Japan-Russia Workshop

SUPERCOMPUTER MODELING, INSTABILITY AND TURBULENCE IN FLUID DYNAMICS

Keldysh Institute for Applied Mathematics
Russian Academy of Sciences, Moscow, Russia

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SIMULATION OF SUPERSONIC FLOWS IN THE WING WAKE AND ITS INTERACTION WITH CROSSING SHOCK WAVES.

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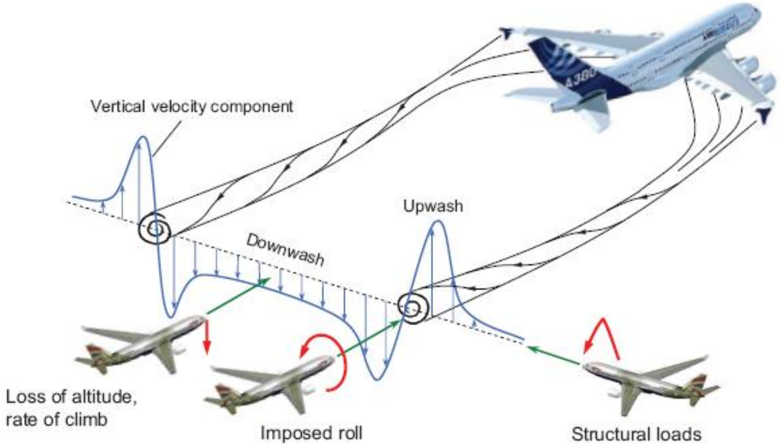
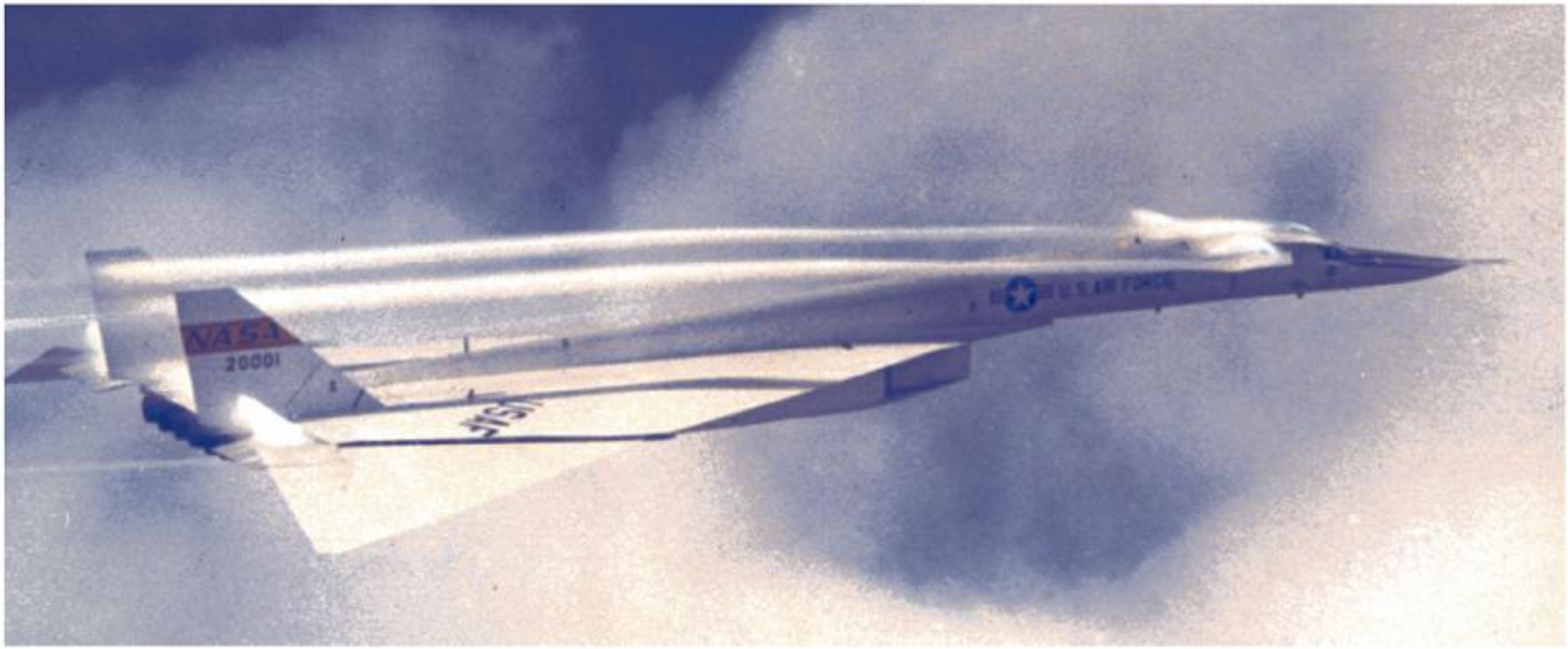
Wing tip vortex on subsonic speed of flight.



Wing tip vortex on supersonic speed of flight.



Photograph of XB-70 in supersonic flight.

1. **Zatoloka V.V., Ivanyushkin A.K., Nikolayev A.V.** Interference of vortices with shocks in airscoops. Dissipation of vortexes. *Fluid Mechanics, Soviet Research*, 1978, vol. 7, pp. 153-158.

2. **Delery J., Horowitz E., Leuchter O., Solignac J.** Fundamental Studies on Vortex Flows. *La Recherche Aerospatiale*, (English ed.), 1984, pp. 1-24.

3. **Glotov G.F.** Interference of a vortex core with shock waves in a free stream and nonisobaric jets. *Uchenie zapiski TsAGI*, 1989, vol. 20, No. 5, (in Russian).

4. **Ivanyushkin A.K., Korotkov Yu.V., Nikolayev A.V.** Some features of an interference of shock waves with aerodynamic wake. *Uchenie zapiski TsAGI*, 1989, vol. 20, No. 5, (in Russian).

5. **Cattafesta L. , Settles G.** Experiments on shock/vortex interaction. AIAA Paper, No. 0315, 1992.

6. **Kalkhoran I.M., Smart M.K., Betti A.** Interaction of a supersonic wing tip vortex with a normal shock. *AIAA Journal*, 1996, vol. 3, No. 34, pp. 1855-1861.

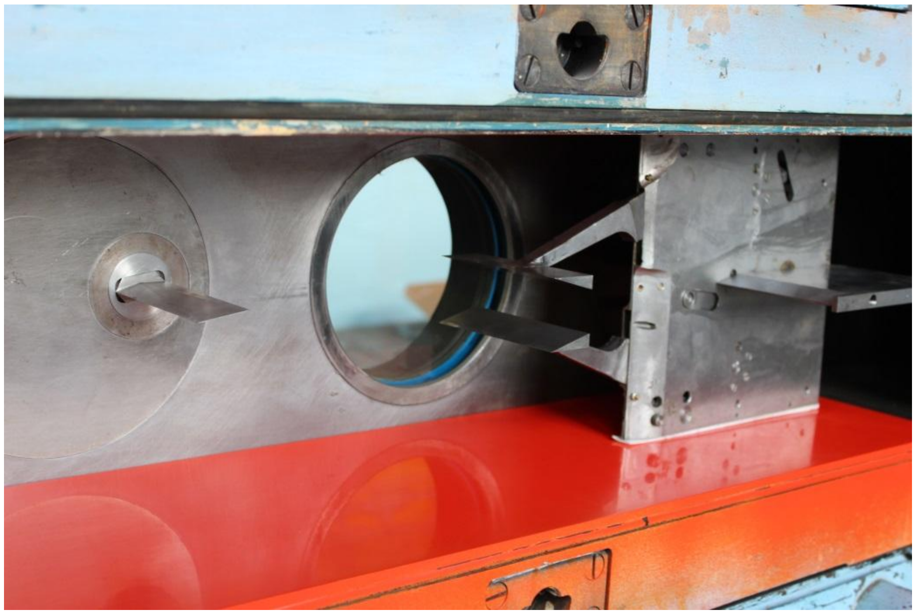
8. **Borovoy V.Ja., Kubishina T.V., Skuratov A.S., Yakovleva L.S.** Vortex in a supersonic flow and its influence on a flowfield and heat transfer of the blunted body. *Mechanica zhidkosti i gaza*, 2000, No. 5, pp. 66-76, (in Russian).

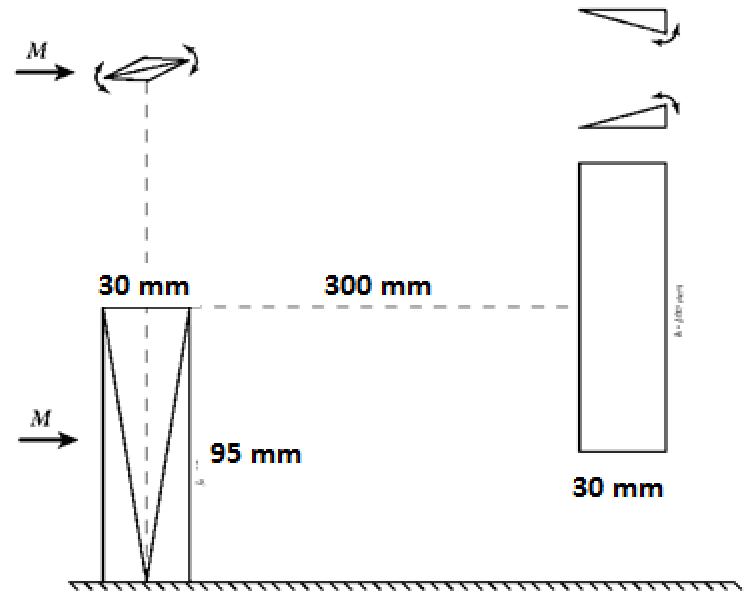
9. **A. M. Shevchenko, A. E. Lutsky, A. S. Chernoguzov, K. Yu. Polkova.** Techniques and results for investigations of supersonic wing-tip vortices. Proc of XIII International Conference on the Methods of Aerophysical Research, Novosibirsk, 5-10 February, 2007, Part 3, pp. 215-220.

