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[Extended Abstract]

Consequences of Borescope Blending Repairs on Modern HPC Blisk Aeroelasticity

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Introduction

To fulfil the steadily increasing demands in the field of aero engines, original equipment manufacturers (OEMs) adopted the blade integrated disk (blisk) design to civil aviation. In contrast to conventional bladed disk assemblies, blisks endure higher rotational speeds and improve aerodynamic efficiency while significantly reducing the weight of modern high pressure compressors (HPCs). Due to missing friction at the blade to disk contact surfaces mechanical damping of blisks is comparably low [1] and an increasing risk for aeroelastic instability (flutter) emerges. Especially in the service sector, detection and repairs of foreign object damages (FODs) on HPC blisks are relevant. To ensure structural integrity of the components all damages - exceeding a size specified by the OEM - are repaired by e.g. borescope blending of the concerned area. In case of critical damage sizes engine strips are necessary to replace the whole component. Regarding the financial aspect of such events it is necessary to define the structural and aeroelastic limits for blending repairs as accurate as possible. The aim of this paper is to identify the aeroelastic effects caused by borescope blending repairs in terms of changes in the aerodynamic damping and the forcing acting on neighbouring blade rows. According to this knowledge, recommendations for acceptable blending procedures can be acquired for the service sector.

Methods

Origin of any further investigations is the aeroelastic problem described in Eqn. (1)[2].

$$m_i\ddot{q}_i + m_i\omega_i^2 q = f_{aero_i} \quad with \quad f_{aero_i} = f_i^m + f_i^D \tag{1}$$

Herein m_i is the generalized mass, ω_i denotes the natural frequency, q_i the displacement and f_{aero_i} the aerodynamic forces. According to Crawley [2] the aerodynamic forcing f_{aero_i} is a simple superposition of motion dependent aerodynamic forces f_i^m and aerodynamic disturbance forces f_i^D. Separation of the fluid forces allows an individual consideration of different aeroelastic problems [3]. Negligence of disturbance forces caused by neighbouring blade rows enables flutter analysis and the computation of aerodynamic damping, whereas setting $f_i^m = 0$ yields to the forced response problem.

To quantify the effects of borescope blending repairs on the aeroelastic behaviour of a modern HPC blisk, a detailed analysis of the steady and unsteady flow fields for different blending sizes is performed. An exemplary case of a blended blade in comparison to the reference design is shown in Fig. 1.

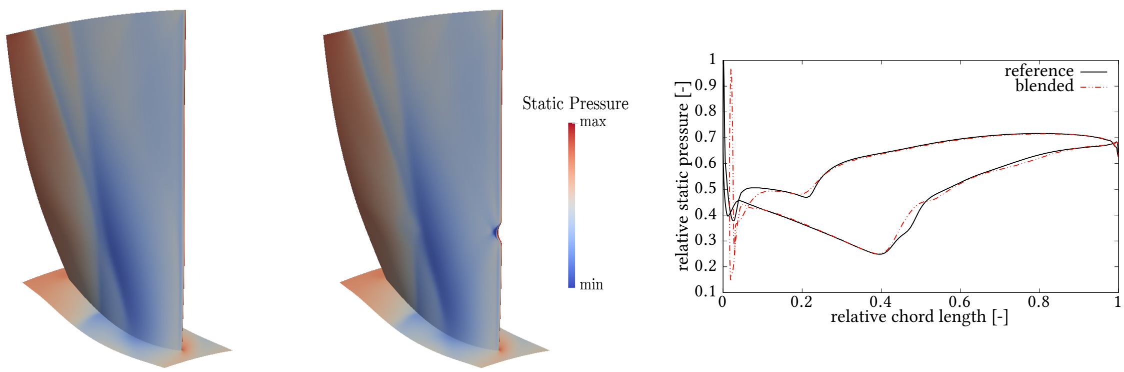

Figure 1. Comparison of Static Pressure for Reference Geometry and Blending Repaired Blade

The left adjusted contour plot in Fig. 1 visualises the static pressure distribution at the blade suction side. A distinct drop of the static pressure values is visible in the area of the blending repair. For a better understanding of blending consequences the static pressure distribution along a layer in the center of the blended region is plotted in Fig. 1 (right). Obviously the flow field is not only affected in the direct surroundings of the blade imperfection. Also for relative chord values > 0.6 the steady flow slightly differs from the reference design. To evaluate the effects of those deviations in terms of aerodynamic damping different approaches like single passage flutter (SPF) and aerodynamic influence coefficient (AIC) computations are investigated. Regarding the forced response problem a comparison of the Fourier transformed forcing signals is realised. Distinctions of the excited engine orders are visualised by a comparison of the resulting Fourier coefficients.

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