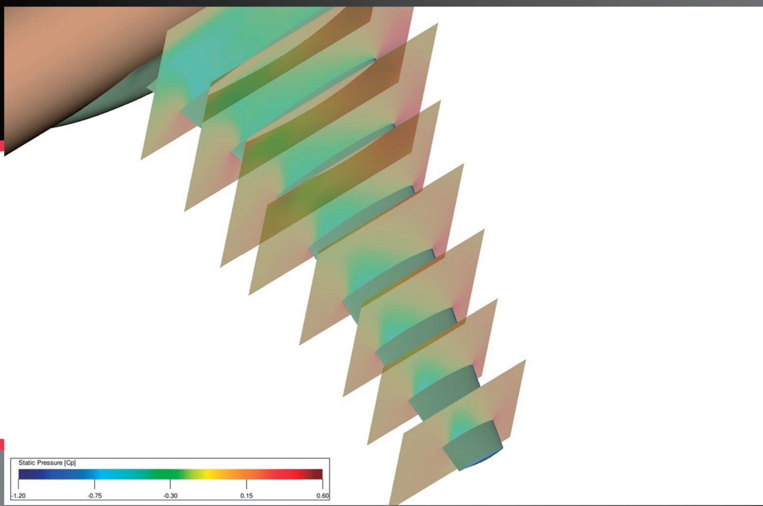


Exa's Contribution to the APC II

***André Ribeiro**, Benedikt König, Ehab Fares,*
Raoyang Zhang, Yanbing Li, Pradeep Gopalakrishnan, Hudong Chen

May 19 2016

Introduction

- Recently PowerFLOW has been extended to transonic flows
  - *Lattice Boltzmann based solver*
    - D3Q39 LBM
    - Cubic Volume Cells (Voxels)
    - Surface elements (Surfels)
  - *Fully transient*
  - *Turbulence Model: LBM-VLES*
    - Modified RNG k-ε model for unresolved scales
    - Swirl model
    - Extended wall model

Run summary

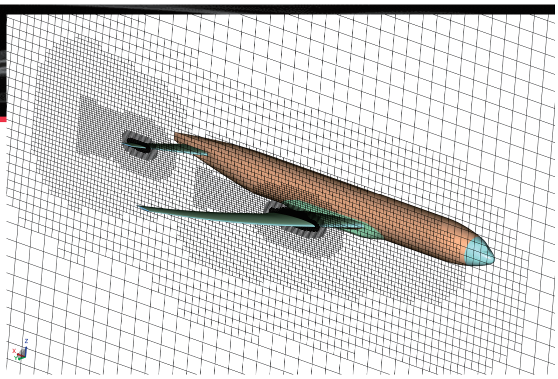
- Cases for which PowerFLOW simulations were performed

	Re = 1.5M (buffet)	Re = 2.3M
Cp cuts	Mid span of main wing	Full wing/tail sections
Cp’ cuts	Mid span of main wing	No
Cd/Cl/Cm	Yes	Yes
AoA simulated	4.87°, 5.92°	2.94°
Sting	No	Yes/No
Resolutions	C/M/F	F

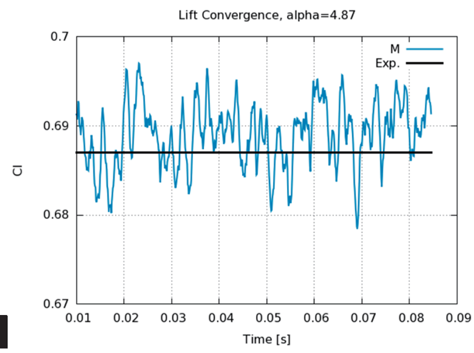
König, Fares, Nölting, “Validation of a Transonic Lattice-Boltzmann Method on the NASA Common Research Model”, AIAA Paper 2016-2023