10. **Rizzetta D.P.** Numerical Investigation of Supersonic Wing-Tip Vortices // AIAA Journal, V 34, No 6, June 1996, pp.1203-1208.

11. **A.M. Shevchenko, I.N. Kavun, A.A. Pavlov, Al.A. Pavlov, A. S. Shmakov, V.I Zapryagaev.** Unsteady effects in wing wake / shock interactions. Proc of 2nd European Conference for Aerospace Sciences, Brussels, 1-6 July, 2007, Paper No. 2.01.03., 8p.

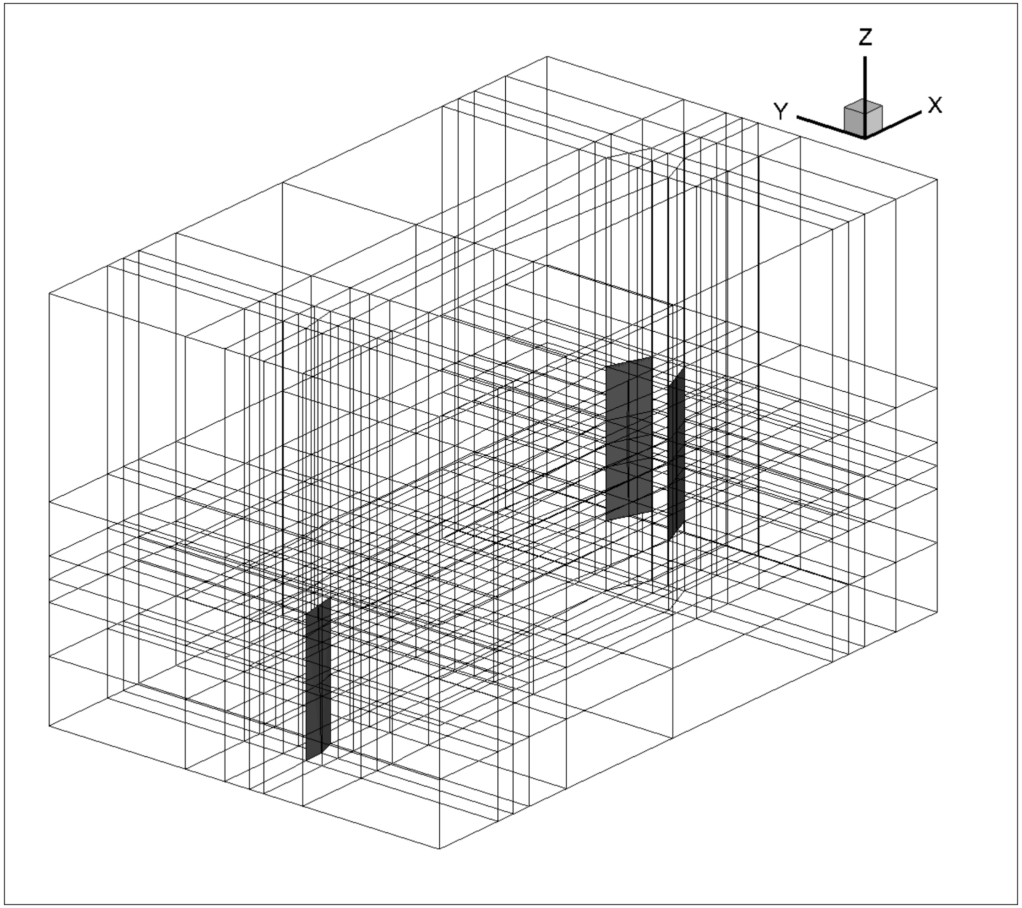
Setup for experiment





Wind tunnel T-325 ITAM SB RAS
M=3, α=0÷10º, β=15÷25º

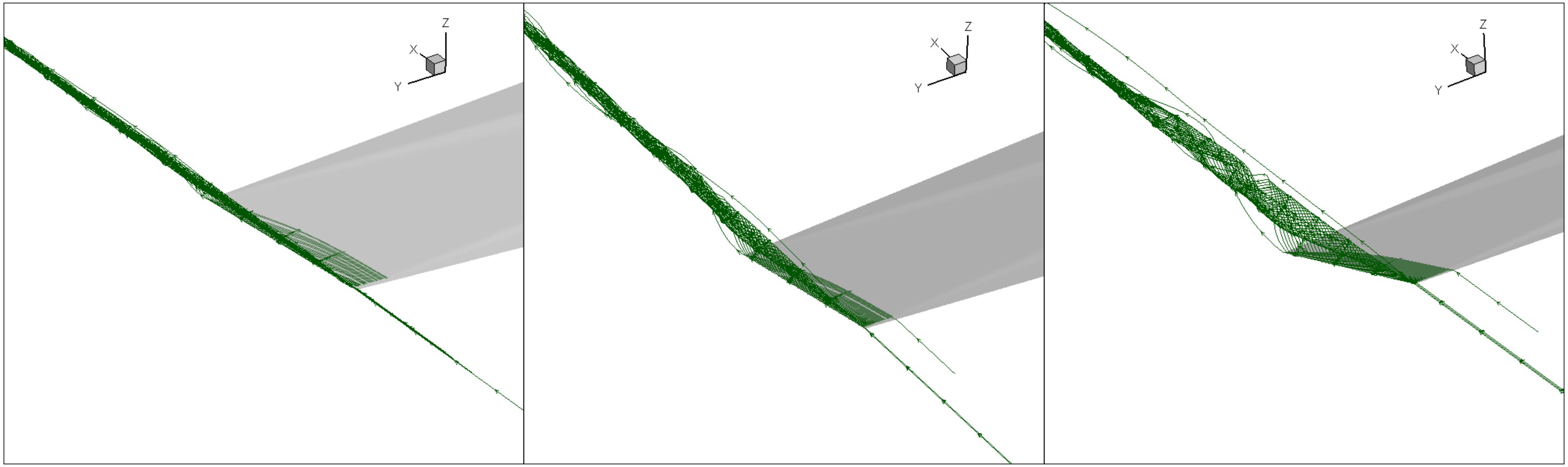
Setup for numerical simulation



Multi block mesh, cells number 18 667 500, URANS, SA turbulence model, WENO 3.

Wing tip streamtraces

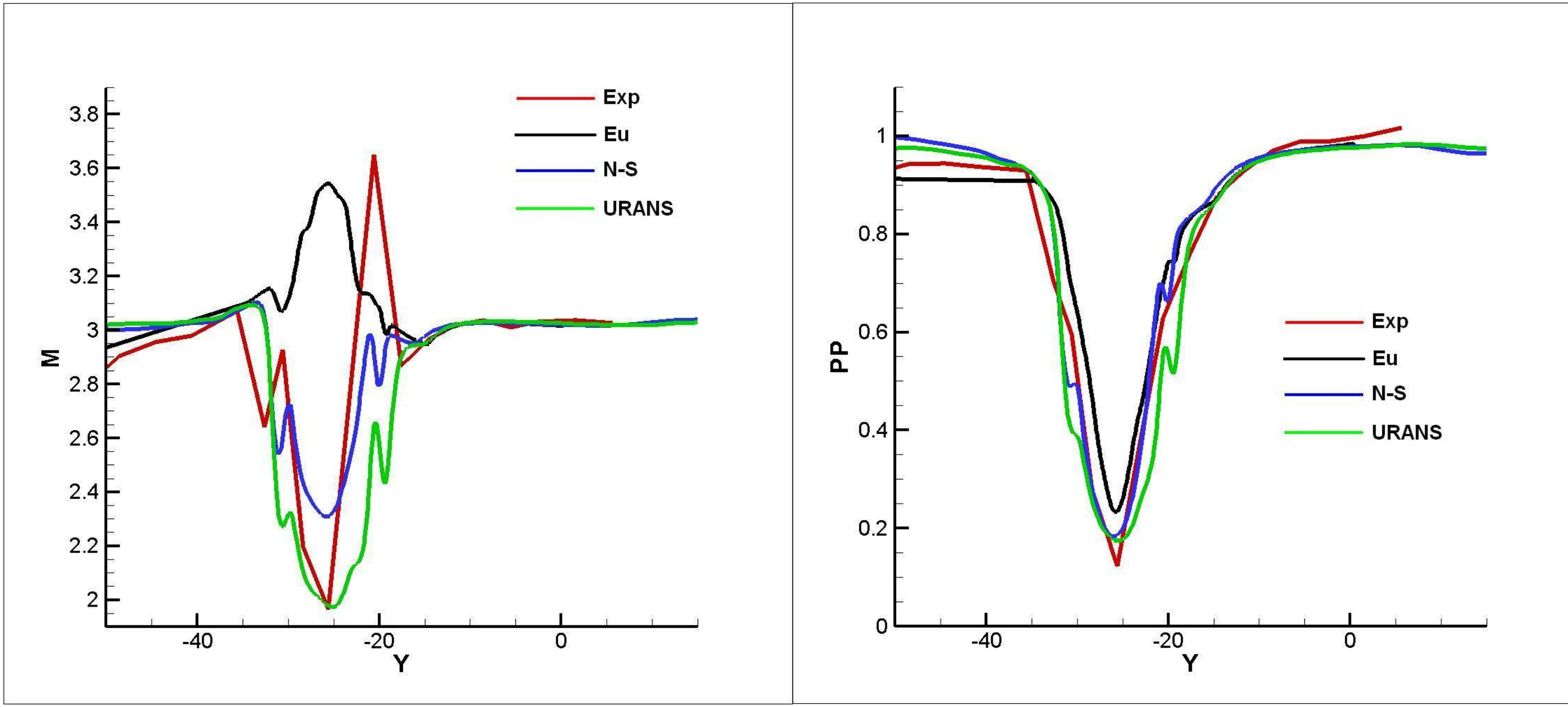
α = 4°   α = 12°   α = 18°



A. A. Davydov, T. V. Konstantinovskaya, A. E. Lutskii, A. M. Kharitonov, A. M. Shevchenko, A. S. Shmakov. Modeling of a supersonic flow field in the core of the wingtip vortex at Mach 6 //Mathematical Models and Computer Simulations, January 2013, Volume 5, Issue 1, pp 25-36.

