MSES

MSES

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at the Massachusetts Institute of Technology (MIT)

MSES

MSES is a coupled viscous/inviscid Euler method for airfoil design and analysis featuring:

Subsonic, Transonic and Supersonic Single- and Multi-Element Airfoil Analysis

- Forced or free boundary layer transition
- Transitional separation bubble modeling
- Lift and drag predictions to just beyond $C_{L\ max}$
- Blunt trailing-edge treatment

Polar and Mach Number Sweeps Mode

- Program steps through angles of attack
- Program steps through Mach numbers while holding lift or angle of attack constant

Input files

blade.xxx – airfoil geometry and grid domain

- Created by user
- Used in MSET and AIRSET programs
- „xxx“ – variable extension
- XINL – x-location of the left grid inlet plane
- XOUT – x-location of the right grid outlet plane
- YBOT – y-location of the lowest grid streamline
- YTOP – y-location of the topmost grid streamline

```
NAME
XINL XOUT YBOT YTOP
X(1,1) Y(1,1)
X(2,1) Y(2,1)
X(3,1) Y(3,1)
.      .
.      .
X(i,1) Y(i,1)
999.0  999.0
X(1,2) Y(1,2)
X(2,2) Y(2,2)
X(3,2) Y(3,2)
.      .
.      .
X(i,2) Y(i,2)
999.0  999.0
X(1,2) Y(1,2)
.      .
.      .
```

Input files

mses.xxx – runtime parameters

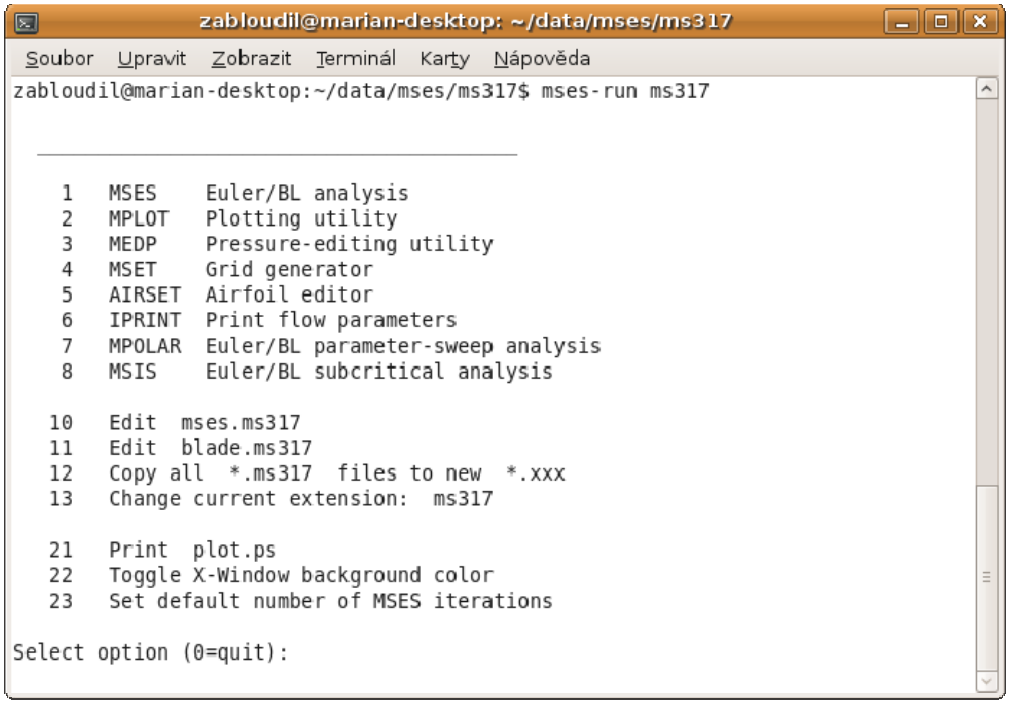
- Used in solver programs MSES, MSIS, MPOLAR and MPOLIS
- GVAR(1) … GVAR(N) – list of integers specifying the global variables to be used
- GCON(1) … GCON(N) – list of integers specifying the global constraints to be used
- MACHIN – free stream Mach number
- CLIFIN – specified C_L (if C_L option invoked in GCON)
- ALFAIN – free stream angle of attack
- ISMOM – momentum/entropy conservation
- IFFBC – farfield boundary conditions
- XTRSn, XTRPn – top and bottom surface transition strip x/chord location on element n
- MCRIT – critical Mach number above which artificial dissipation is added
- MUCON – artificial dissipation coefficient

```
GVAR(1) GVAR(2) … GVAR(N)
GCON(1) GCON(2) … GCON(N)
MACHIN  CLIFIN  ALFAIN
ISMOM   IFFBC
REYNIN  ACRIT
XTRS1   XTRP1   XTRS2   XTRP2 …
MCRIT   MUCON
```

