11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Reduced Dissipation SLAU and AUSM$^+$-up towards High Resolution Unstructured Grid Simulations

Keiichi Kitamura[1] and Atsushi Hashimoto[2]

[1] Nagoya University, 1 Furo-cho, Chikusa, Nagoya, Aichi 464-8603, kitamura@fluid.nuae.nagoya-u.ac.jp
[2] JAXA, 7-44-1 Higashimachi, Jindaiji, Chofu, Tokyo 182-8522, hashimoto.atsushi@jaxa.jp

Key Words: *Reduced Dissipation, SLAU, AUSM$^+$-up, Euler Fluxes, Unstructured Grid*

The reduced dissipation approach[1][2] has been applied to two AUSM-family flux functions (SLAU[3] and AUSM$^+$-up[4]) towards high resolution simulations (e.g., transonic buffet) on unstructured grids. In this approach, the dissipation term (of the pressure flux) in each flux function is locally controlled ($0 < \gamma_{HR} < 1$, γ_{HR}: dissipation coefficient) where a cell-interface orientation angle is small (i.e., cell geometry is nearly squared) and/or where flows are smooth, and the original methods are recovered otherwise ($\gamma_{HR}=1$).

- HR-SLAU (High Resolution SLAU, $0 < \gamma_{HR} < 1$, γ_{HR}: dissipation coefficient)

The pressure flux is modified as:

$$(\tilde{p})_{HR-SLAU} = \frac{p_L + p_R}{2} + \frac{\left.P^+\right|_{\alpha=0} - \left.P^-\right|_{\alpha=0}}{2}(p_L - p_R) + \gamma_{HR}\cdot(1-\chi)\left(\left.P^+\right|_{\alpha=0} + \left.P^-\right|_{\alpha=0} - 1\right)\frac{p_L + p_R}{2} \quad (1)$$

- HR-AUSM$^+$-up:

$$(\tilde{p})_{HR-AUSM+-up} = \left.P^+\right|_{\alpha}\cdot p_L + \left.P^-\right|_{\alpha}\cdot p_R + \gamma_{HR}\cdot p_u \quad (2)$$

- HR-Roe[1][2] (also known as Unstructured Roe):

$$\mathbf{F}_{HR-Roe} = \frac{1}{2}(\mathbf{F}_L + \mathbf{F}_R) - \frac{\gamma_{HR}}{2}\left|\hat{\mathbf{A}}\right|\cdot(\mathbf{Q}_R - \mathbf{Q}_L) \quad (3)$$

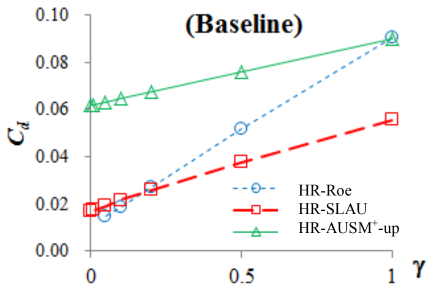

Fig. 1 Computed C_d vs. γ_{HR} (Baseline: δ_i =0, δ_j =0, 1st-order, M=0.3).

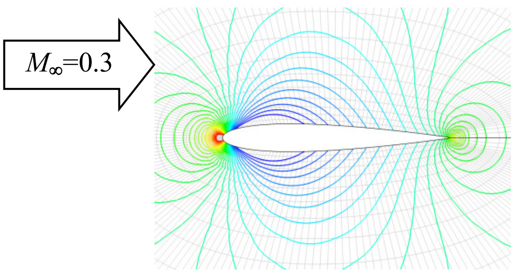

Fig. 2 Computed C_p contours on grid without perturbation: HR-SLAU (γ_{HR} =0).

Preliminary numerical results (in which γ_{HR} is fixed at certain values) in Figs. 1 and 2, and Table 1 clearly indicate linear reductions of C_d (representing numerical errors in these Euler simulations) according to γ_{HR} for all the three methods (except for unstable cases of HR-Roe with small γ_{HR}). Figures 3 – 6 demonstrate better performances of the developed methods (HR-SLAU and HR-AUSM$^+$-up), compared with those by the original counterparts (γ_{HR}=1) or the existing method (HR-Roe[1][2]): the smallest errors were produced by HR-SLAU in most cases, and HR-AUSM$^+$-up was the most robust, even with grid perturbations or the 2nd-order extension. In practice, γ_{HR} is given according to grid quality and flow conditions on unstructured grids as in HR-Roe[1][2], and thus, further studies are needed to specify this value.