Experimental and numerical data comparison

M = 3, a = 10.

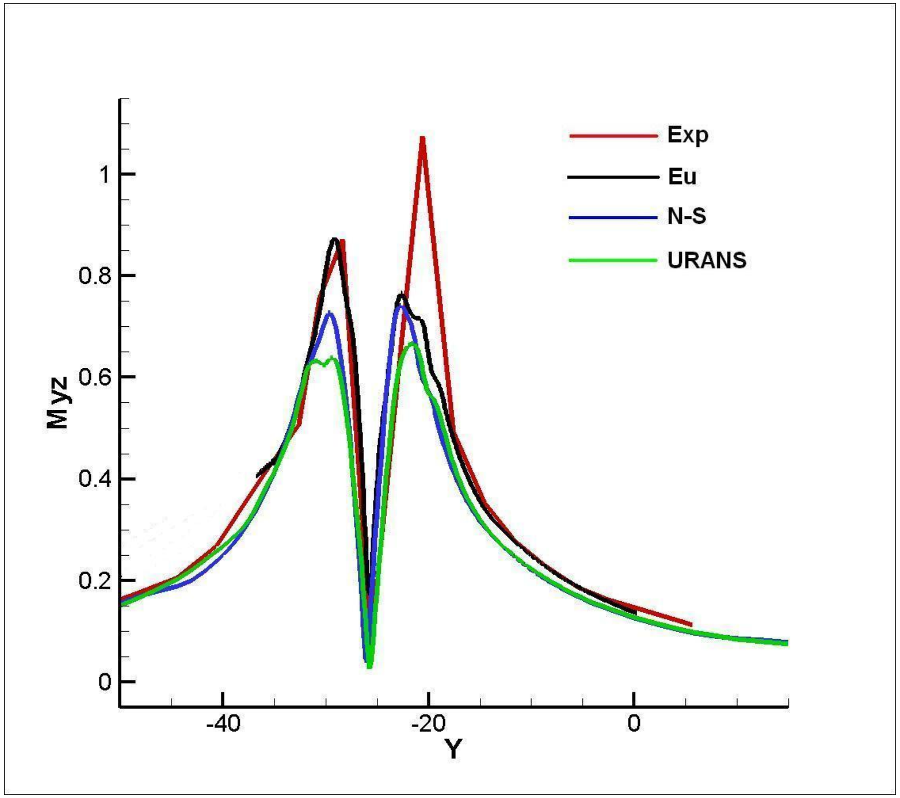


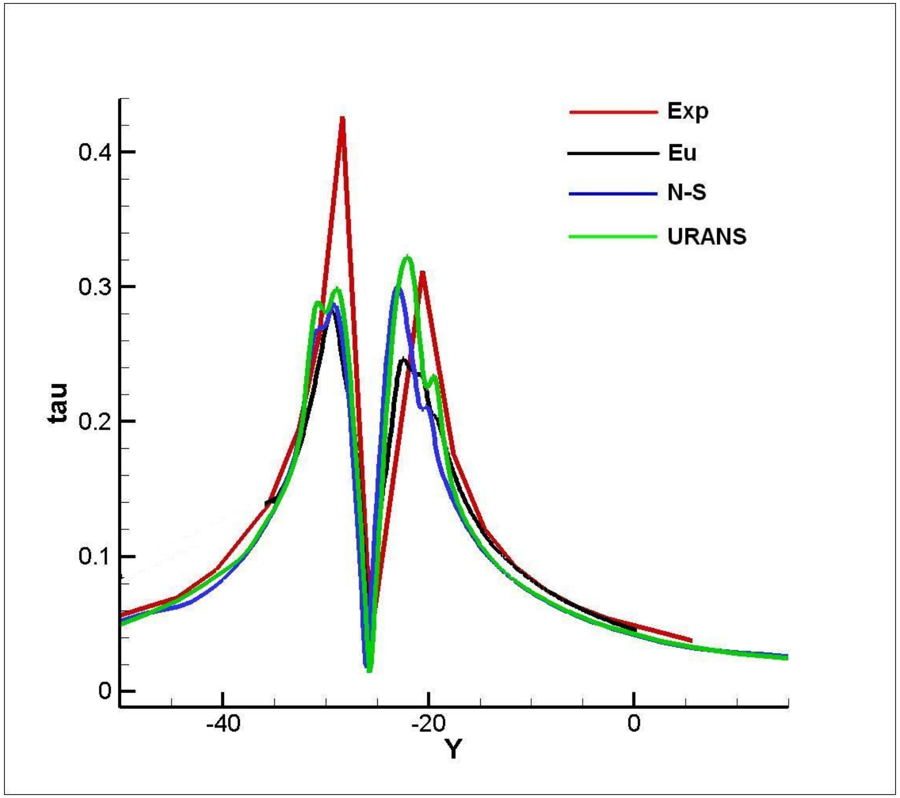
Mach number and Pitot pressure in the vortex core

Batchelor G.R. Axial flow in trailing line vortices // J.Fluid. Mech, 1964,20, P.645-652

Experimental and numerical data comparison

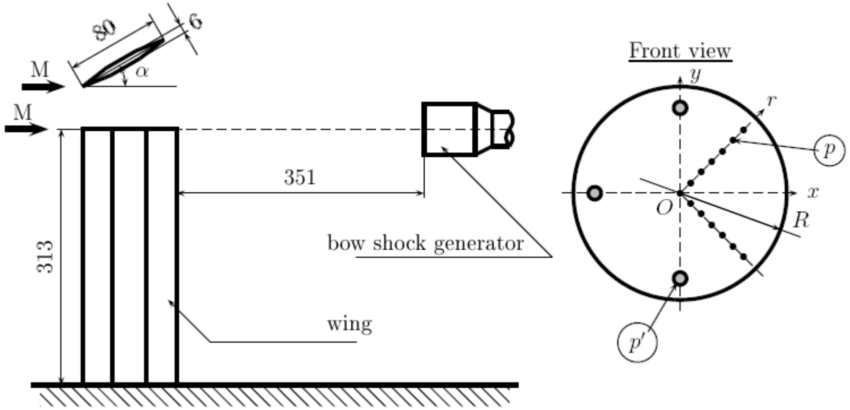
M = 3, a = 10.