Executing MSES

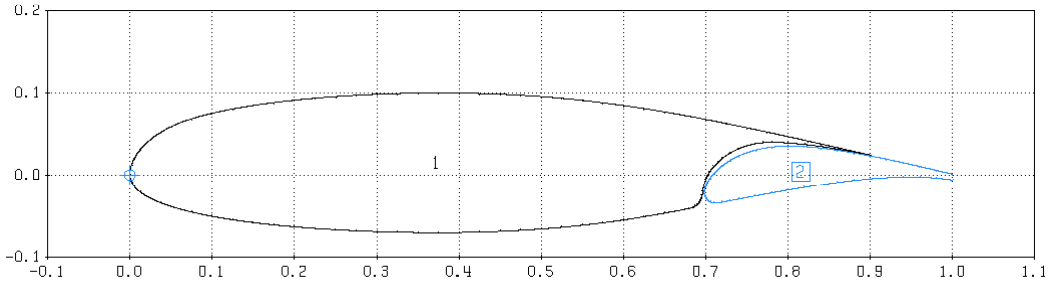
mrun xxx

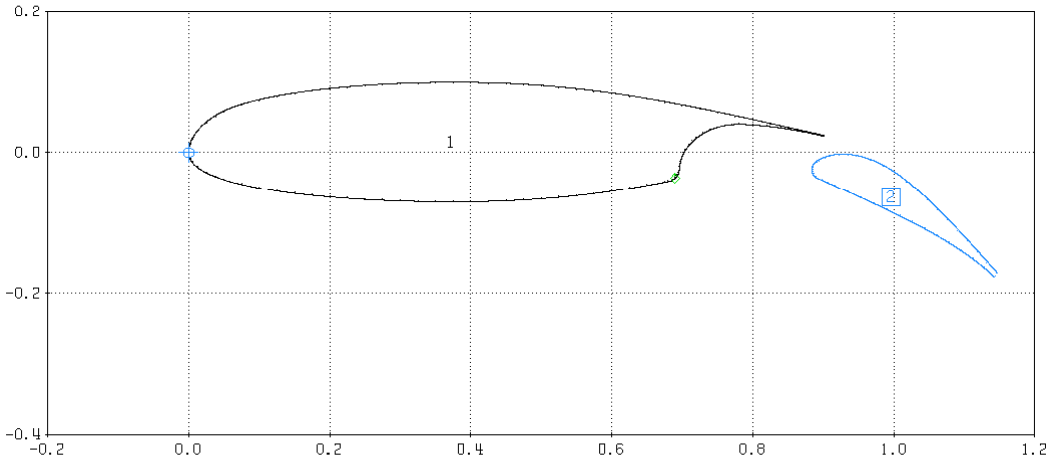
- With “xxx” extension to distinguish case being run
- For repetitive program execution
- Menu for executing all programs



Airfoil geometry manipulator

- Translate elements
- Rotate elements
- Scale elements
- Split off flap
- Modify contour
- Add/delete corner points