Exa

Setup

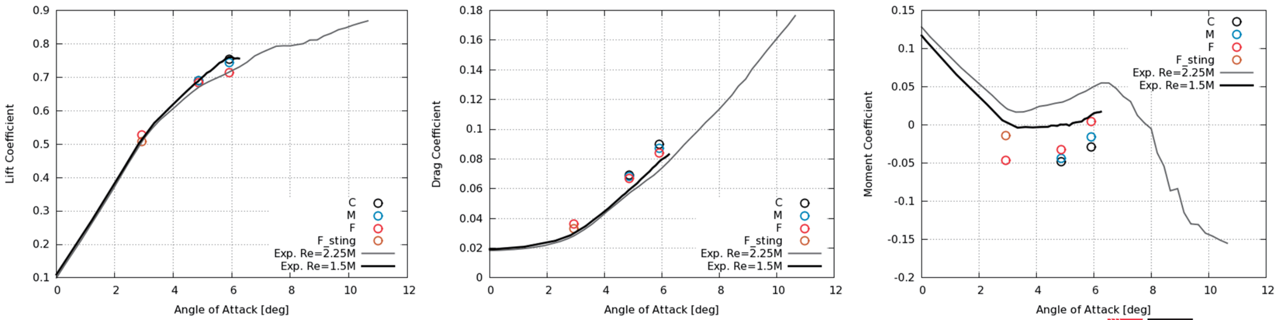


- Grid
  - *Cartesian grid*
  - *y+ ~100*
  - *3 resolutions were run*
    - Factor of 1.32 between them
    - Full grid convergence study available for AIAA DPW
      - *Sting effects and wing twist studies also available*
- Statistical convergence
  - *Cases run for about 0.085 seconds*
    - Second half used for statistics
    - CPUh: C=2600, M=5600, F=12600

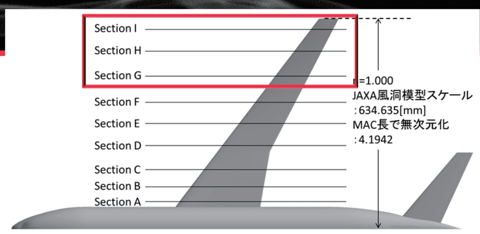


Results

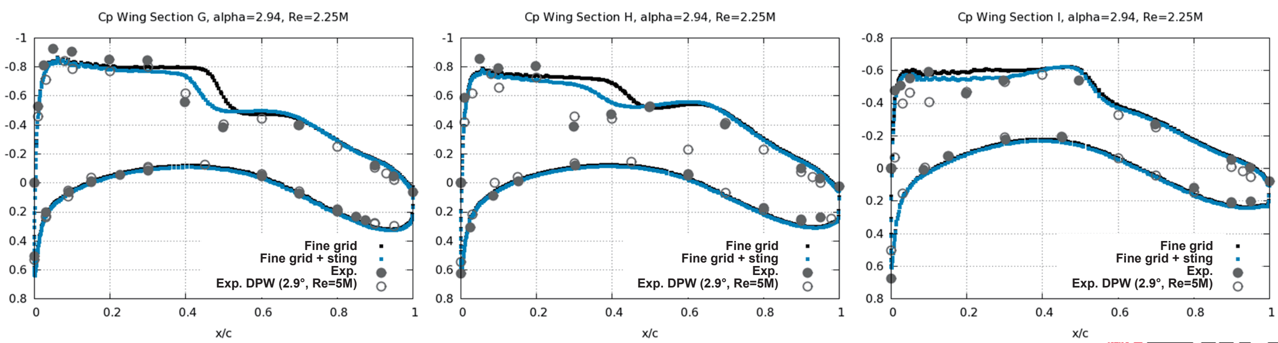
- Forces
  - Low AoA results agree well with experimental Cl, Cd
  - High AoA results seem closer to high-Re experiments



Results – Low AoA

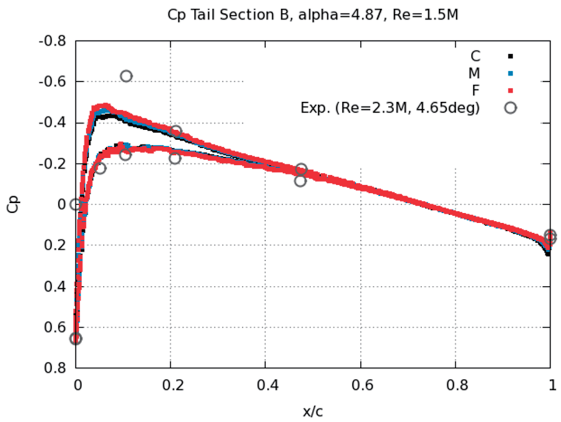


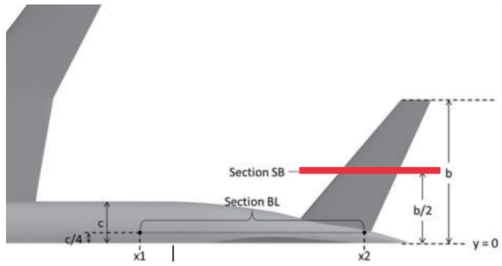
- Cp cuts
  - 2.94° Re=2.25M closer to Re=5M



