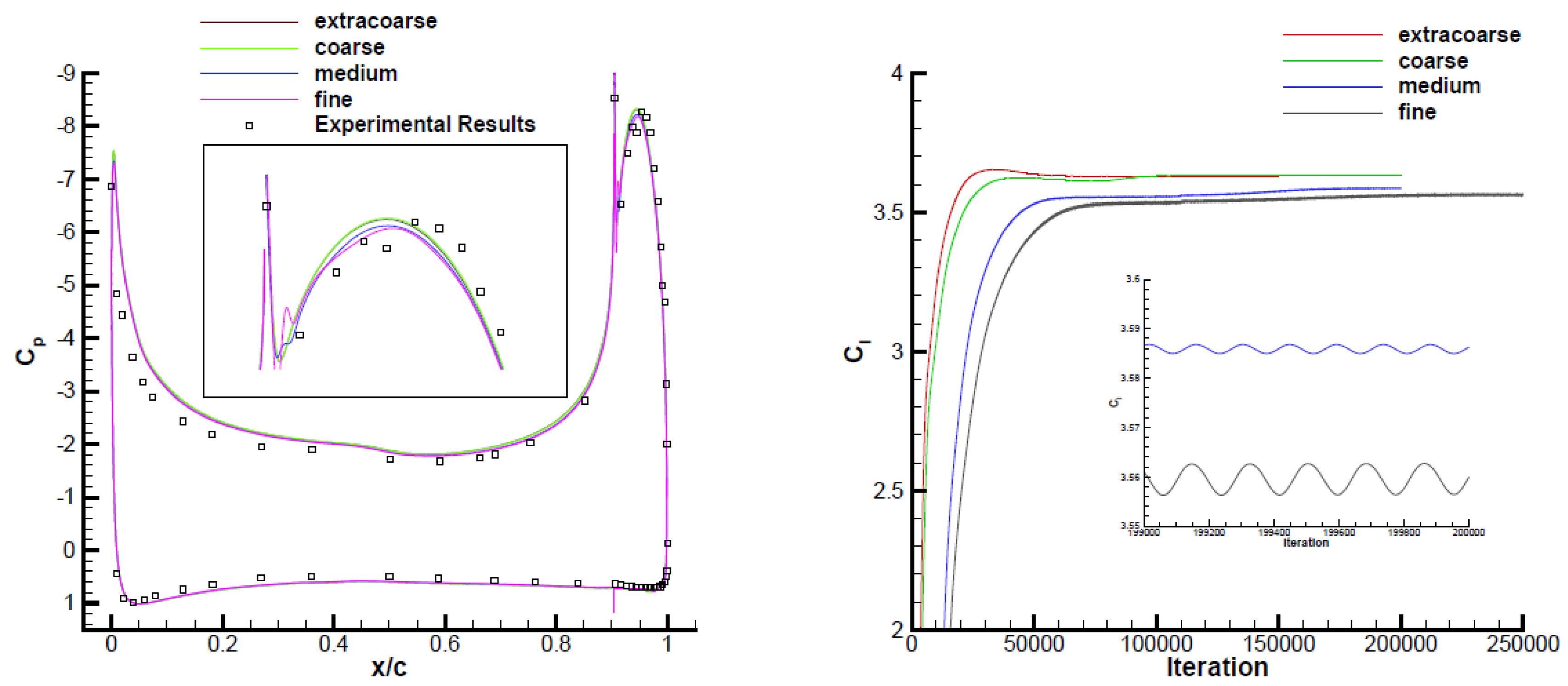
LABORATORY

Modelling and Simulation Tools for the Fluidic Control of Aircraft

Abstract:

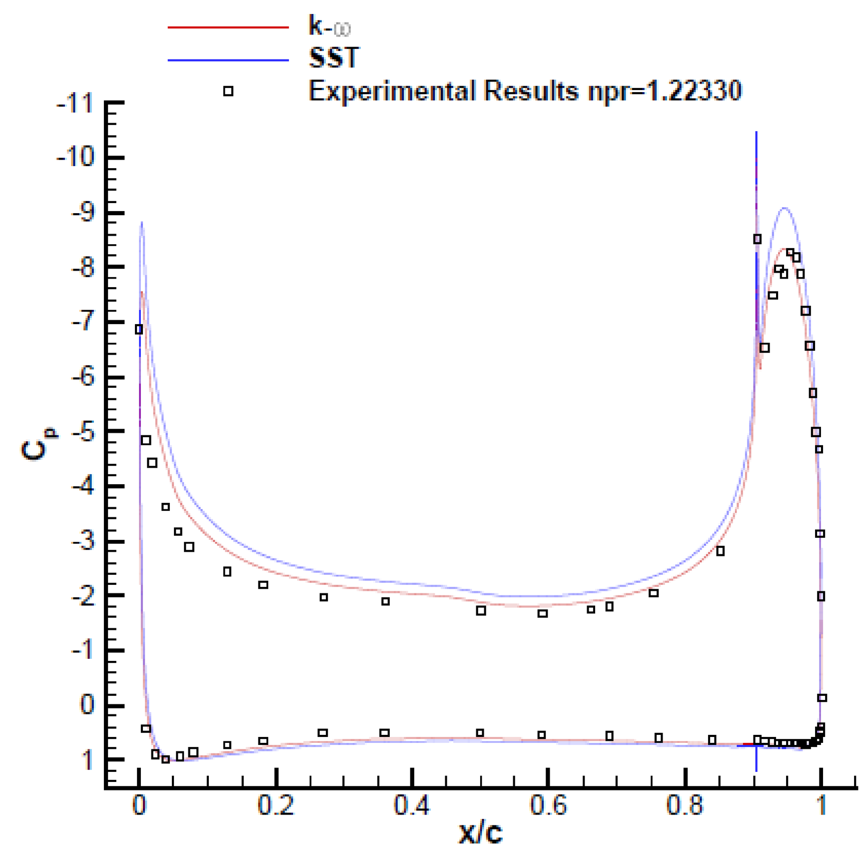
To develop computational fluid dynamic (CFD) modelling techniques for complete aircraft configurations employing fluidic controls. The purpose of this is to replace conventional control surfaces for increased manoeuvrability and improved stealth. A unmanned combat aerial vehicle (UCAV) and a coanda jet validation test cases are simulated to demonstrate the capabilities of the CFD solver used to accurately predict the flow physics needed for such planforms and devices. The fluidic devices are then applied to the UCAV configuration to investigate their effectiveness compared to conventional control surfaces. The numerical simulations are done using the PMB code which is research code developed here at the University of Liverpool. This solves the Reynolds Averaged Navier-Stokes Equations on multi block grids using a finite volume formulation.