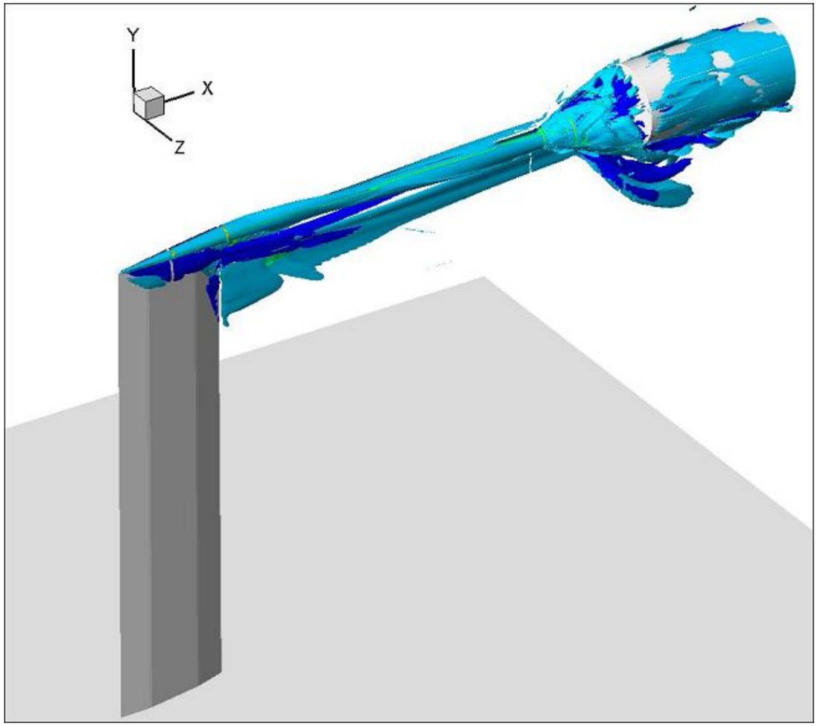




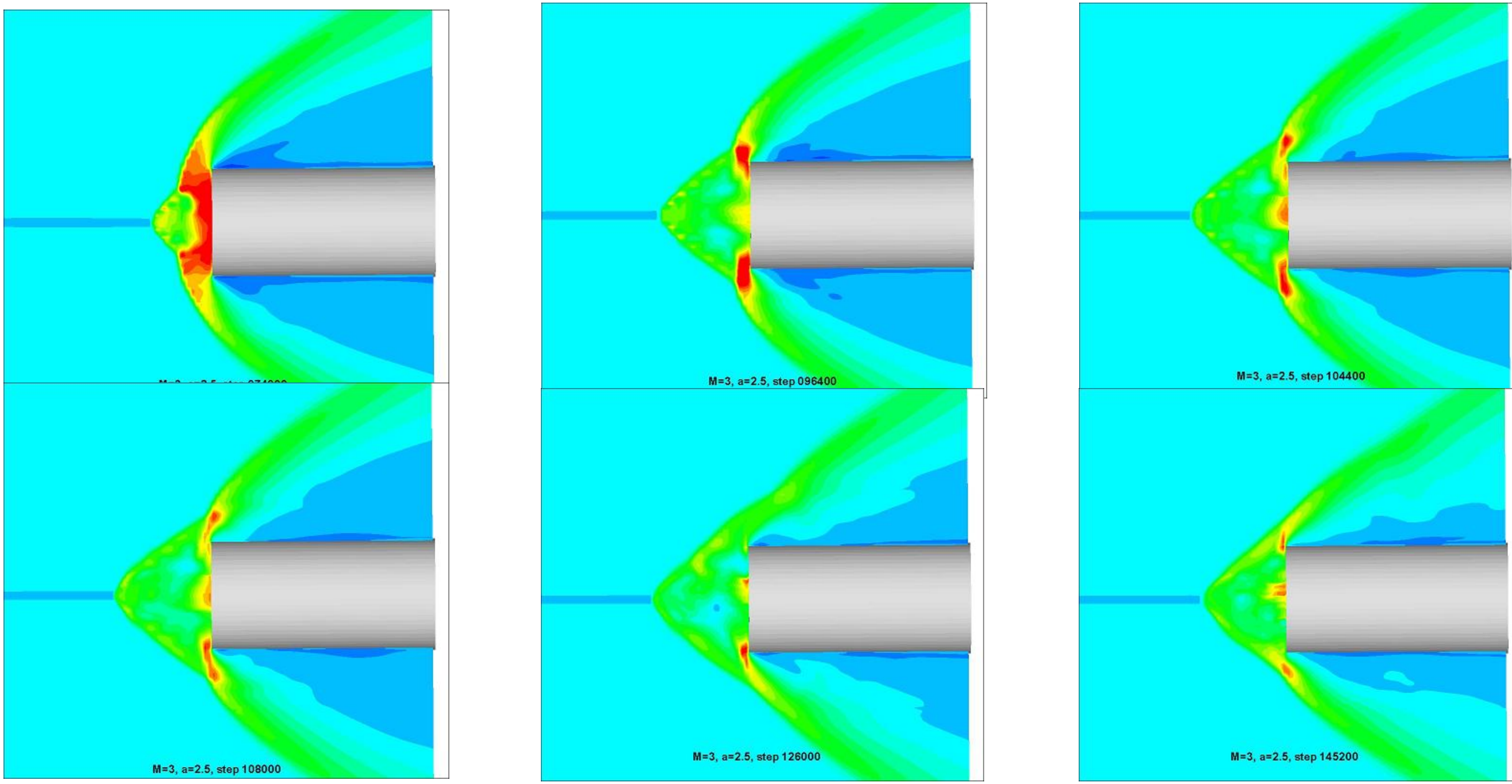
Cross-flow Mach number Myz and (Myz/Mx) value in the vortex core

