IMPROVING ACCURACY AND ROBUSTNESS OF A DISCRETE ADJOINT METHOD FOR AERODYNAMIC SHAPE OPTIMISATION

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ABSTRACT

Onera is in charge of the development of the $elsA$ software [1] one of the two large CFD codes used by Airbus. Discrete adjoint method has been considered for (RANS) flows in $elsA$, for the computation of the derivatives of aerodynamic functions (C_p, C_l,...) with respect to design parameters. In this framework, the sensitivity of the objective function $\mathcal{J}(\alpha) = J(W(\alpha), X(\alpha))$ is computed by following equations [2]

$$\frac{d\mathcal{J}}{d\alpha_i} = \frac{\partial J}{\partial X}\frac{dX}{d\alpha_i} + \lambda_J^T(\frac{\partial R}{\partial X}\frac{dX}{d\alpha_i}) \qquad (\frac{\partial R}{\partial W})^T\lambda_J = -(\frac{\partial J}{\partial W})^T$$

(where X is the mesh, W is the conservative variable vector, α_i is a component of the design parameter vector α and R is the space dicretisation residual). Discrete adjoint equations are solved by iterative algorithms, such as

$$\frac{\partial R}{\partial W}^{T(APP)}\left(\lambda_J^{(l+1)} - \lambda_J^{(l)}\right) = -\left(\frac{\partial R}{\partial W}^{T(ACC)}\lambda_J^{(l)} + \frac{\partial J}{\partial W}\right), \tag{1}$$

where $\frac{\partial R}{\partial W}^{(ACC)}$ is an accurate approximation of the true jacobian $\frac{\partial R}{\partial W}$, and $\frac{\partial R}{\partial W}^{(APP)}$ a suitable matrix for the convergence of the algorithm.

When the turbulent viscosity is considered constant in the computation of $\frac{\partial R}{\partial W}^{(ACC)}$ equation (1) is not too difficult to solve. Unfortunately the resulting sensitivities $\frac{d\mathcal{J}}{d\alpha_i}$ may be very inaccurate for design parameters that produce, for example, local changes of shape close to a shock-wave. When the turbulent viscosity is differentiated, the discrete adjoint equation may be very difficult to solve for complex geometries. ONERA recently carried out a specific study to tackle this issue for a discretization of (RANS) & (Spalart-Allmaras) model equations. It involves : (a) two types of approximate Jacobian (b) using or not RPM [3] on top of equation (1) (c) two types of artificial dissipation added to the right-hand side of equation (1). Detailed results will be presented for the AS28G wing and the XRF1 wing-body configuration.

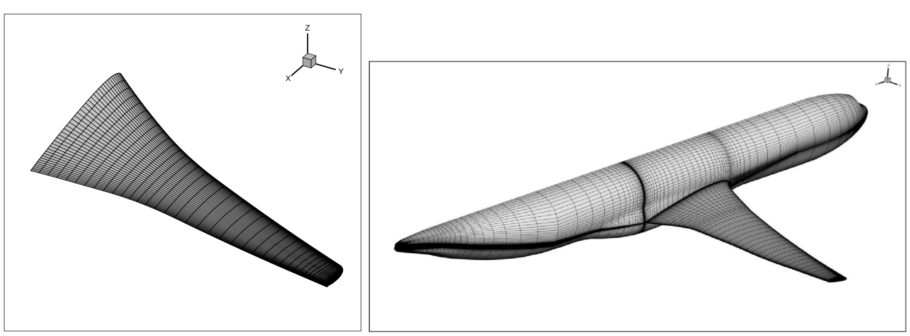

Figure 1: AS28G wing - XRF1 wing-body

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