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Engine integration based on high-fidelity optimisation technique

The goals of the European Vision for 2020 are very challenging. One of the requirements is a 50% cut in the CO_2 emissions. An optimisation technique that deals with drag reduction of an aircraft is an important aspect to meeting this requirement, since the aerodynamic drag is one of the main drivers for the CO_2 emissions. Considering a 3D geometry including pylons and propulsion system will capture the complex aerodynamic interactions such as shock reflections between engines and other parts of an aircraft. Application of high-fidelity CFD tools provides reliable prediction accuracy.

The HISAC project was initiated within the 6th European research program framework and was aimed at investigating the technical feasibility of an environmentally-friendly small size supersonic transport aircraft. Within this project the DLR has developed and applied, among other things, a process for aerodynamic shape optimisation.

The paper will describe the work done at the DLR during the development of the process for aircraft aerodynamic shape optimisation focusing on propulsion system integration. Furthermore the application and the achieved results on drag coefficient minimisation will be presented and discussed. The base geometry is the project reference geometry with double trapezoid wing, cylindrical body and rear fuselage mounted engines. The engines are represented in a zero-bypass turbojet manner with defined fixed single cone axis symmetrical intake and nozzle geometry.

The developed optimisation process is able to consider not only a shape variation but also a movement of the engines including the pylons. The major software components are CATIA, Centaur and TAU[1]. CATIA updates the parameterised CAD geometry and provides clean intersections between each part of the aircraft. Centaur generates hybrid meshes. TAU performs 3D-Euler calculations which are accurate enough at supersonic speeds. Furthermore some additional shell scripts provide a proper file and data transfer. All of them are controlled through the SynapsPointerPro framework using the gradient-free SupPlex[2] optimisation algorithm. A full optimisation loop includes a geometry update, a mesh creation, a 3D-Euler CFD solution, an aerodynamic coefficients evaluation and an update of the parameters of the geometry.

The design variables for the main optimisation run in order to minimise the drag coefficient are chosen with respect to the project agreed constraints such as wing planform and cabin shape. The number of the design variables is kept as low as possible since the number of the optimisation loops required to solve the design problem is directly linked to it. Seven design variables control the front and rear part of the fuselage. Three other parameters control the position of the engines. A mesh with about 1.3 Million vertices was used in order to capture shock reflections on the fuselage and to ensure a reasonable surface resolution. Even though only 10 design parameters were used, the optimisation leads to a configuration with more than a 50% reduction in drag coefficient after 197 runs. Fig.1 shows the Mach number distribution for initial and optimised geometries.

The paper will show that the developed optimisation process has the potential to reduce the drag of an aircraft and thus contribute to the decrease of the CO_2 emissions.

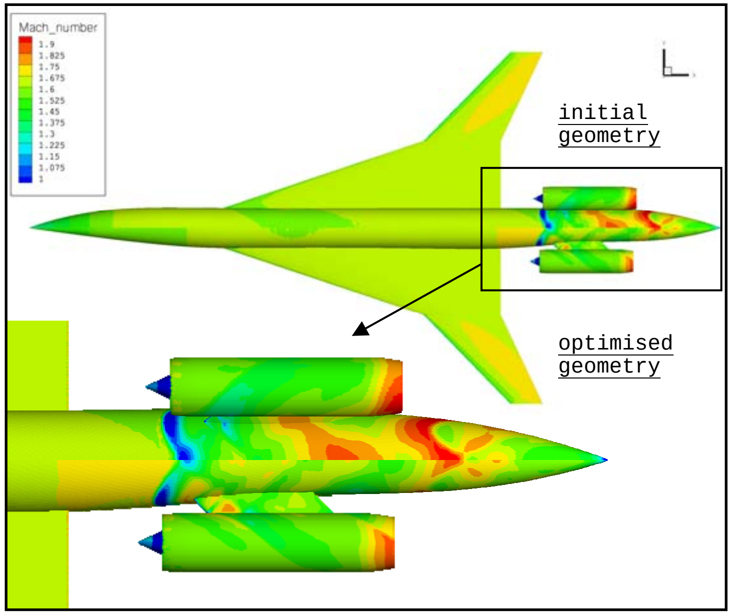

Fig.1: Mach number distribution for initial/optimised geometries, top view

References

[1] Gerhold, Th. (2005), “Overview of the Hybrid RANS TAU-Code” In: Kroll, N., Fassbender, J. (Eds) MEGAFLOW – Numerical Flow Simulation Tool for Transport Aircraft Design, Notes on Multidisciplinary Design, Vol. 89, Springer.

[2] Rowan, T. (1990), “Functional Stability Analysis of Numerical Algorithms” Thesis, Department of Computer Sciences, University of Texas at Austin, USA.