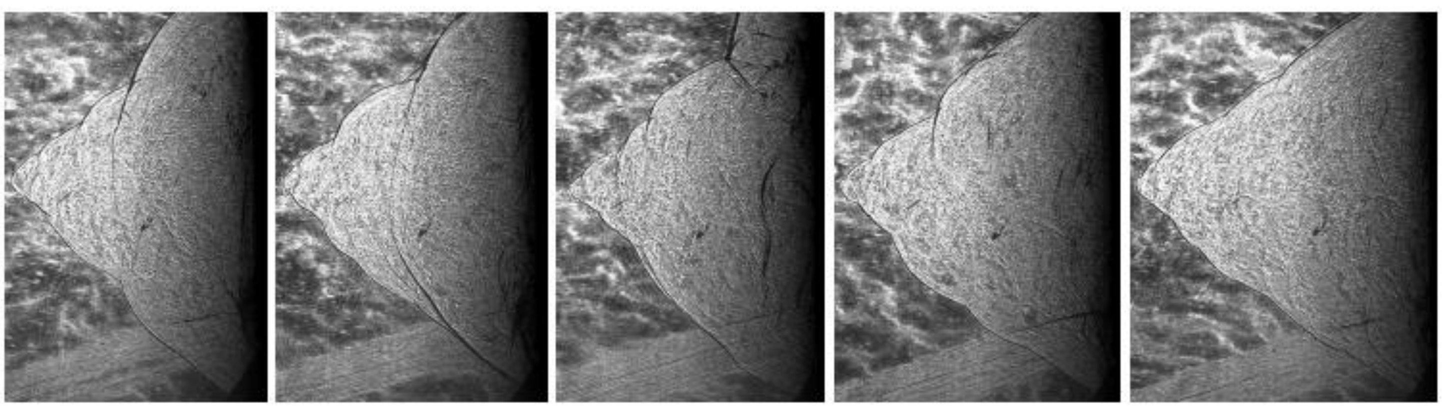
Vortex interaction with bow shock

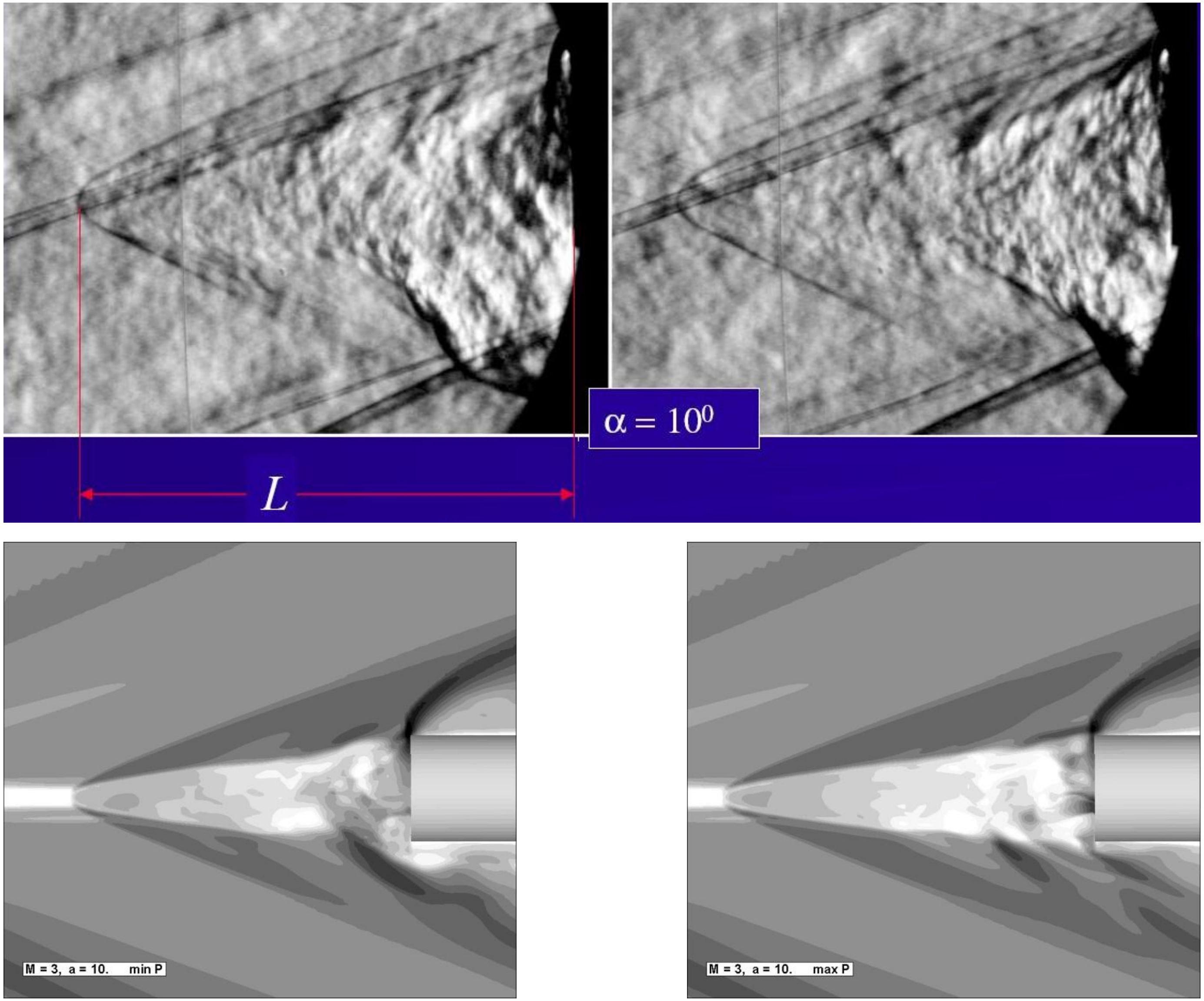




Vortex interaction with bow shock. M=3

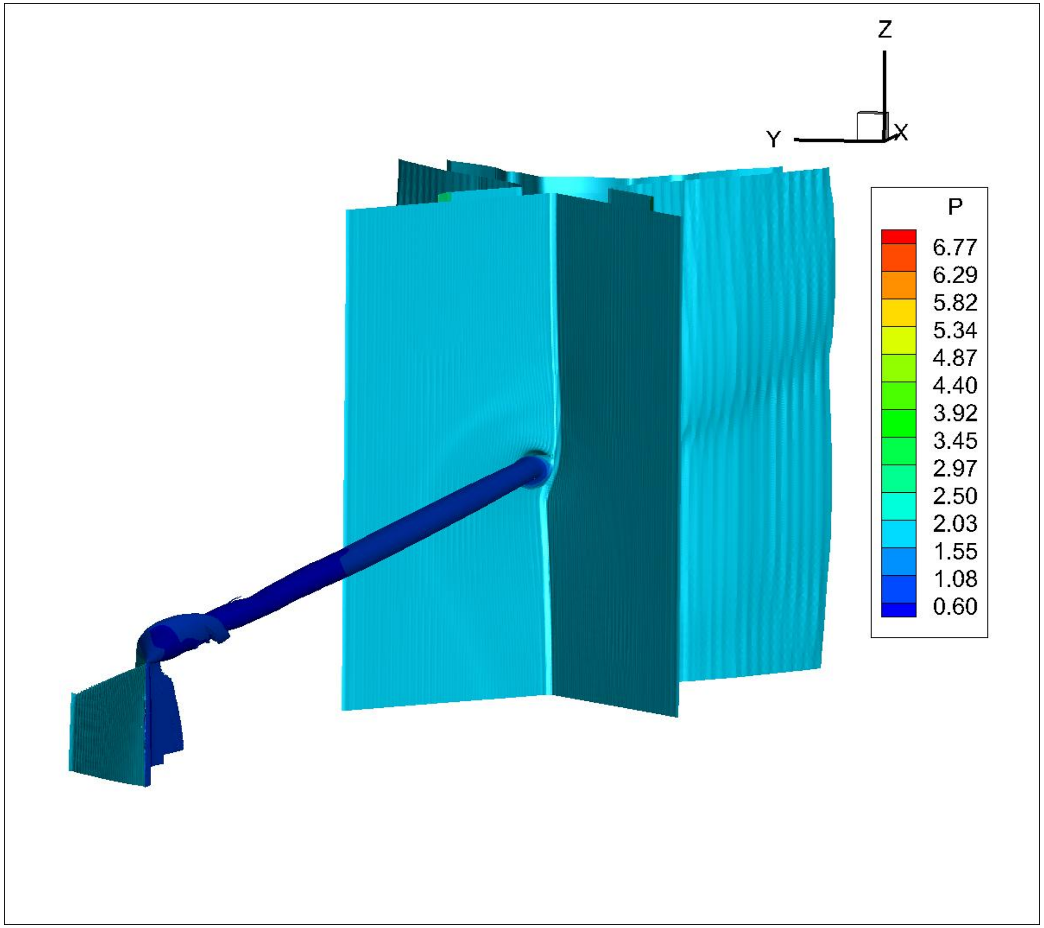






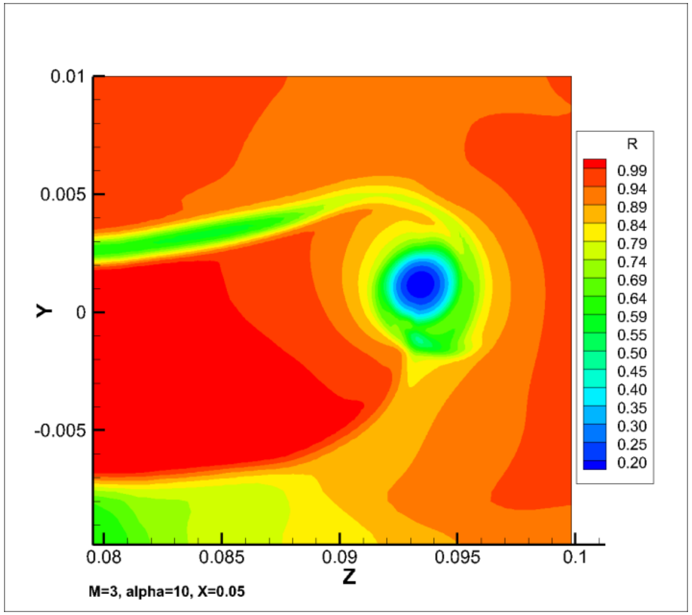
L_exp=145-155 mm **L_num=153-165 mm**

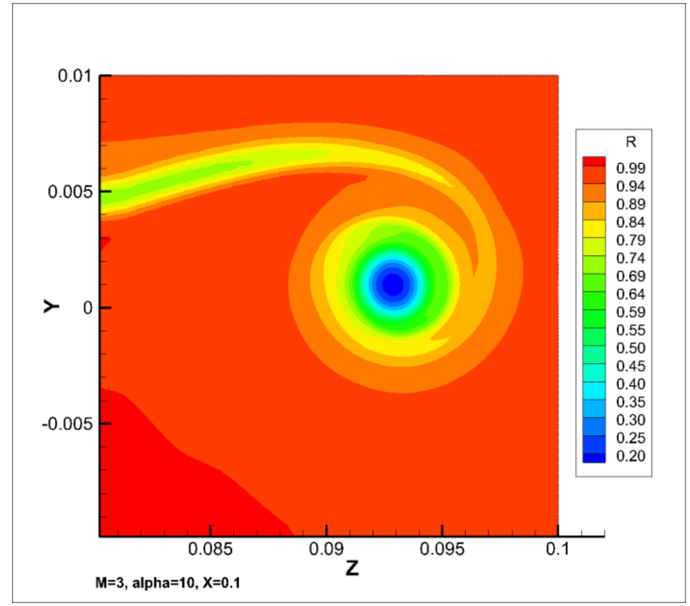
Flow stucture

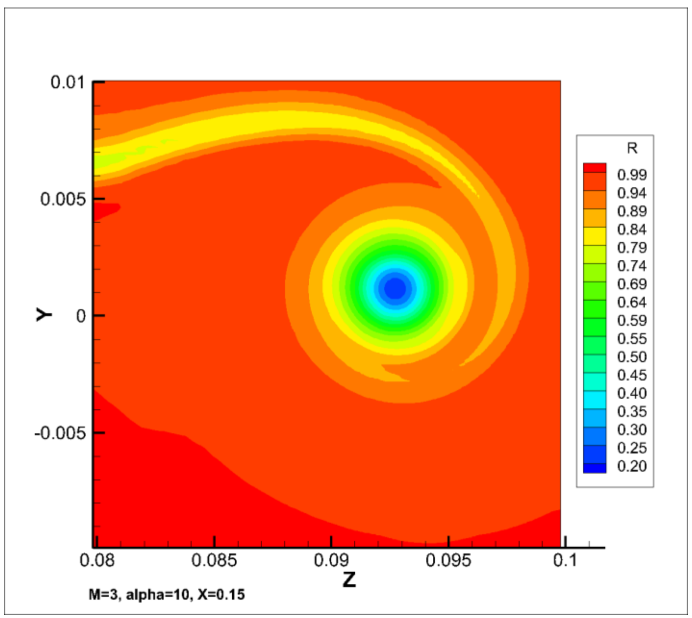