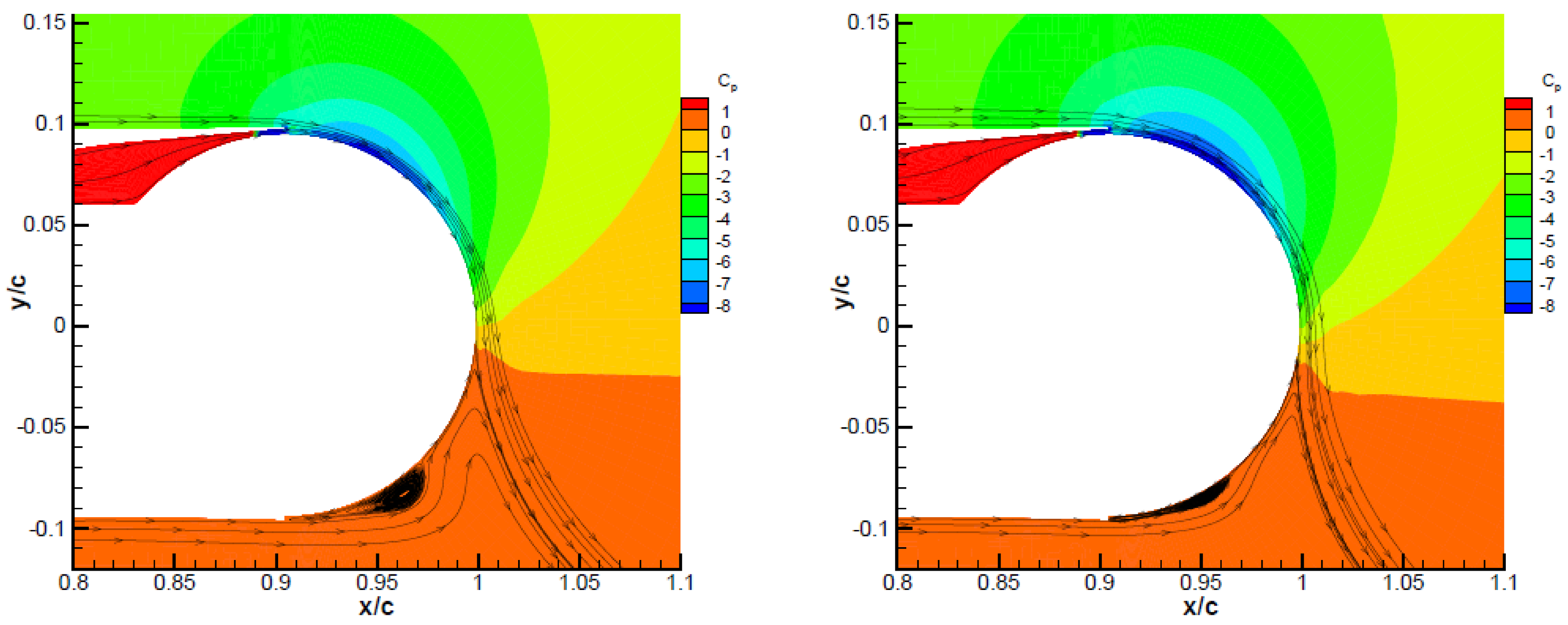


Left: Comparison of the surface pressure coefficients for the four levels of grid refinement.
Right: Comparison of the lift coefficient for each grid with a close-up showing the unsteady nature of the flow.

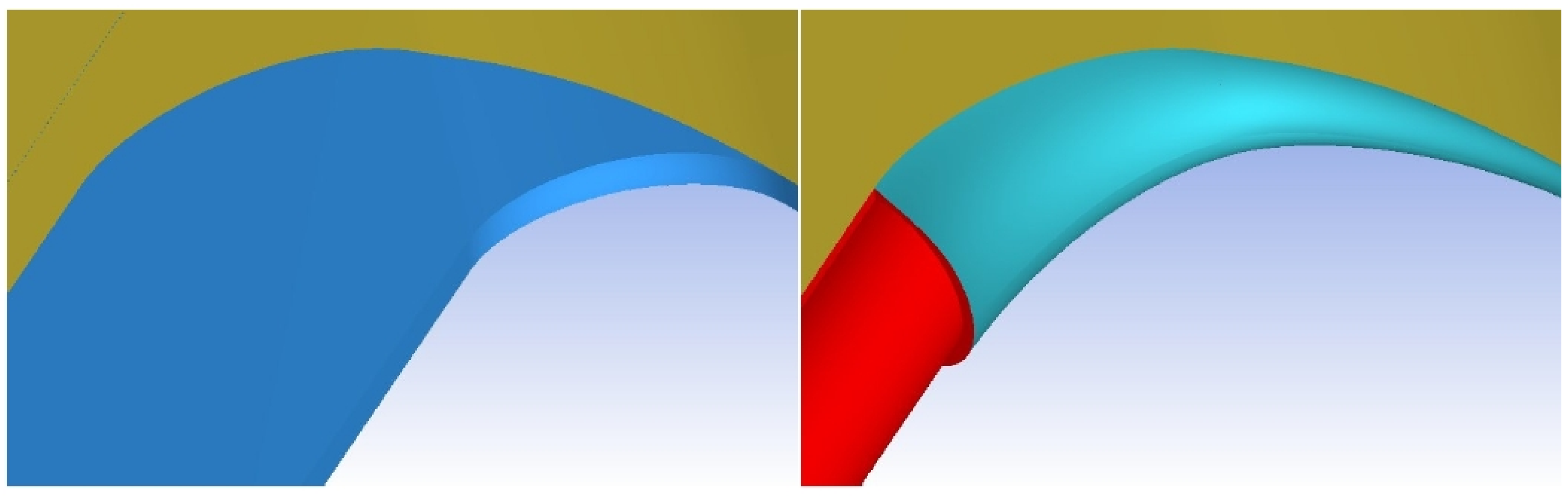
Coanda Jet Validation Case:

Trailing edge circulation control (TECC) uses fluidic injections and the coanda effect at the trailing edge of an aerofoil to increase the amount of circulation generated. The CC-E0020EJ is a an aerofoil employing TECC designed specifically as a CFD validation test case. This case is used to determine the level of grid refinement needed and the turbulence model that is suitable for predicting the flow physics accurately. The k-ω model predicts an earlier separation of the jet relative to the SST model thus providing better comparisons with the data that is available from the wind tunnel experiments.



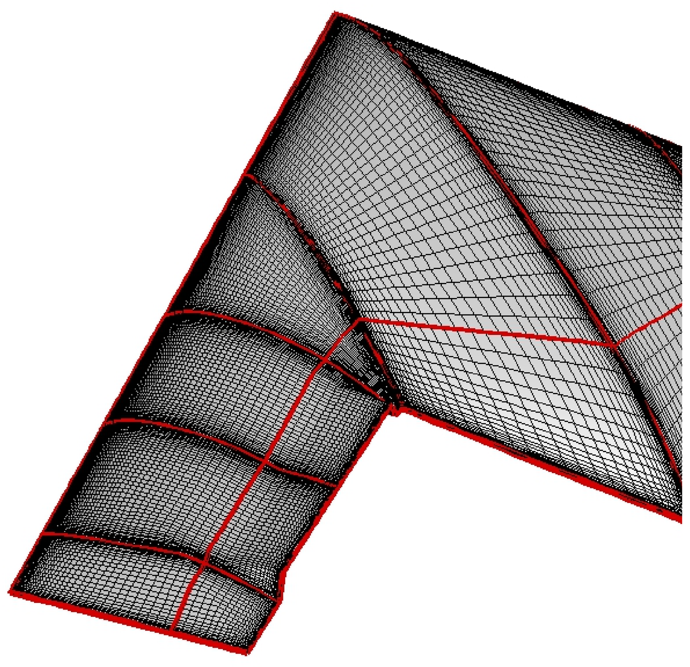


Top Left: Comparison of the surface pressure distribution for the two turbulence models tested.
Bottom Left: Streamlines on C_p contours for the k-ω model.
Bottom Right: Streamlines on C_p contours for Menter's SST model.



