Unsteady Aerodynamics and Heat Transfer in Turbines RQ22 – 16

Ryan Sauder

DAGSI Quarterly Review | 17 November 2023

Unsteady Aerodynamics and Heat Transfer in Turbines RQ22 – 16

Student: Ryan Sauder

Student Email: sauder.5@wright.edu

Faculty: Dr. Mitch Wolff

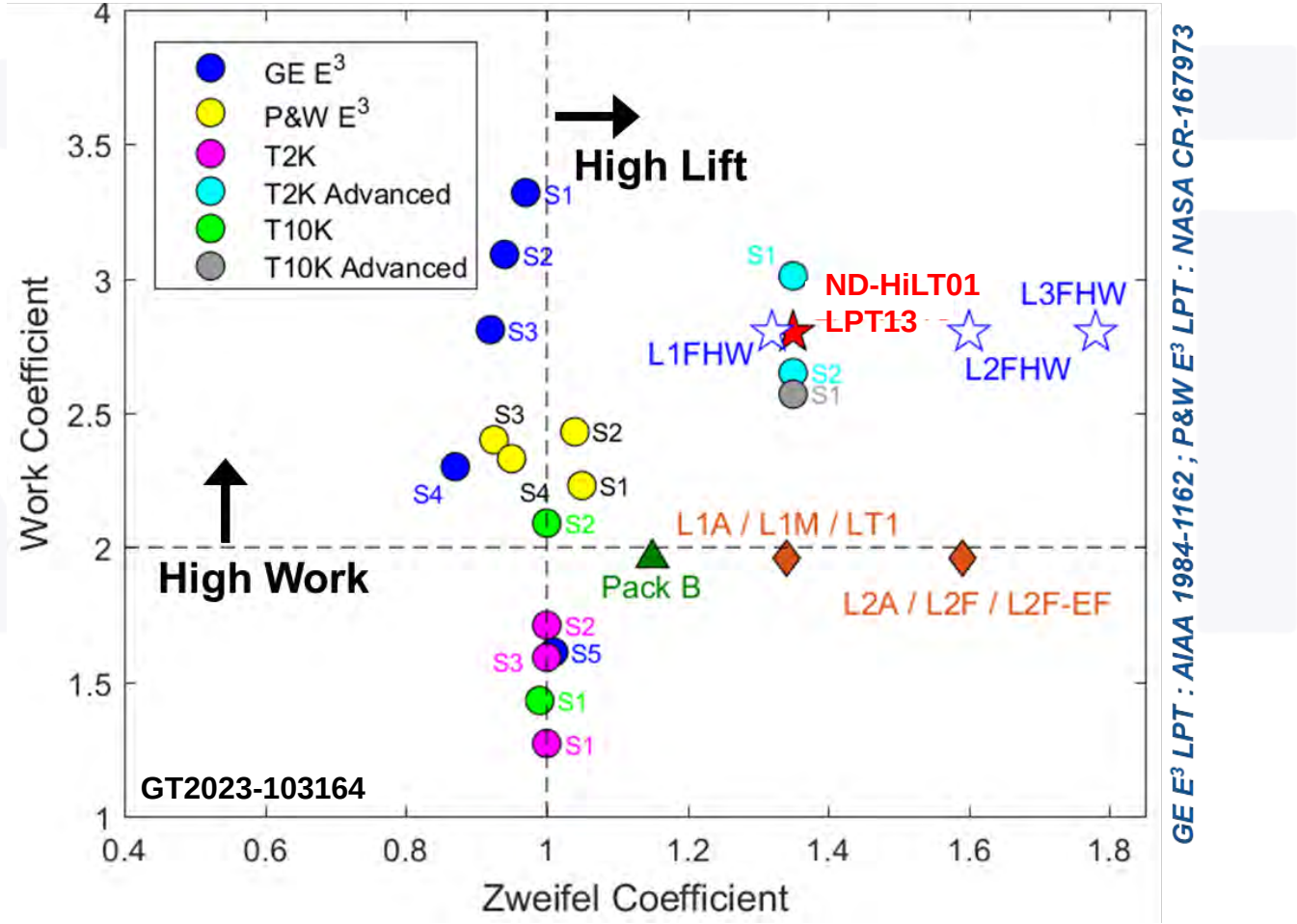
Faculty Email: mitch.wolff@wright.edu

