Proposal Title: Design, Analysis, and Evaluation of a Novel Propulsive Wing Concept

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Abstract:
The proposed study seeks to develop a propulsive transonic wing concept. The research will address the need for ultra-efficient commercial vehicles and the transition to low-carbon, low noise propulsion. Recent studies into alternative aircraft configurations and propulsion technologies have shown significant promise. These include the Hybrid Blended Wing Body (HBWB) and MIT's double bubble D8. Both concepts show a high degree of synergistic aero/propulsion integration. Outboard of the fuselage or main body, both configurations utilize a conventional wing surface. Further increases in efficiency can be achieved by combining the respective configuration's merits with an advanced, ultra-low drag concept airfoil section on the main wing. The new propulsive wing will employ a transonic Griffith/Goldschmied concept airfoil section, which features long runs of laminar flow at high Reynolds numbers and an active design using discrete suction for pressure recovery near the trailing-edge. The suction based recovery will be tailored to provide a static pressure thrust. Mass flow from the suction system will then be routed out the airfoil trailing-edge, adding the additional benefit of wake filling.

The basic Griffith airfoil concept was developed in the 1940's. The contour is designed to produce a boundary layer that experiences a very favorable pressure gradient across the entire chord of the airfoil, except near the trailing-edge. This very favorable pressure gradient dampens the instabilities leading to transition, producing long runs of laminar flow. For the original Griffith concept, pressure recovery at the trailing-edge is associated with a discontinuous increase in pressure. A suction slot is used at the location of this sudden pressure rise to maintain boundary-layer attachment and laminar flow. Subsequent development by Fabio Goldschmied modified the trailing-edge pressure recovery region to produce a section that could develop a positive static pressure thrust, significantly reducing the drag of the section, and under design conditions, produce a net thrust. The initial designs and testing were done for a subcritical Mach number. Experimental and computational studies have proven the basic static pressure thrust concept, though all prior designs have employed thick airfoil sections, featuring very low critical Mach numbers (Mcr ~ 0.45). The current effort will attempt to extend the concept to a transonic regime by increasing the critical Mach number. Additionally, a synergistic aero/propulsion design approach will be implemented by driving the suction and trailing-edge ejector system with a high efficiency cross-flow fan.

The study will be broken into three major thrusts. These include a systems/ energy balance study to determine the required efficiency of the new transonic concept airfoil in order to provide an overall benefit to the aircraft, and also to determine the trades associated with various levels of drag reduction with additional input power to the suction system and trailing-edge ejector. The second thrust will be the design of a transonic Griffith/Goldschmied airfoil with a critical Mach number of at least Mcr~0.70. The design will be developed and evaluated computationally using high fidelity CFD and multidisciplinary optimization. Finally, the newly designed transonic Griffith/Goldschmied section will be tested experimentally in a low speed subsonic wind tunnel to verify its ability toefficiently produce static pressure thrust and extended laminar flow.

In summary, the proposed study seeks to develop a propulsive wing concept by designing a new transonic laminar flow Griffith/Goldschmied airfoil, while also exploring possibilities of developing static pressure thrust and wake filling. The new wing concept will directly contribute to NASA's SFW N+3 configuration goals for aircraft efficiency.