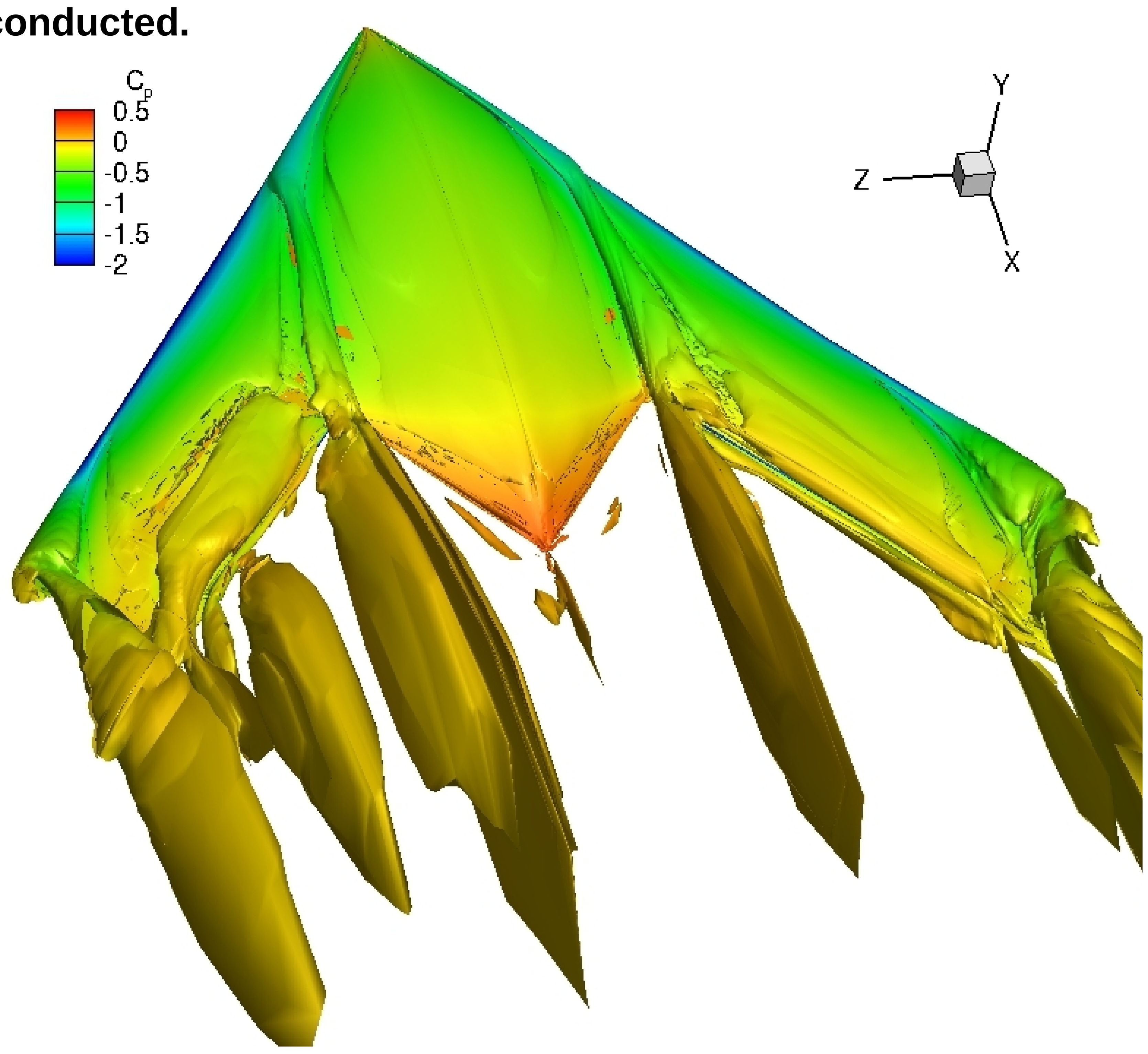
Screenshot of the root of the SACCON's wing before(left) and after(right) the modifications for the TECC are made.

UCAV Validation Case and Modifications:



Surface mesh for the SACCON with flaps deployed.

The SACCON (Stability and Control CONfiguration) is a generic UCAV planform which exhibits flow structures typically encountered by most UCAV's. This and the large amount of available experimental data for it makes it suitable as a test case and to investigate the effectiveness of the TECC on a full aircraft. The modifications are then made and the performance of the devices is compared to the baseline configuration with conventional flaps using static simulations. Also an investigation of how the control moments for the aircraft are produced by the CC device is conducted.



Iso-surfaces of λ_2 criterion coloured with C_p for the SACCON employing CC at an angle of attack of 15°.

Conclusions and Future Work:

The PMB code is shown to be capable of predicting the flow physics of coanda jets and vortical flows with reasonable accuracy. The TECC is applied to the SACCON and its effectiveness at the low angles of attack is demonstrated with static computations. Future work includes simulations of the UCAV performing manoeuvres with the CC devices to demonstrate its practicality as a control method and investigate its dynamic performance and also further modifications for other fluidic controls such as leading edge circulation control, to reduce flow separation over the wings, and fluidic thrust vectoring, for stability and pitch control.

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