AFRL Sponsor: Dr. John Clark

AFRL Directorate: AFRL/RQTT

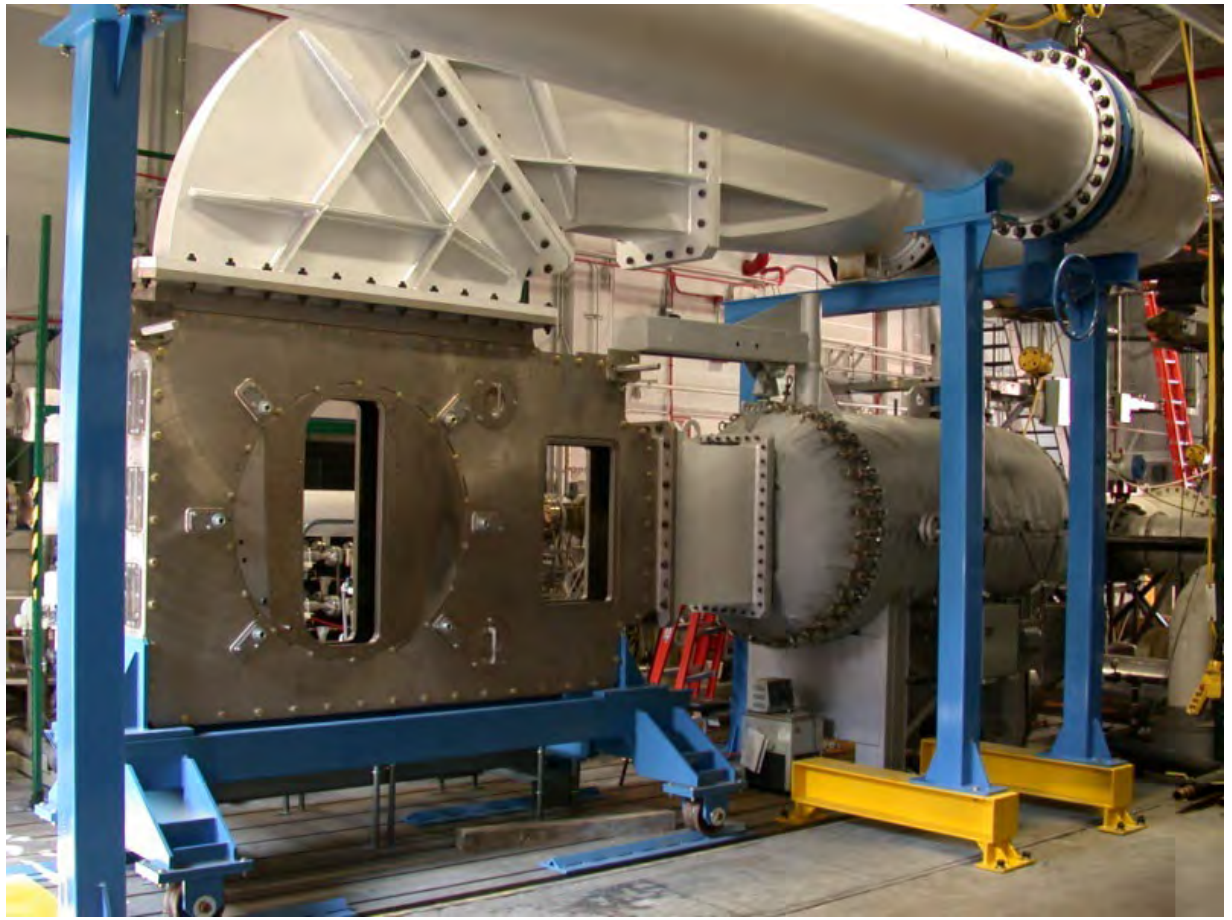
L2FHW and L3FHW: Seeking to Extend the LPT Design Space

- 30% of engine weight in the Low Pressure Turbine (LPT)
- Reduce module weight by increasing airfoil lift
- Low speed testing has shown promise
- Present study seeks to validate new airfoils in high speed flow