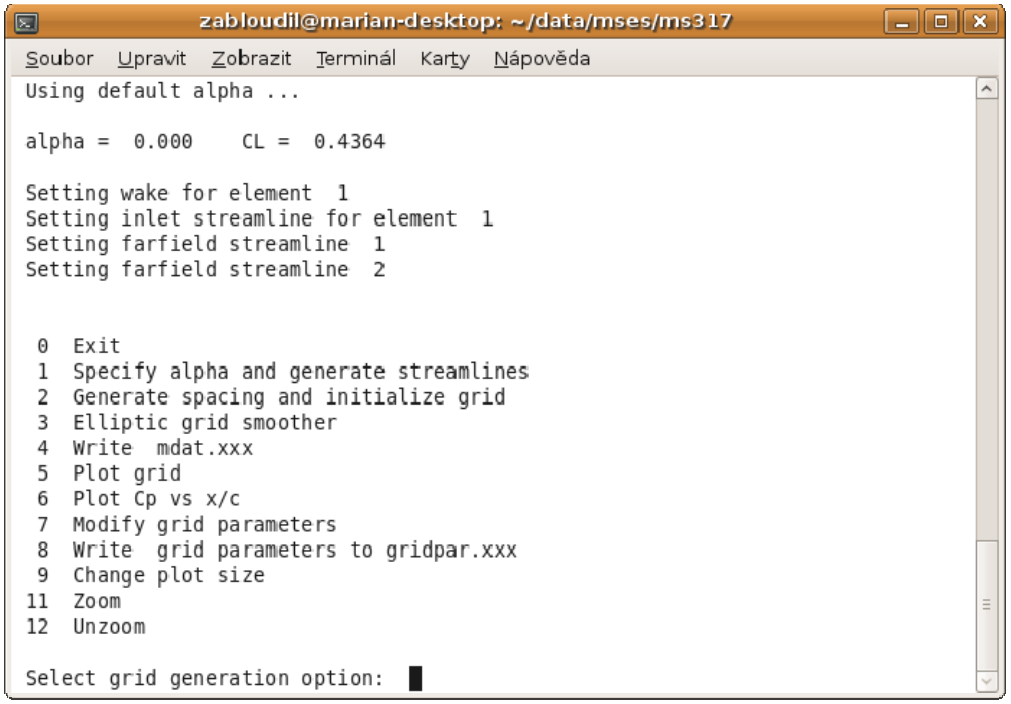


MSET

Grid and flow initializer

- Options 1, 2, 3, 4 must be issued as a minimum.
- 1 – specifies angle of attack to generate a panel solution to trace stagnation lines and the upper and lower farfield streamlines.
- 2 – initial surface gridding. Distributes grid nodes along the streamlines on the element surfaces. Intermediate streamline nodes are generated in the flowfield interior.

