“Design of a Low-ATR, Long-Range Aircraft Using Passive Flow Control”

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Meeting the EU’s 2050 climate goal puts enormous pressure on aircraft manufacturers, operators and regulatory authorities to decarbonise the aviation sector. Given the concurrent need for a short-term reduction of aviation’s environmental footprint and a long-term road map towards carbon-neutral flight, a clever balance between technology readiness level, operational profitability and climate impact is sought. Whereas past engines and airframes were optimised for minimum Direct Operating Cost (DOC), a novel holistic design approach pursued by several authors suggests that aircraft optimised for minimum Average Temperature Response (ATR) achieve the lowest global warming impact. For the same tube-and-wing configuration as current DOC-targeted airliners, this new optimisation aim was shown to result in low-sweep, high-aspect-ratio wings and moderate bypass-ratio (BPR) turbofan engines, flying at lower cruise altitudes and Mach numbers. Particularly on long routes this will inevitably spawn an increase in airfare prices, which may however be limited by adding evolutionary technologies to the aforementioned aircraft redesign recipe. This project investigates the combined ATR reduction potential of propfan engines, synthetic fuels, riblets and Natural Laminar Flow (NLF) airfoils, whilst limiting the DOC increase to 15% relative to an Airbus A330-200.

After conducting a profound market analysis, it is believed that governments will prioritise ATR minimisation over noise reduction in the future, justifying the use of propfan engines. The whole propfan engine model devised as part of this project combines an intercooled turbofan core with two counter-rotating, geared, unducted rotors, enabling a BPR of 30 and a specific fuel consumption of merely 9.8 g/(kNs) under take-off conditions. Considering the increased global warming potential per kg of fuel at higher altitudes and Mach numbers, the envisioned aircraft is designed to operate at a cruise altitude of 5000 m and a Mach number of 0.55. Moreover, Fischer Tropsch synthetic kerosene is employed in a 50% blend ratio with Jet-A-1 fuel (the current limit set by ASTM regulations), whose cost is expected to break even with that of Jet-A-1 as early as 2030.

Given the reduced cruise Mach number at which the envisioned aircraft will be flying, it eliminates the necessity of adopting wing sweep. With no sweep, cross-flow instabilities within the boundary layer are attenuated, delaying the onset of transition from laminar to turbulent flow. This gives enough reason to adopt an NLF airfoil to aid in delaying transition, since a laminar boundary layer is preferred over a turbulent one with respect to reducing the total skin-friction drag. These airfoils have been specifically designed to shift the onset of transition aftwards. Although adopting an NLF airfoil will help in delaying transition, the process of transition is nevertheless inevitable. This was the motivation to adopt riblets. Riblets are micro-groves aligned in the streamwise direction, which reduce the skin-friction drag within the turbulent boundary layer. They can be applied on any surface of the aircraft where the flow is believed to be turbulent. Hence, the combination of adopting no wing sweep and an NLF airfoil to delay the onset of transition and maximising the laminar flow over the wing, along with the use of riblets in the regions where the flow ultimately becomes turbulent, will reduce the total combined drag of the aircraft, and therewith its ATR footprint.