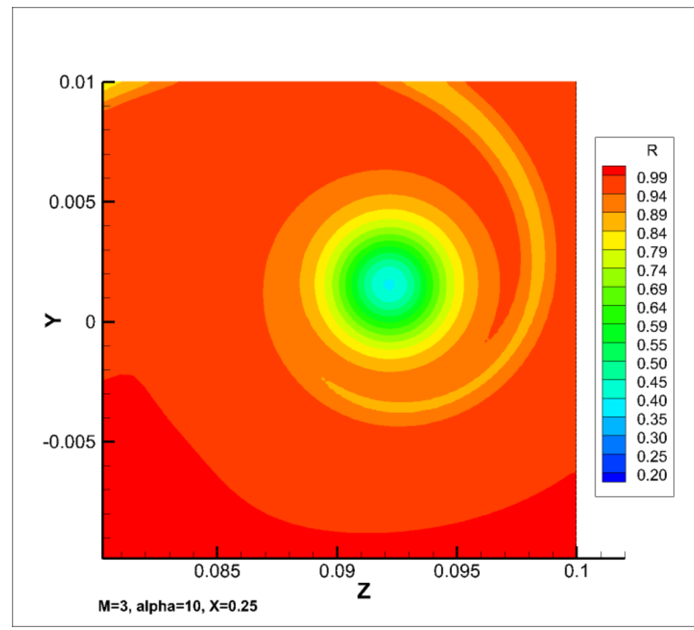
M=3,α=10°

Vorticity and pressure iso surfaces

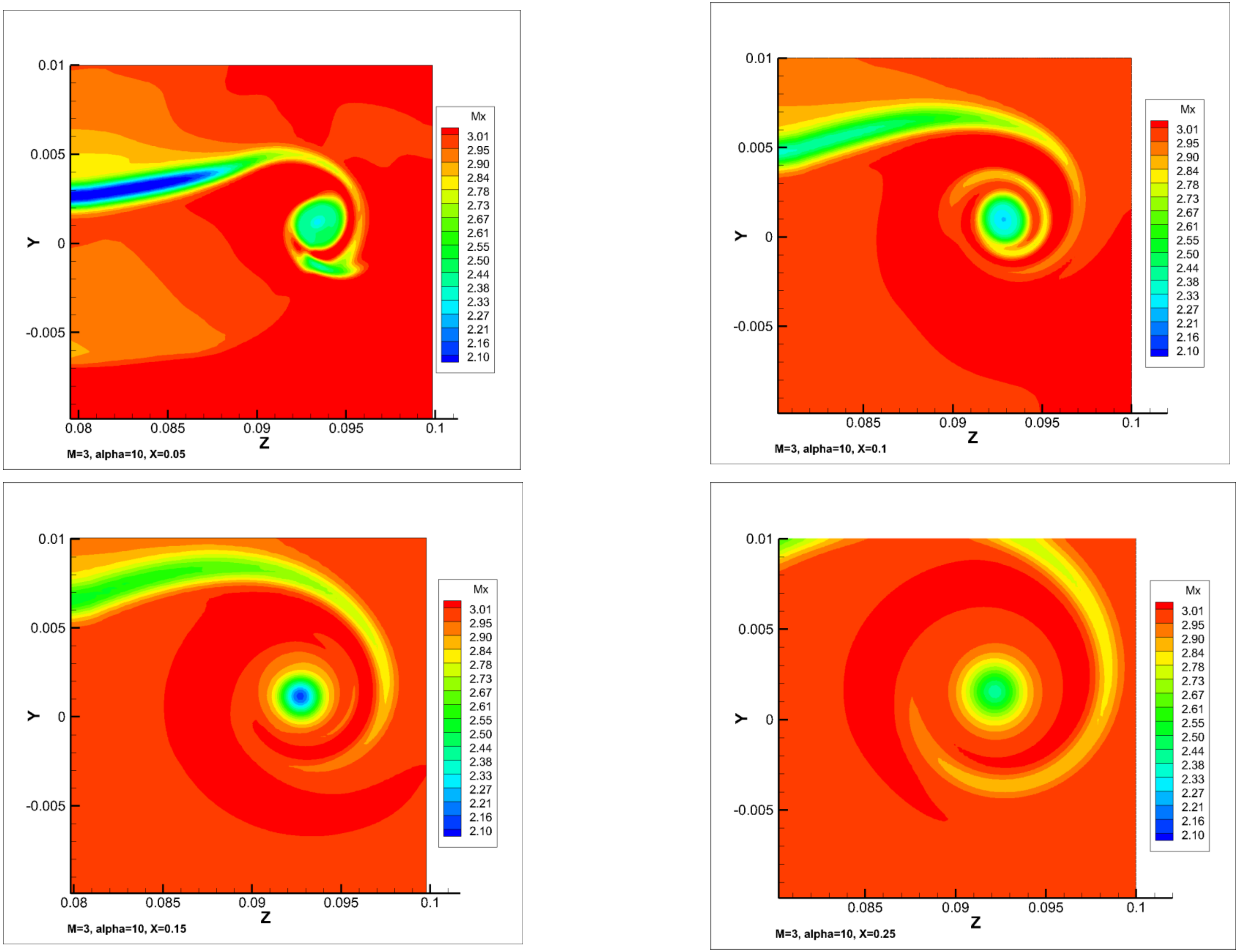






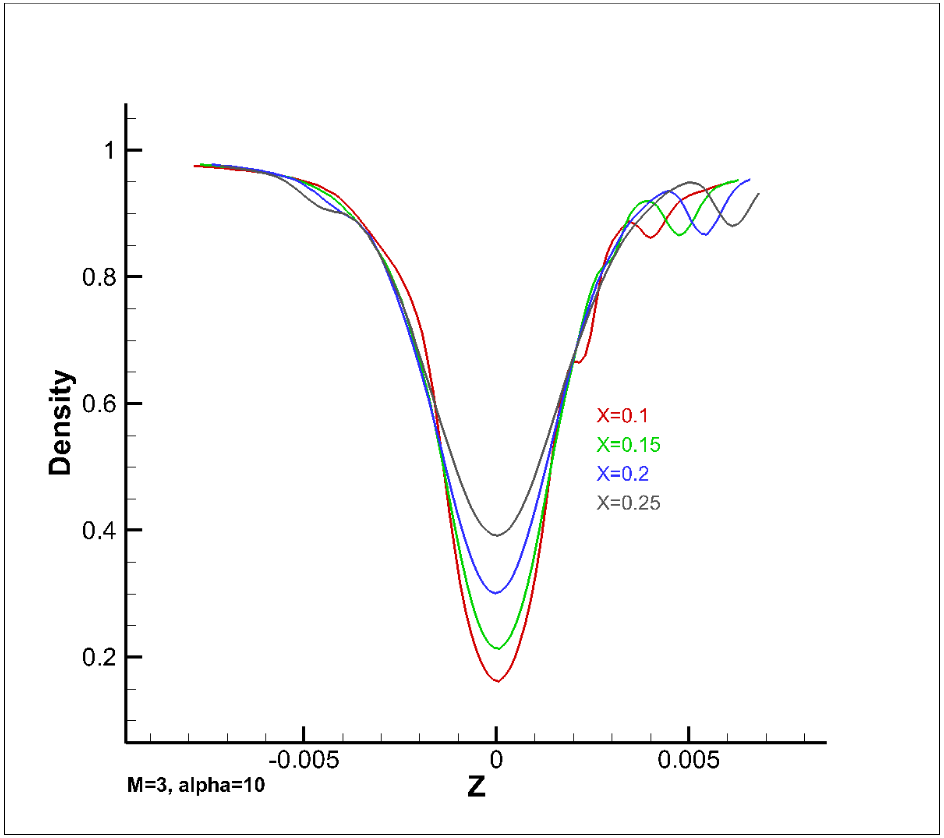


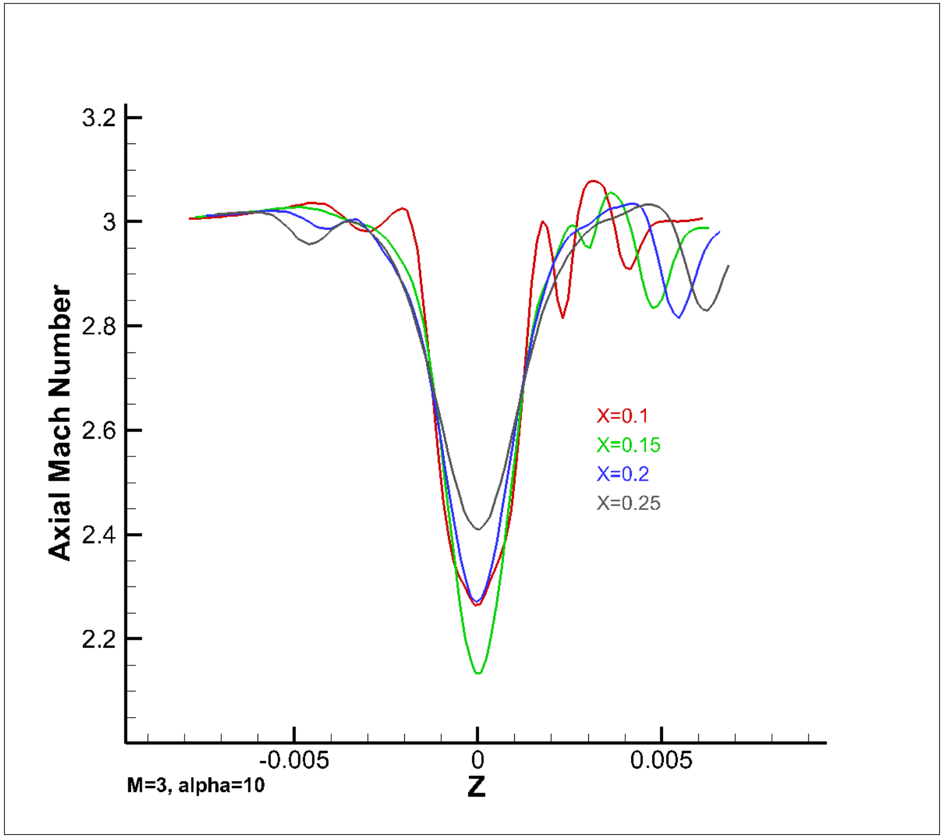
Density distribution on x=const sections.



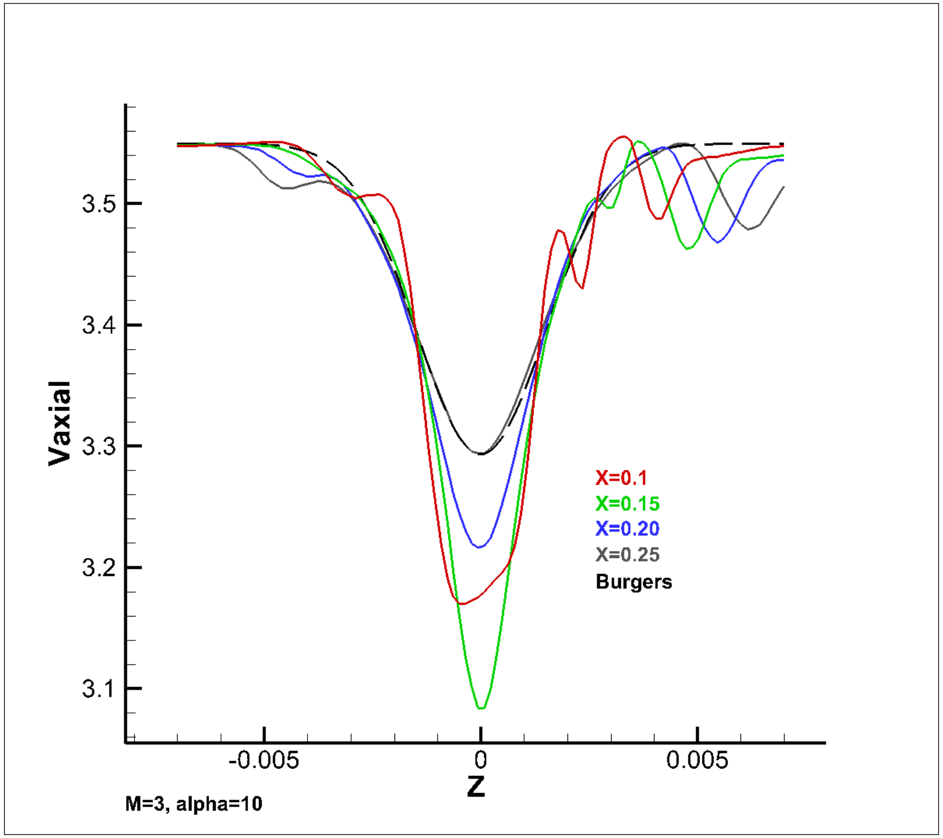
Mach number distribution on x=const sections.