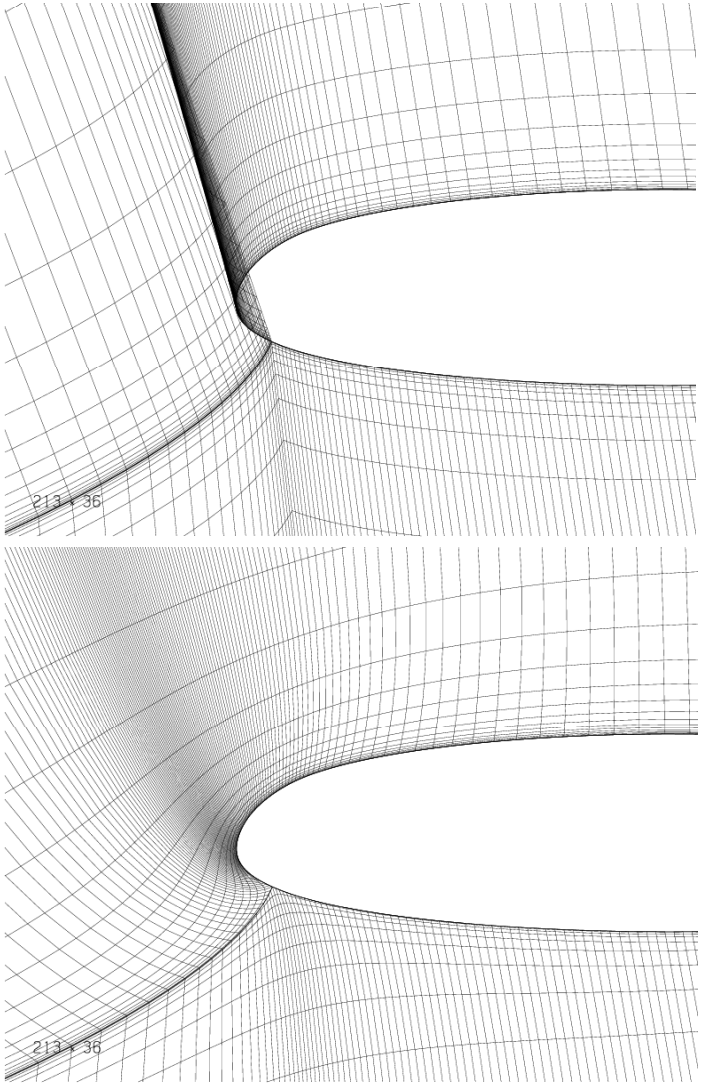
  The resulting grid is not yet suitable for MSES calculation!



MSET

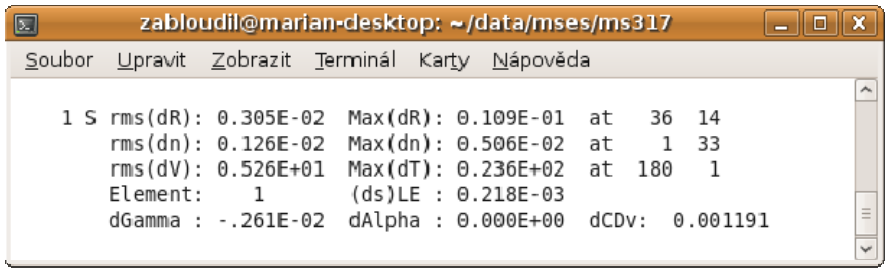
Grid smoothing

- 3 – elliptic grid smoothing of linearly interpolated grid. Eliminates all kinks, overlaps and makes all grid streamlines correspond to streamlines of inviscid incompressible flow.
- 4 – writes out the initial solution to file mdat.xxx, which is then ready for the MSES solver.
- The grid can be viewed with option 5. Options 2,3 or 1,2,3 can be repeated to obtain acceptable grid.



Flow solver

- Solves the Euler equations.
- Has two input files: mdat.xxx and mses.xxx.
- User specifies “n” – maximum number of iterations to be executed.
- Possibility to coarse/refine the grid to speed up the convergence by typing “-” or “+” at the iteration number prompt.
- After each iteration, MSES prints out a table of flow parameters change (r.m.s. and max)