Table 1 Drag Coefficients C_d (Baseline)

C_d ($\times 10^{-2}$)	γ_{HR}=1	0.5	0.2	0.1	0.05	0.01	0
HR-Roe	9.04	5.15	2.72	1.89	1.51	(div.)	(div.)
HR-SLAU	5.56	3.76	2.59	2.16	1.93	1.74	1.69
HR-AUSM$^+$-up	8.98	7.59	6.74	6.45	6.31	6.19	6.16

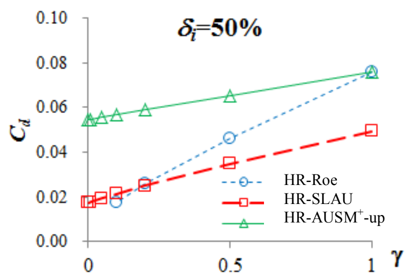

Fig. 3 Computed C_d vs. γ_{HR} : δ_i =50%.

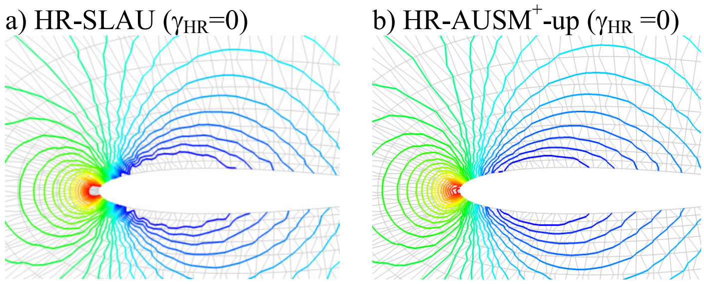

Fig. 4 Computed C_p contours on perturbed grid: δ_i =50%.

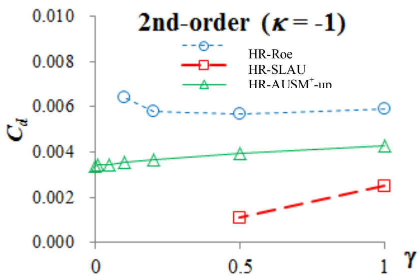

Fig. 5 Computed C_d vs. γ_{HR} : 2nd-order.

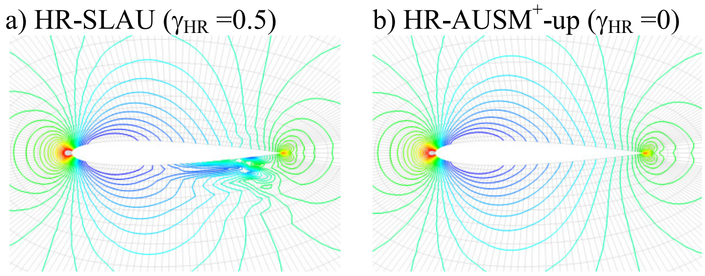

Fig. 6 Computed C_p contours on grid with 2nd-order.

REFERENCES

[1] Winkler, C.M., Dorgany, A.J. and Mani, M.: A Reduced Dissipation Approach for Unsteady Flows on Unstructured Grids, AIAA 2012-0570, 2012.

[2] Tajallipour, N., Owlam, B.B., and Paraschivoiu, M.: Self-Adaptive Upwinding for Large Eddy Simulation of Turbulent Flows on Unstructured Elements. *J. Aircraft*, Vol. **46**(3), pp.915–926, 2009.

[3] Shima, E. and Kitamura, K.: Parameter-Free Simple Low-Dissipation AUSM-Family Scheme for All Speeds, *AIAA Journal*, Vol.**49** (8), pp.1693-1709, 2011.

[4] Liou, M.S.: A Sequel to AUSM, Part II: AUSM$^+$-up for All Speeds, *Journal of Computational Physics*, Vol. **214**, pp. 137-170, 2006.