Holistic concepts for Aeropropulsion

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Purpose

The purpose of this effort Is to develop a holistic concept for energy extraction by a turbine by combining the benefits of biomimicry and flow control concepts that have until now only been studied in isolation.

Background

The Variable Speed Power Turbine (VSPT) is a viable solution for vertical take-off and landing (VTOL) and high-speed cruise rotorcraft. It avoids the complexity and weight of variable transmission that is used on fixed speed power turbines. A key challenge for the VSPT is to maintain high turbine efficiency over main rotor speed variations from 54% to 100% speed to minimize overall fuel burn. The power turbine must therefore operate at a large range of incidences (60 degrees or greater,) and in low Reynolds number regimes. The flow entering the power turbine from the combustor contains considerably more emissions than comparable fixed wing aircraft engines due to rich fuel burn. For fixed wing aircraft, current low pressure turbine (LPT) designs are unable to maintain aerodynamic performance at altitude cruise conditions where the Reynolds number has dropped substantially from the sea level value. These low Reynolds number issues prompted NASA to host a large international LPT aerodynamics workshop in 2010. Currently, boundary layer separation at low Reynolds number is either accepted, or the blading is designed for reduced loading to avoid the issue. LPT efficiency is known from system studies to have the strongest impact on engine specific fuel consumption reduction and is the heaviest component in the engine. Hollow LPT blades have been envisioned as a way to reduce engine weight. Reducing blade weight as well as reducing the cruise performance loss would doubly benefit future engine designs which are attempting to reduce weight by increasing the per stage work and thereby reducing stage count. The results of this work would simultaneously enable incidence tolerance, weight and NOx reduction by 1) Biomimetic geometric features such Seal Vibrisae sustained high performance over a wide range of incidences, 2) Self-regulating the flow to and from the suction and pressure side using internal circuits of fluidic diverters in a thick hollow blade and 3) Ejecting the fluid into the wake in a pulsed mode to reduce noise and reduce aerodynamic losses. Flow for control can be suctioned through an under rotor tunnel or from strategic locations on the blade surface in the case of the split-blade geometries. Flow control has been investigated in the past on low pressure turbines using synthetic jets and other forms of actuation. Other approaches to incidence tolerance incorporate incremental improvements and optimizations to conventional blade shapes. The novelty of this proposal is to dramatically improve engine performance using passive flow control and through innovative geometry. The LPT is one of the heaviest components of the engine. Weight reduction of 2% can be achieved by reducing blade height and shroud radius by up to 5% to account for larger available effective flow area. Existing concepts trade performance and weight for incidence tolerance. The separation resistance and noise reduction through boundary layer ejection at low Reynolds number is equally applicable to fixed wing gas turbine engine low pressure turbines (LPTs.)