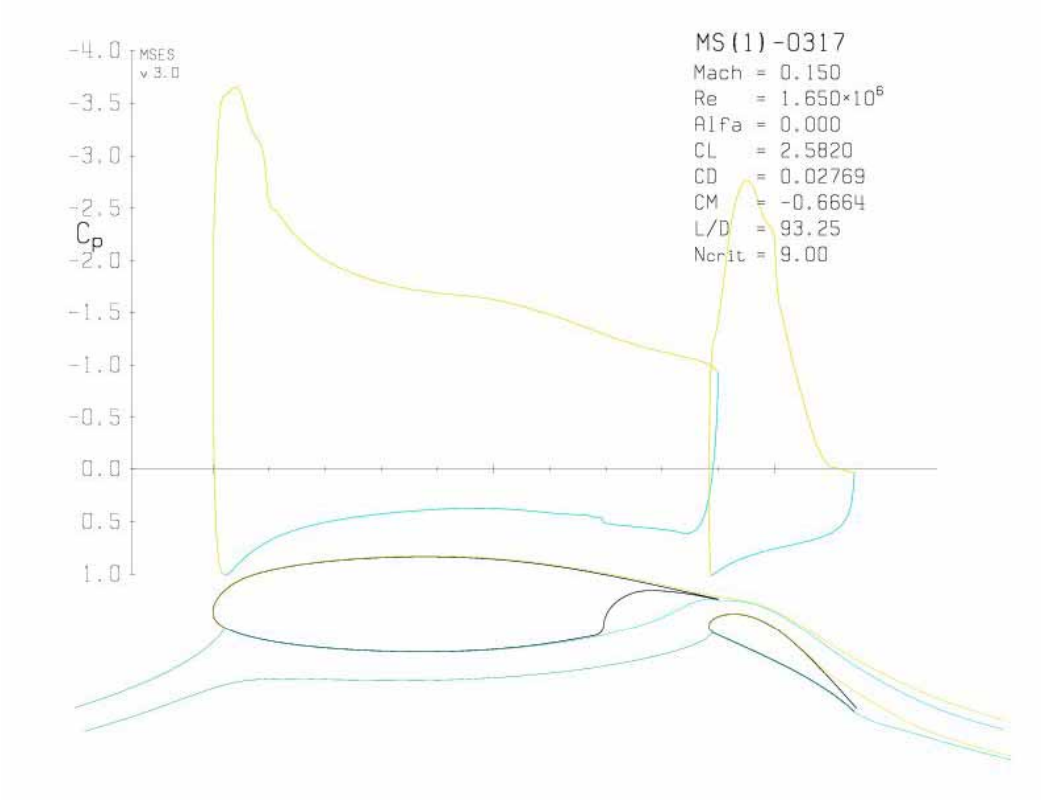


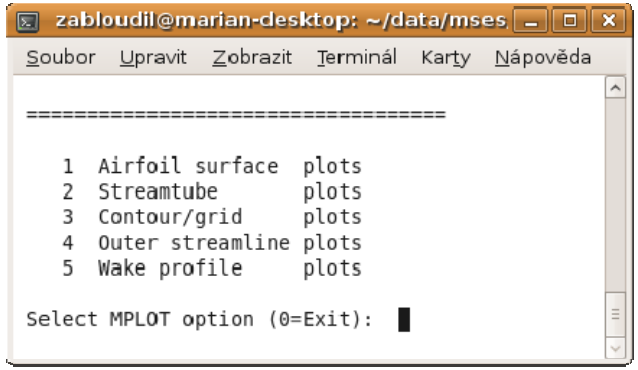
- The number of iterations specified before is only a limit.
- MSES will terminate early if the r.m.s. drop below the convergence tolerance limits and the maximum changes drop 10x these limits.
- Writes the solution back to mdat.xxx

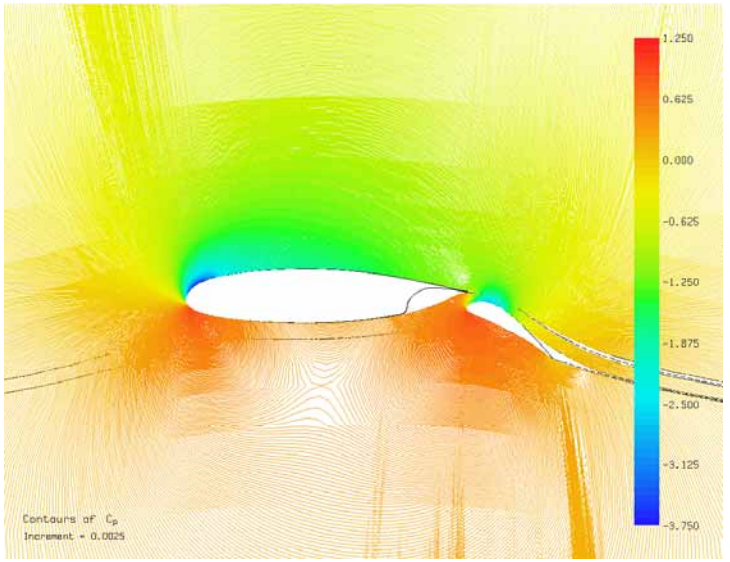
MPLOT

Solution plotter

- Displays solution in mdat.xxx whether it is converged or not.