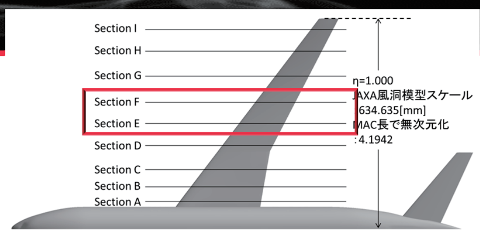
Results – High AoA

- Cp
  - *Tail could be refined more*

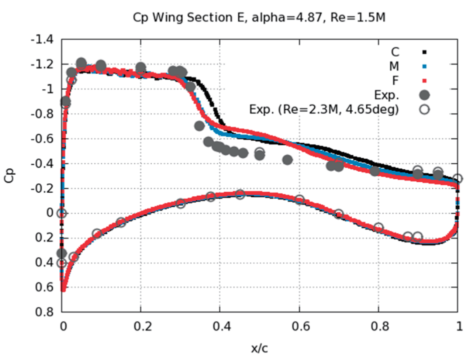


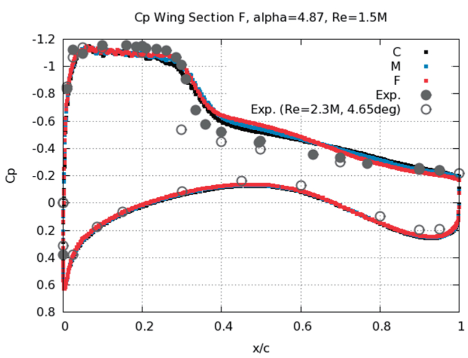


Results – High AoA



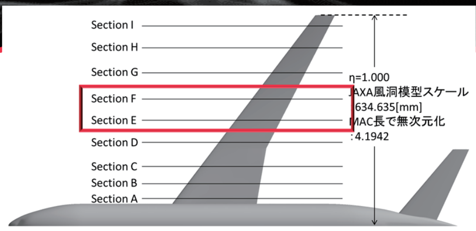
- Cp
  - *At 4.87° shock position agrees very well with exp.*
  - *Exp. show some Re dependence*

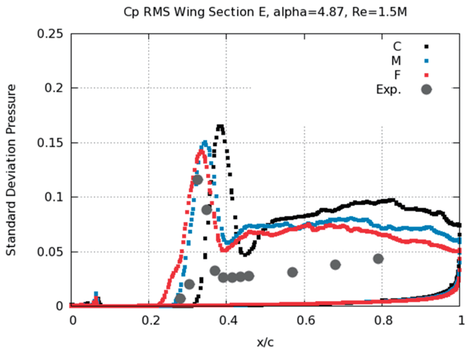


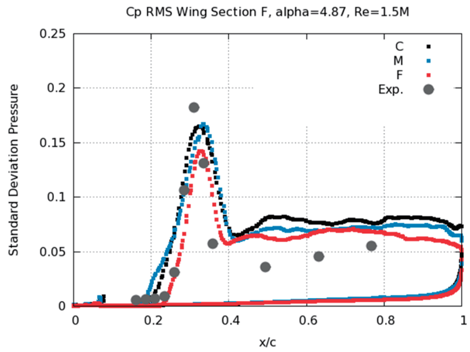


Results – High AoA

- Cp RMS
  - *At 4.87° shock range and levels agree very well with exp.*





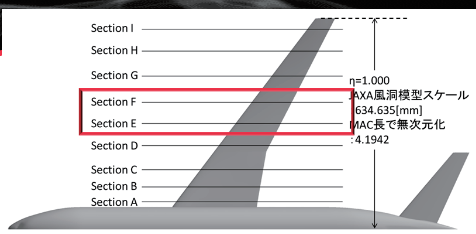


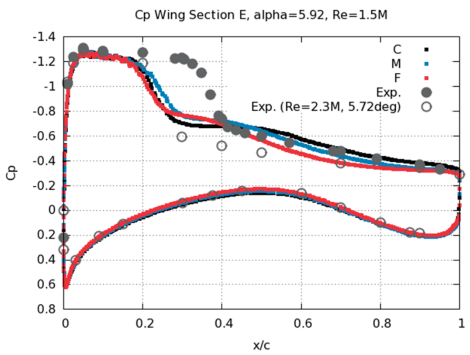
Exa

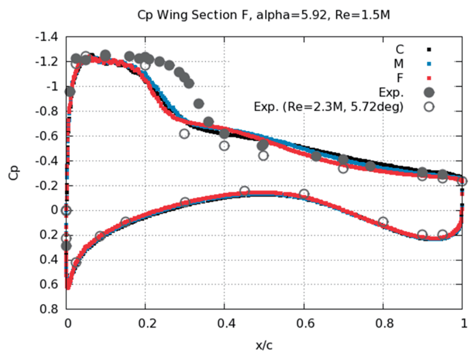
9 © Exa Corporation

Results – High AoA

- Cp
  - *At 5.92° shock position is upwind of exp.*
  - *Exp. show significant Re dependence*