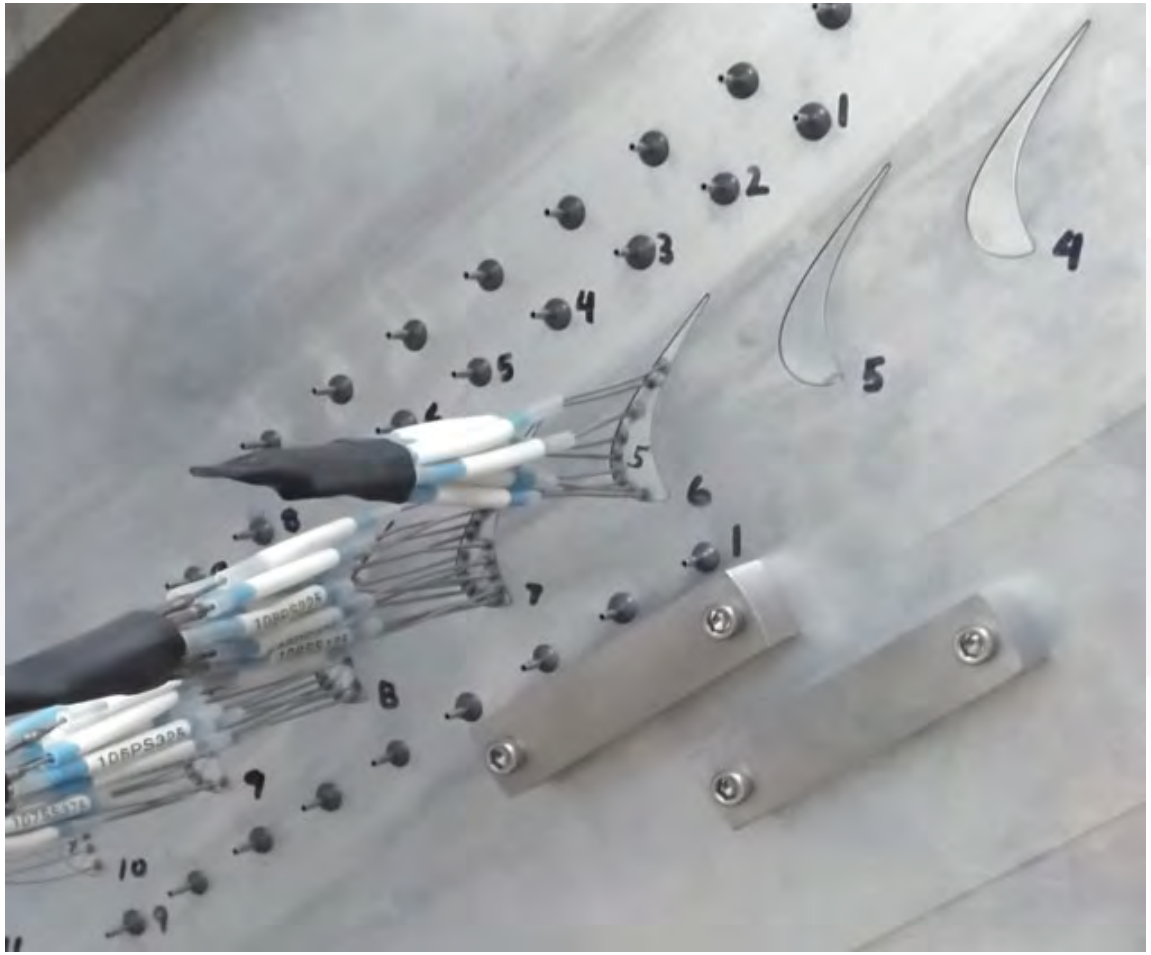
Testing Facility: Transonic Turbine Cascade (TTC)

- Maximum flowrate → up to 30 lb_m/s
- Minimum exit static pressure → ~3psia
- Maximum inlet total pressure → 27psia
  - Rupture disk
- Angle of attack → 70° range
- Independent control of Mach and Reynolds number



TTC Instrumentation

- Pressures measured using NetScanner 9116 → 128 pressure channels
- Pressure in Temperature measured in stagnate settling tank
- Inlet and Exit Total Pressure Traverses
  - Quantify loss
- 9 inlet static pressure taps
  - ½ Chord upstream
- 18 exit static pressure taps
  - 9 → ½ chord downstream
  - 9 → full chord downstream



The Airfoils

- L2FHW – Testing completed
  - Zweifel Coefficient → 1.60
  - Design Exit Mach Number → 0.78
  - 5 Instrumented blades
    - 57 Static pressure taps
  - 15 Blades in cascade
- L3FHW – Testing ongoing
  - Zweifel Coefficient → 1.78
  - Design Exit Mach Number → 0.78
  - 5 Instrumented blades
    - 54 Static pressure taps
  - 14 Blades in cascade