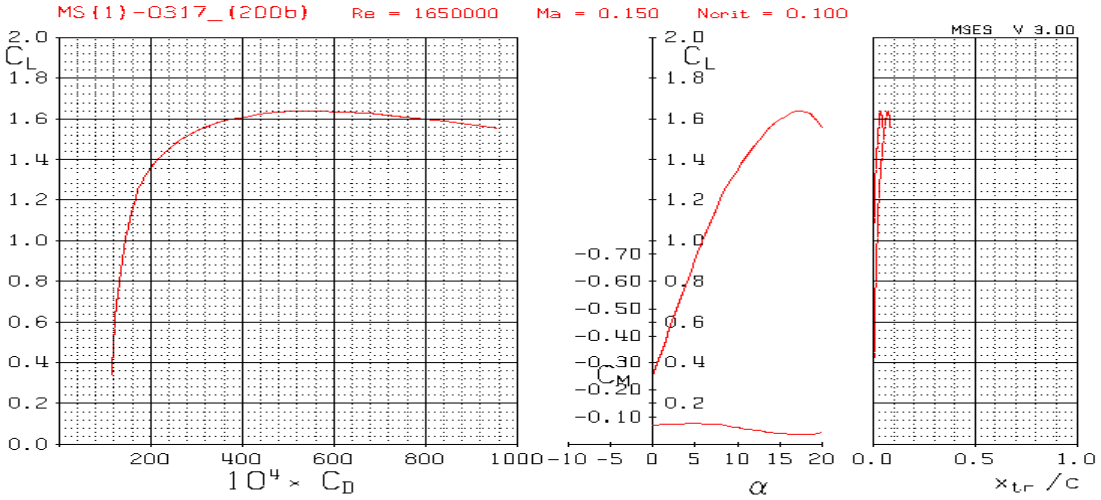




MPOLAR

α-sweep calculation driver

- Conveniently sweeps through a range of specified angles of attack.
- Takes advantage of the quadratic convergence of the Newton method.
- Much more efficient than running a sequence of independent cases with MSES.
- Requires an alfas.xxx file, which contains the sequence of angles of attack.
- Writes out the integrated parameters to polar.xxx and the surface pressure distribution and boundary layer variables to polarx.xxx
- Results from polar.xxx can be plotted using program PPLOT.



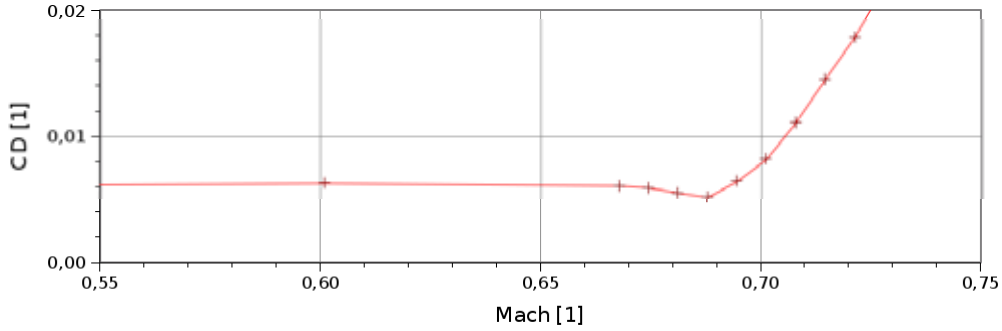
MPOLARC, MPOLARM

C_L-sweep calculation driver

- Essentially the same as MPOLAR.
- Converges on specified lift coefficients.
- Requires a cls.xxx file, which contains the sequence of lift coefficients.
- Output files polar.xxx and polarx.xxx have same format as for MPOLAR.