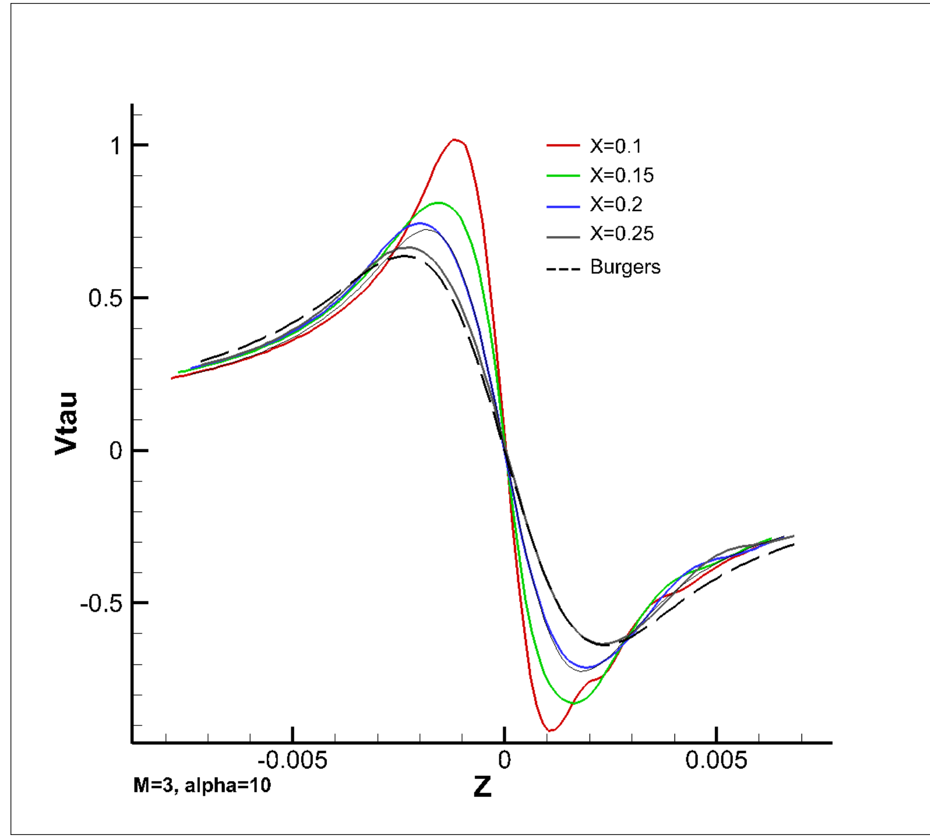
Spatial vortex evolution





Comparison with the Burgers vortex



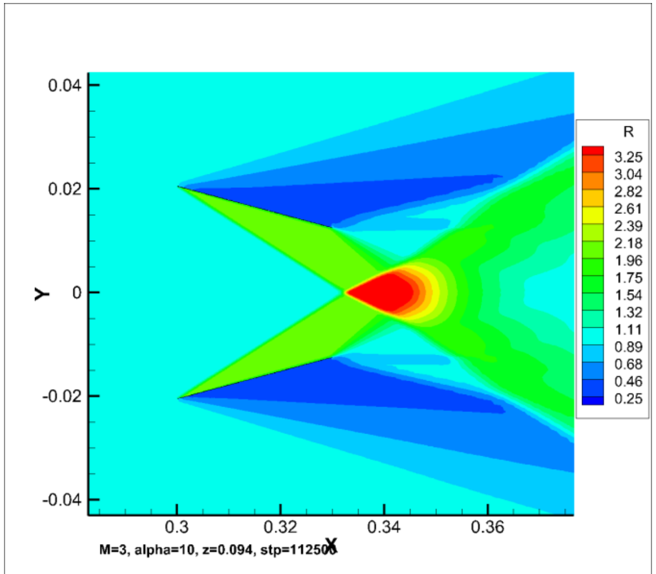


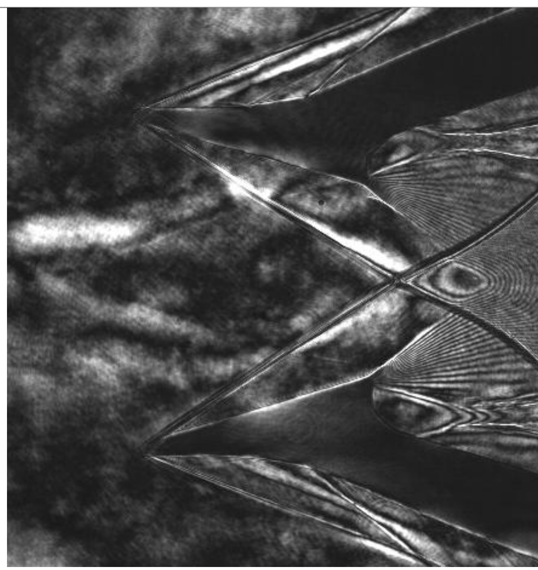
$$V_\infty - V_\infty(D)\left(e^{-(z/r_c)^2}\right)$$

$$\Gamma_0\left(e^{-(z/r_c)^2}\right)/z$$

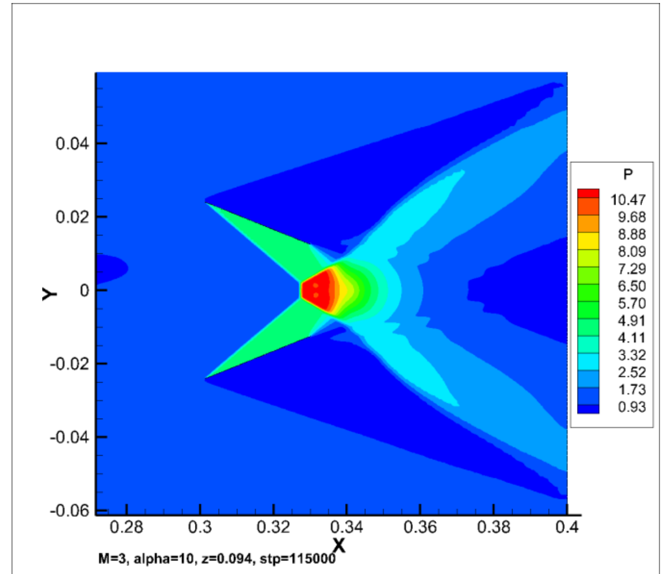
Regular and Mach shock waves interaction