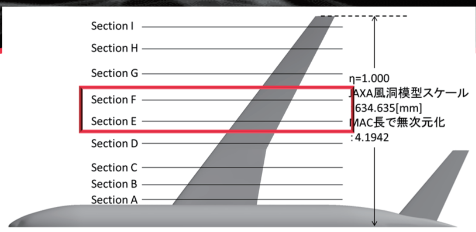


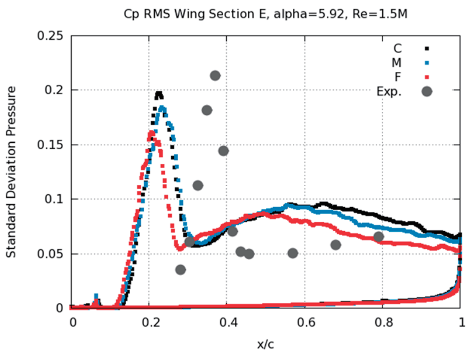
Exa

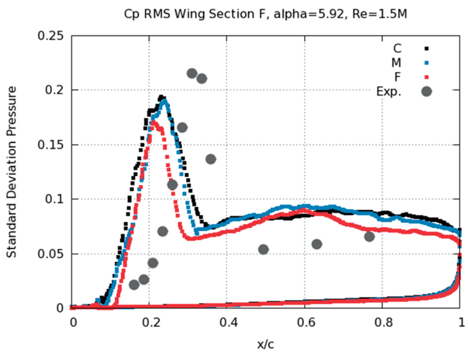
10 © Exa Corporation

Results – High AoA

- Cp RMS
  - *At 5.92° shock range is upwind and levels agree well with exp.*



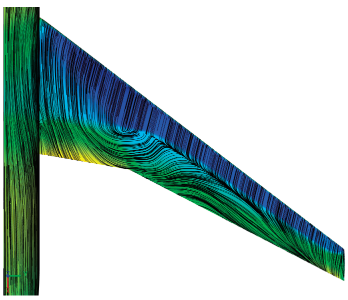


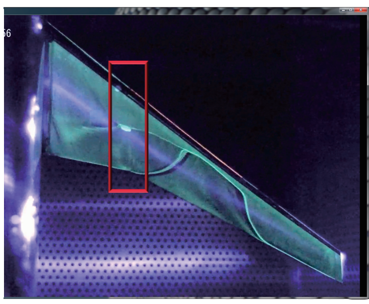


Exa

High Angles Investigation

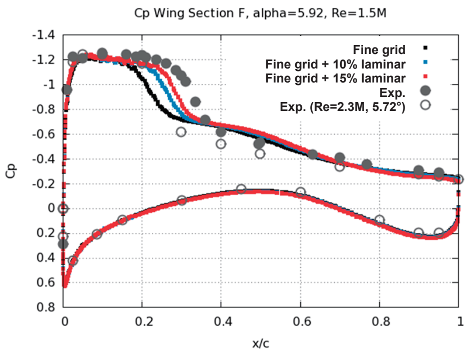
- Notes on inboard wing and shock position
  - *This part of the wing has complex flow features in the wind tunnel at high AoA*
  - *Results from APC-1 also show CFD codes to be sensitive at high AoAs*
  - *Shock very close to trip*

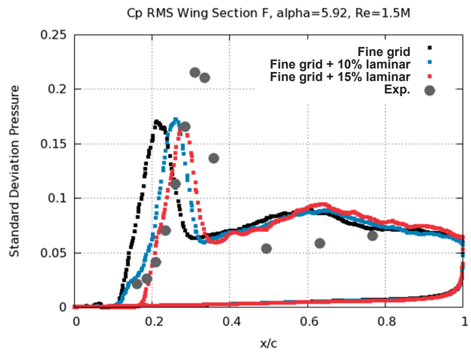




High Angles Investigation

- Results for high AoA match high Reynolds experiments better
  - *Related to laminar to turbulent transition?*
    - Trip at 10% chord, low Reynolds number

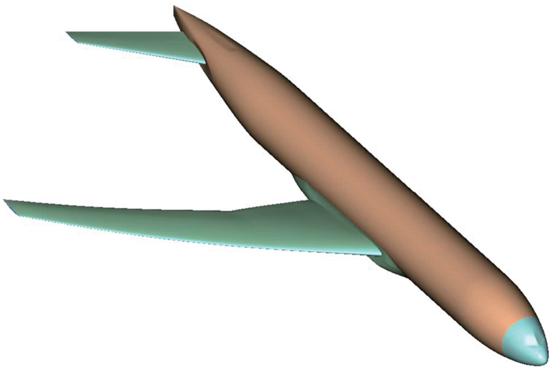




Conclusions

- Sting effects were investigated
  - *Similar conclusions to the NASA CRM simulations*
- Buffet simulations were successfully performed
- Results are in some regions closer to higher Reynolds numbers experiments
  - *Sensitivity to the transition location was demonstrated*

Extra Analysis



15 © Exa Corporation

Thank You!

Questions?

16 © Exa Corporation