Mach-sweep calculation driver

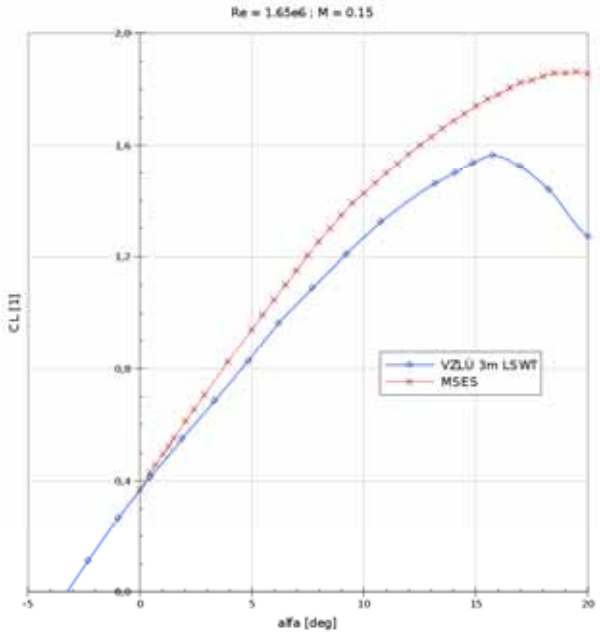
- Generates a Mach sweep in a manner similar to a polar.
- Requires a file machs.xxx containing the Mach numbers to be executed.
- Results are written to files msweep.xxx and msweepx.xxx

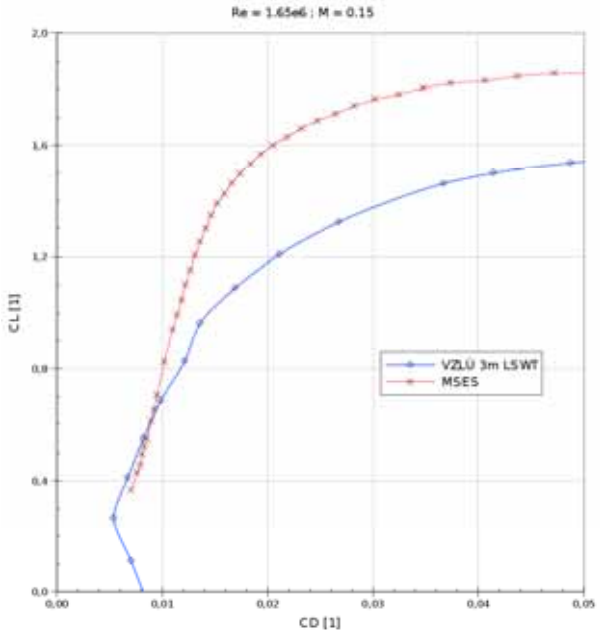


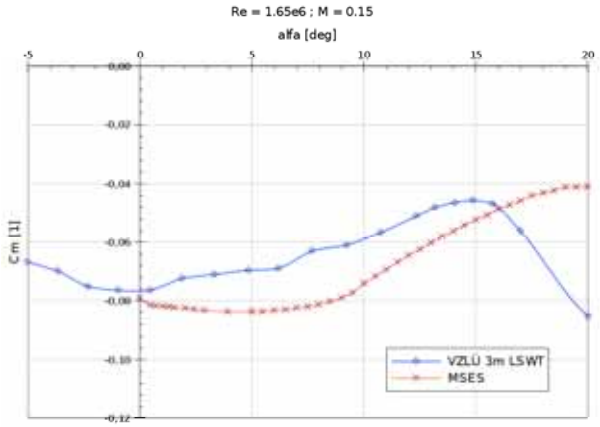
Results Comparison

Comparison with VZLÚ wind tunnel results:

- Cruise configuration
- MSES overpredicts $C_{L\ max}$ and α_{crit}
- Overpredicts $dC_L/d\alpha$
- Good drag agreement



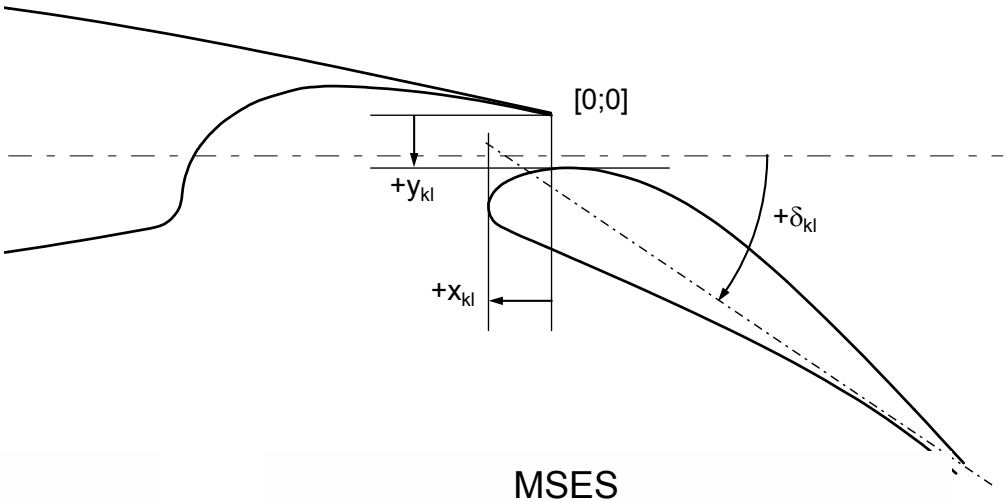




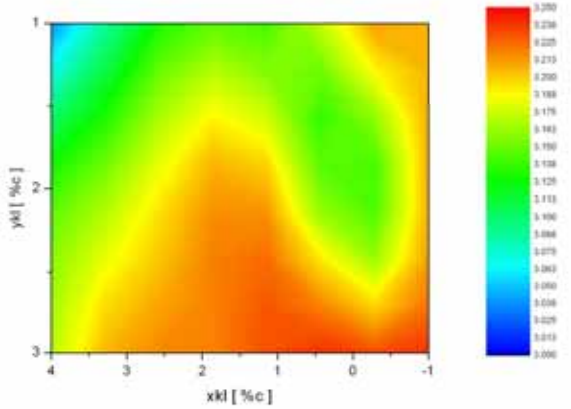
Results Comparison

Comparison with VZLÚ wind tunnel results:

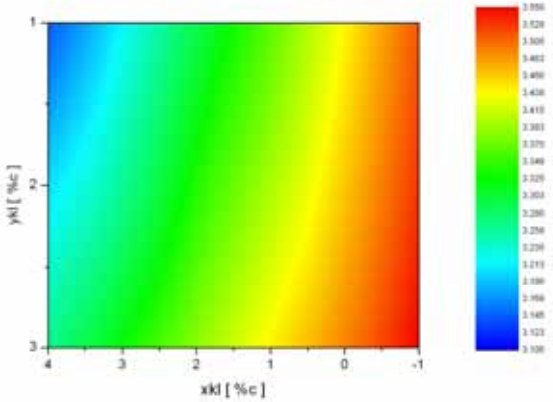
- Take-off configuration
- Flap deflection 20°
- $C_{L\,max}$ comparison
- Disagreement caused by wrong α_{crit} prediction



Wind Tunnel



MSES



Other Features

Computational Design of Multi-Element Airfoil Systems

- Mixed inverse design mode
- Modal inverse design capability
- Modal geometry perturbations

Multi-Point Optimization of Single- and Multi-Element Airfoils With Geometric Thickness and Area Constraints

THANK YOU FOR YOUR ATTENTION!