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[Extended Abstract]

Impact of Front- and Rear Stage High Pressure Compressor Deterioration on Jet Engine Performance

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Introduction

The current civil aviation is characterized by rising cost- and competitive pressure. To assert their position in the market successfully, the airlines have to lower the direct operating costs (DOC). Of these, the engine-related proportion of the DOC is about one quarter. These costs are subdevided into three roughly equivalent parts: Depreciation / financing, fuel and maintenance & overhaul [1]. The operator of an aircraft-fleet tries to run the fleet with the most efficient jet engines. Nevertheless, all jet engines are affected by deterioration, which decreases their performance. The performance is characterized by parameters like exhaust gas temperature (EGT) and specific fuel consumption (SFC). To restore performance parameters like EGT and to maintain a fuel-efficient operation of the aircraft, the jet engines have to be overhauled to restore their performance. To improve current jet engine maintenance, the MRO (Maintenance, Repair and Overhaul) companies are performing a transition from the EGT based- to the condition based maintenance. Thereby, the condition based maintenance is characterized by tailored maintenance actions for each part of the jet engine, depending on the individual engine history and operating conditions. For this purpose, the influence of each engine component and its piece parts to the engine performance needs to be known. Using the example of the high pressure compressor (HPC), the aerodynamics of its individual blading has to be determined to predict the changes of the resulting compressor map. Thus, the MRO would be able to repair and rearrange the blading in such a way that the costumers demands are met as cost-effective as possible.

This paper contributes to this maintenance development. Therefore, a modular performance synthesis model of a popular two-shaft bypass jet engine was set up and validated by test cell data. To analyze the impact of deteriorated HPC-bladings, the characteristic parameters of the geometry of a front- and a rear stage of the HPC are modified and implemented in a full HPC-model. The aerodynamics of the HPC are simulated using methods of computational fluid dynamics (CFD). With the deteriorated throttle lines, the reference HPC-map was scaled and implemented in the performance model of the jet engine. Thus, it is possible to identify the more relevant HPC-stages, to predict the possible performance range by repairing the stage and to analyze the interactions between the engine components.

1. Methods

To determine the geometric variances of deteriorated HPC airfoils, a multitude of HPC airfoils was digitized. This paper focuses on modified front- and rear stages of the HPC. Therefore, more than two complete rotor bladings of flown jet engines [2] and additional 40 flown stator vanes of the analyzed HPC-stages have been digitized by a structured light 3D-scanner in conjunction with a photogrammetric system. To determine manufacturing tolerances, 30 new airfoils of each analyzed compressor row have been digitized, too. The airfoils have been analyzed with respect to their geometric parameters by an in-house programmed algorithm [3]. Afterwards, aerodynamic sensitivities to the geometric properties have been investigated using CFD-methods. Therefore, an extensive Design of Experiments (DoE) for the front and rear stage has been carried out [4] [5]. To reduce the number of independent geometric properties, the geometric parameters have previously been scanned for possible correlations [6]. Using the aerodynamic sensitivities strongly correlating with the geometric properties, some geometric stage setups for a wide range within aerodynamic performance were generated and implemented in a full HPC CFD-model. Based on this, the cruise throttle-line for the geometrically changed HPC was calculated. Using this throttle line, the reference HPC map was scaled to achieve a complete forecast of the HPC performance behavior.

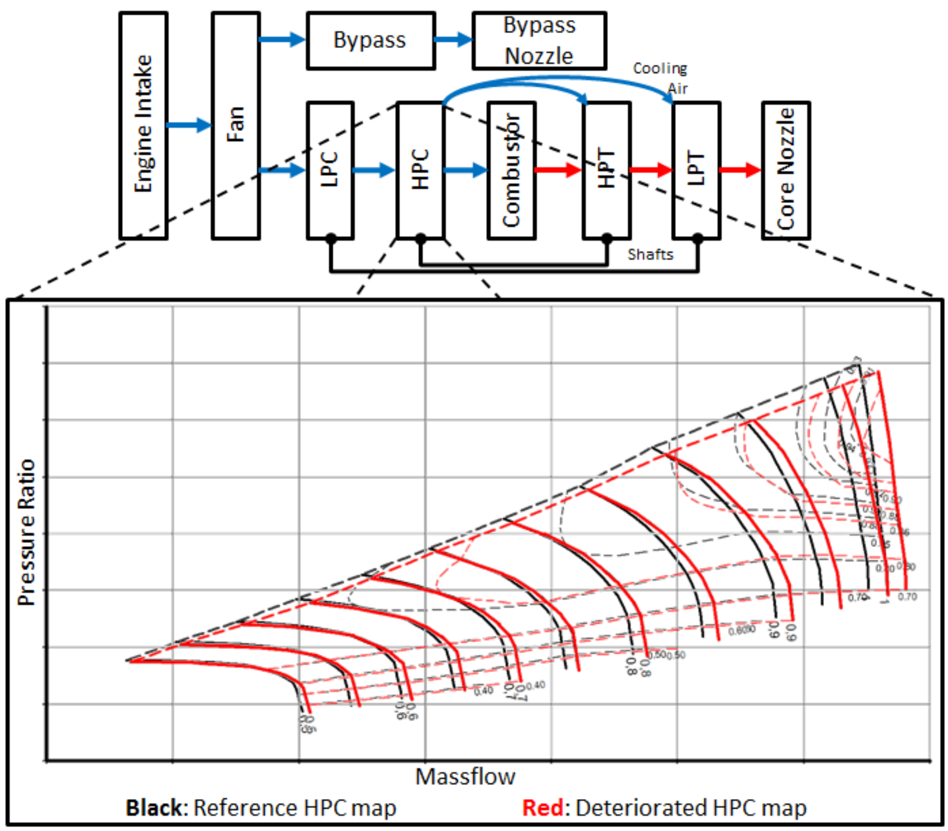

Figure 1. Scheme of a modular performance synthesis model with modified HPC maps

To determine the changes of the engine performance due to changed HPC aerodynamics, a modular performance synthesis model of the analyzed jet engine was set up and validated by test cell data. The modular performance synthesis is calculating the thermodynamic cycle of a jet engine by splitting up the thermodynamic cycle into its individual components (see Fig. 1 upper part). Thereby, the flow is calculated successively in each component independently from the other components. The component behavior can be described by simple equations (i.e. the pressure drop in a tube) or by complex component maps for the turbo-components (see Fig. 1 lower part). Thereby, the modular performance synthesis is characterized by a 1D-calculation method, which is averaging the flow parameters like total pressure and temperature over the cross section. As a result, the modular performance synthesis is able to predict performance parameters like EGT oder SFC.

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