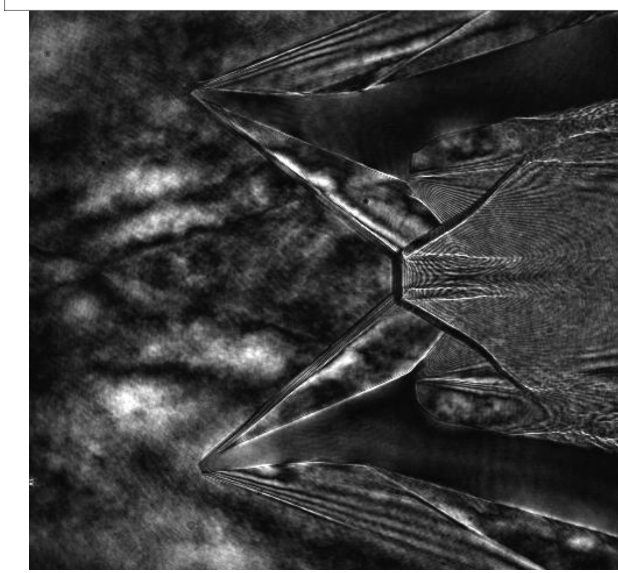
β=15





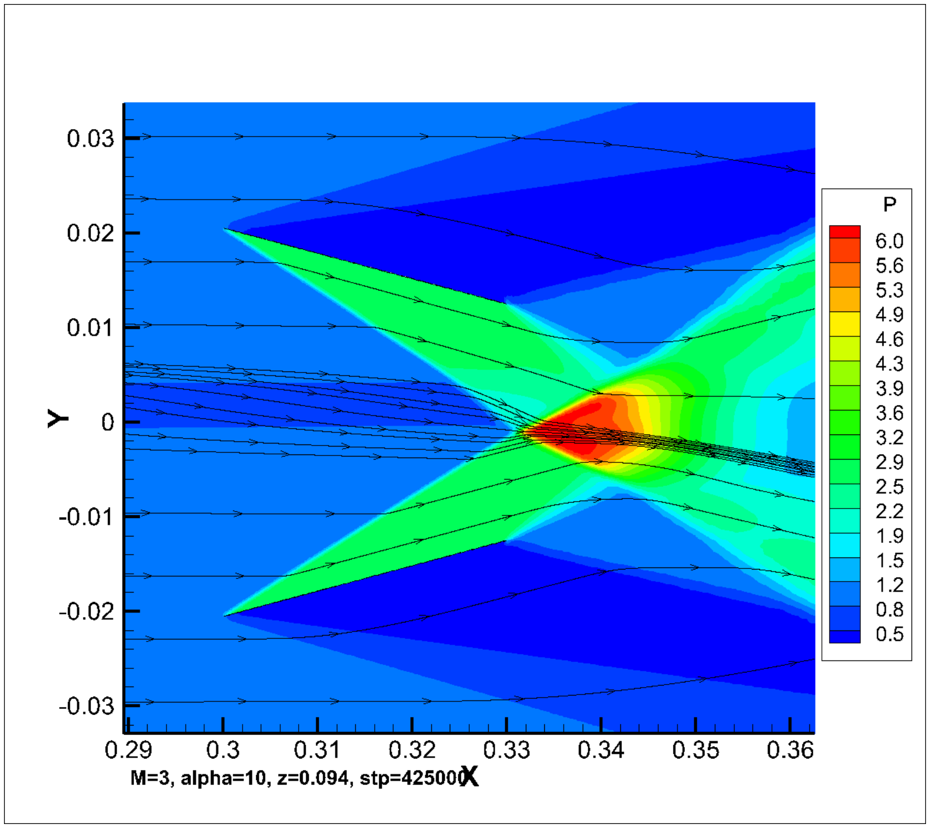
β=22

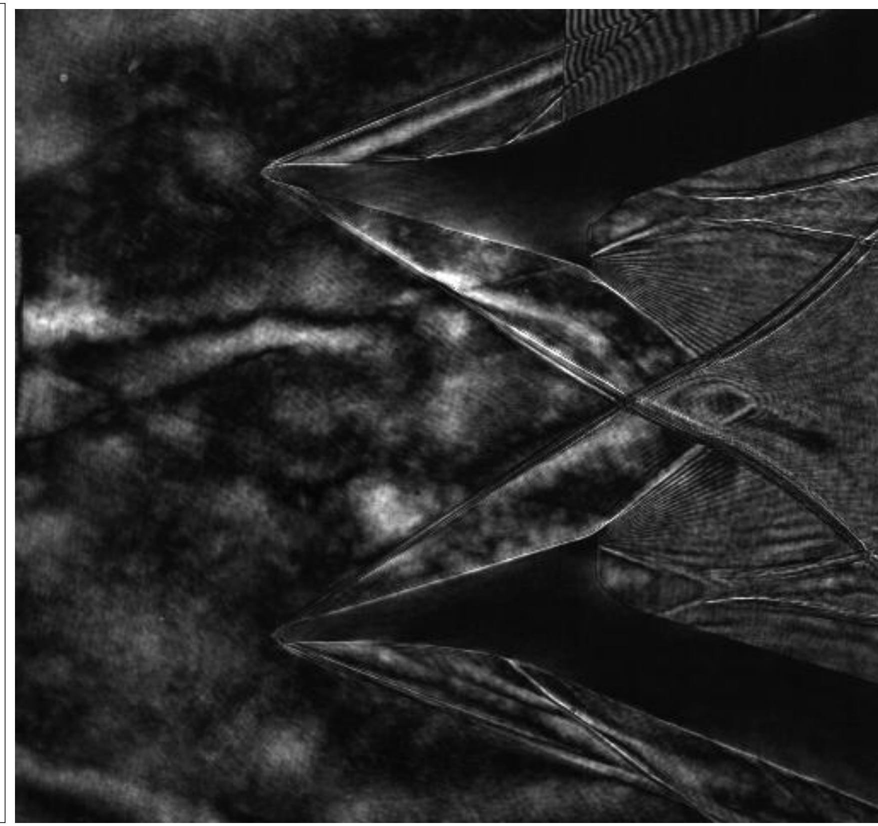




M. S. Ivanov, G. N. Markelov, A. N. Kudryavtsev, and S. F. Gimelshein. Numerical Analysis of Shock Wave Reflection Transition in Steady Flows / / AIAA Journal, Vol. 36 , No. 11 , November 1998.
MS Ivanov , AN Kudryavtsev , SB Nikiforov , DV Khotyanovsky . Transition between regular and Mach -sky reflection of shock waves: new numerical and experimental results / / Aeromechanics and gas-hand speaker , 2002, № 3 , pp. 3-12 .

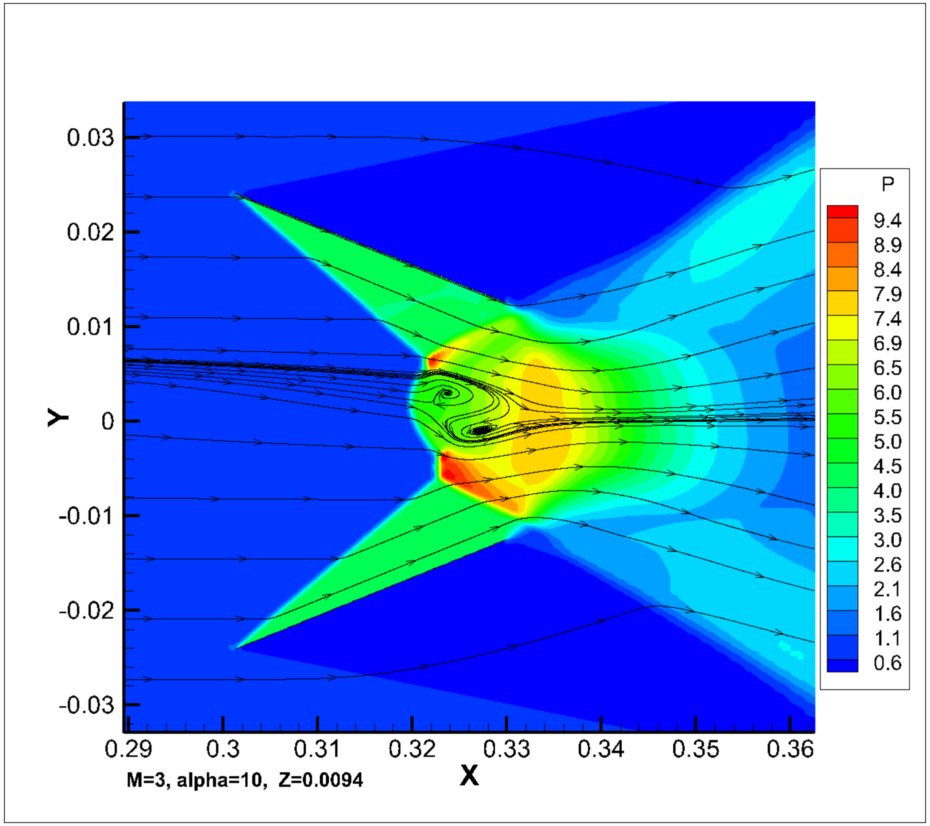
Vortex interaction with regular shock wave structure

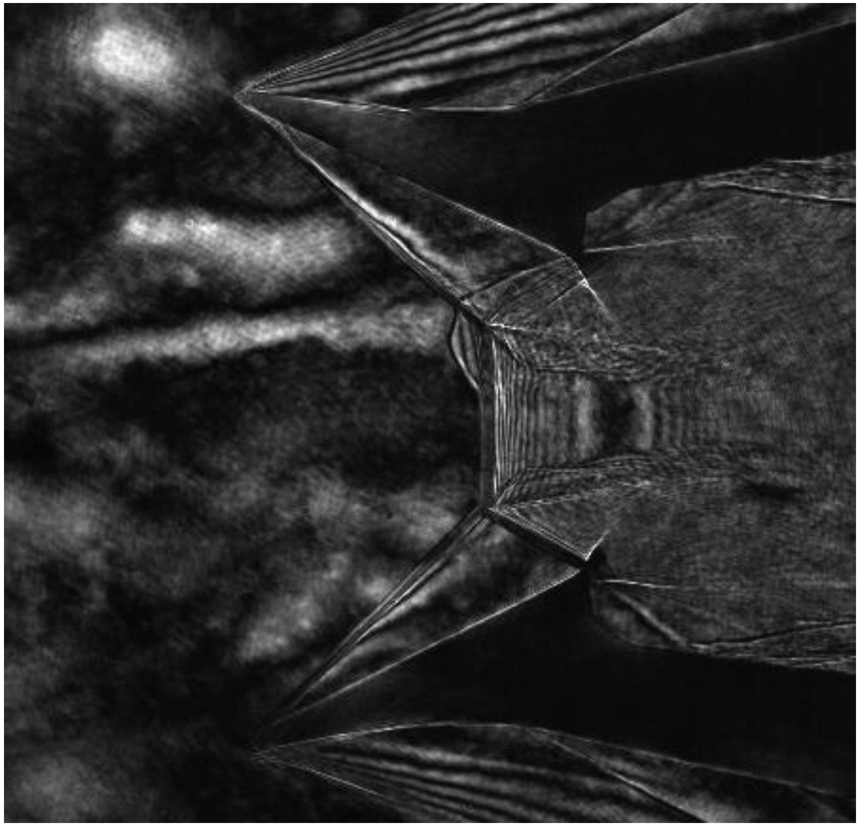




В. Н. Зудов, Е. А. Пимонов Взаимодействие продольного вихря с наклонной ударной волной
ПРИКЛАДНАЯ МЕХАНИКА И ТЕХНИЧЕСКАЯ ФИЗИКА. 2003. Т. 44, N- 4

Vortex interaction with Mach shock wave structure





Conclusions.

The Euler equations model gives the maximum Mach number on the axis of the core, which contradicts the experimental data. Using the model of the averaged Navier-Stokes equations eliminates this drawback.

With increasing Mach number – the total pressure loss increases, twist parameter decreases.

With increasing attack angle – the total pressure loss increases, twist parameterincreases.

The vortex interactions with a shock waves structure occur without its destruction.

For the Mach mode the wing vortex interacts with direct and oblique shocks. There are the vortex core destruction and a recirculation zone formation.

To investigate the mechanisms of vortex dissipation and breakdown the numerical simulations with DES models initiated.