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Numerical Investigations of Transitional SBLI on a Highly Loaded Transonic Compressor Passage in Industrial Applications

Selin Kahraman [1], Paolo Adami [2] and Marius Swoboda [3]

[1, 2, 3] Rolls-Royce Deutschland Ltd & Co KG, Eschenweg 11, 15827 Blankenfelde-Mahlow, Germany,

Selin.Kahraman@Rolls-Royce.com
Paolo.Adami2@Rolls-Royce.com
Marius.Swoboda@Rolls-Royce.com

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The present paper focuses on the adverse effects caused by laminar SBLI at altitude conditions of a transonic stator which is a real engine application in business jets and proposes a design solution to mitigate the limiting effects inherently coming along with transonic speeds. Re numbers of 750k and 200k being respectively sea-level and altitude engine representative conditions have been investigated numerically at over-thrust speed corresponding to the inflow Mach number of 0.89. Under the relevant operating conditions, the strong laminar SBLI effects lead to the passage blocked by the shock wave moving rearward at Re number of 200k. This phenomena which is not marked at Re number of 750k at sea level condition results in significantly higher losses as well as degrading working range at altitude. It is considered as the consequence of complex laminar SBLI observed at high inlet Mach number manifesting itself with subsequent shock wave imposed by the separation bubble originating under the shock. With the new design solution, it is aimed to alleviate these adverse effects controlling the location of shock wave that enables the choking limit being pushed into Mach number of 0.90 and the loss reduced by significant amount at over-speed. It also improves the performance at design speed conditions (Mach number of 0.84) in terms of the working range and the total pressure loss with a relatively small penalty in part load condition (Mach number of 0.76). The several RANS computations have been carried out with the γ-Re_{Θ} transition model to demonstrate the performance covering various Mach and Re numbers within the operating range of the engine. The multiple shock structures in the passage however introduced with high loading may strengthen the instability caused by the multiple shock oscillations. To be able to capture the unsteady effects caused by high loading, the wall-resolved LES has been performed in Hydra, high-order, non-linear solver.