Benefits of Boundary Layer Ingestion with Froude's Propeller Theory

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Abstract

With increasing concern towards the global environmental conditions, it becomes requisite for aviation industry to reconsider its existing impact on the climate change. With a global contribution of about 4.9 percent by the aviation sector in anthropogenic global warming, The Paris Agreement targets to control the emissions and global warming by limiting the increase in temperature to 1.5 $\circ C$ (well below 2.0 $\circ C$ above preindustrial levels). The initiative of environmentally sustainable air travel in year 2050 led by The Advisory Council for Aviation Research and Innovation in Europe (ACARE) points to a 75% reduction in $CO2$ emissions per passenger kilometer and a 90% reduction in nitrogen oxide NOx emissions. It also attributes to a 65% noise reduction of flying aircraft. Therefore, to address the increasing air transport and need for more environmental sustainability Boundary layer ingestion works effectively by increasing the fuel efficiency.

Boundary layer ingestion is a concept of placing aircraft engines or propulsors at the rear of fuselage, so that the slower air is ingested into the engines, which is further accelerated by the engines out the back reducing total drag. This requires integration of airframe and propulsion system unlike current aircraft configurations where the interaction is minimum. Propulsors with boundary layer ingestion generate propulsive force with less power input than conventional engines. A part of airframe's boundary layer or wake is ingested by this novel propulsion system that increases overall aircraft efficiency and reduces emissions.

NASA's STARC-ABL is a conceptual aircraft with tube wing configuration consisting of two turboelectric jet engines and a rear fuselage BLI fan. When compared with conventional technologies, STARC-ABL has 7% block fuel burn reduction for the economic mission, and 12 block fuel burn reduction for the design mission. D8 Double Bubble is a modified tube wing configuration aircraft with a wide lifting fuselage. Relative to similar baseline models, D8 has potential to achieve 71% reduction in fuel burn and 87% reduction in LTO NOx . When compared with its BLI and non-BLI configuration, the former showed 6% reduction in electric power consumption at cruise condition.

In this study, a symmetric airfoil NACA0018 is considered as an axis-symmetric fuselage with Froude's Actuator Disk as a propulsor placed behind the airfoil in freestream and BLI configuration respectively. After carrying out analysis in ANSYS CFD, the aerodynamic and propulsive parameters are demonstrated. The benefits of the BLI configuration are validated in terms of the power saving coefficient as well

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