0.1144	0.0118
31, 32	2228.8	7	0.0831	-0.0340	-0.1152	0.0375

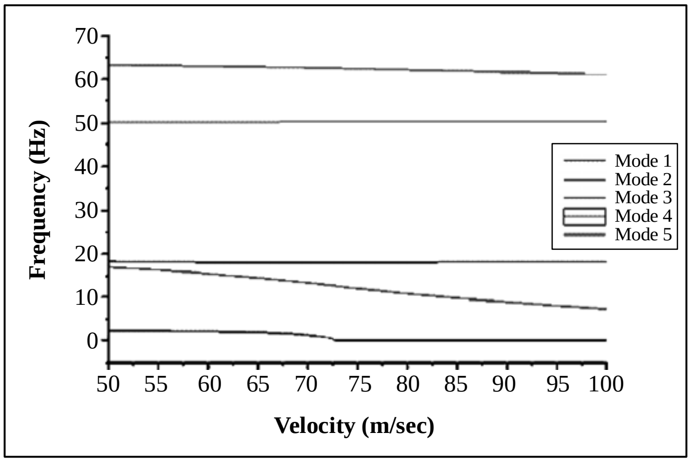

Fig. 9: Frequency vs velocity

CONCLUSION

A comprehensive aeroelastic stability analysis of a high aft-swept transonic fan blade with low hub-to-tip ratio has been performed, utilizing state-of-the-art tools and methods available to the turbomachinery industry today. The evolution of aeroelastic stability in the first bending modes has been studied as the blade loading is increasing. A weakly coupled (one-way) method has been employed to describe the interaction between fluid and structure the in-passage shock motion has been found to be the destabilizing mechanism. The region before shock always corresponds to negative aerodynamic work, showing stabilizing effects, while the region behind the shock corresponds almost directly to the positive aerodynamic work, signifying destabilizing effects. As the loading on blade increases, the shock moves from blade trailing edge to leading edge. This behavior significantly changes the aerodynamic work done on the blade. The increasing of total positive aerodynamic work done on the blade surface is prominent to the dissipative (negative) aerodynamic work. It can be concluded that the energy flowing from blade to surrounding air is more and more difficult when the strength of in-passage shock increases. Additionally, a statistical investigation of intentional and random mistuning has been performed through Monte Carlo simulation. Alternately intentional mistuning with enough frequency offset can stabilizes the randomly mistuned system very effectively. The introduction of intentional mistuning nearly has no effects on aerodynamic damping coefficient when the standard deviation of random mistuning reaches about 2.1%. There is an interesting phenomenon that a large amount intentional mistuning (for example 2%IM) is very sensitive to slight random mistuning.

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