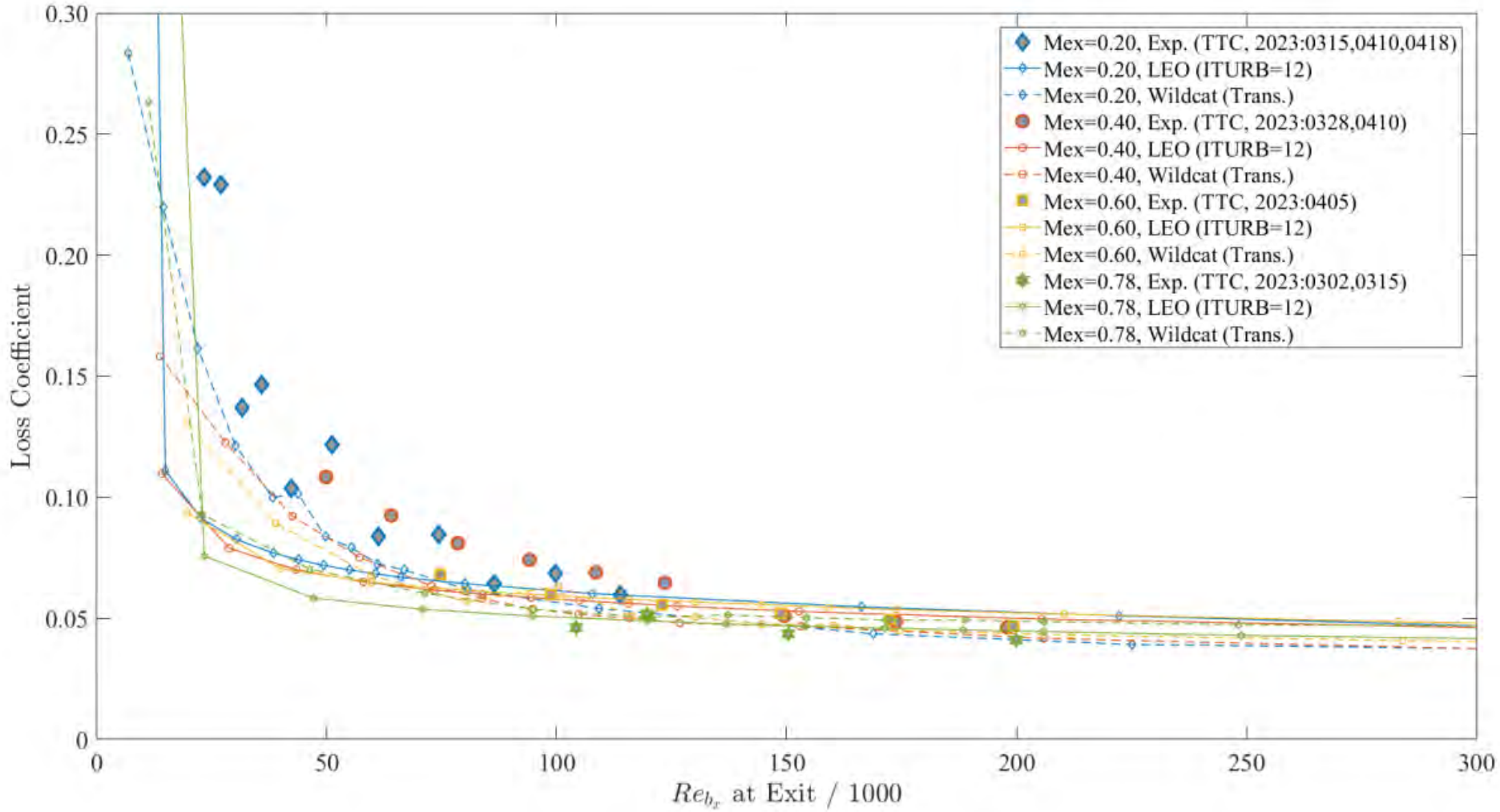
L2FHW Airfoil

$$Z_w = 2\left(\tau / b_x\right)\cos^2\alpha_{ex}\left(\tan\alpha_{in} - \tan\alpha_{ex}\right)$$

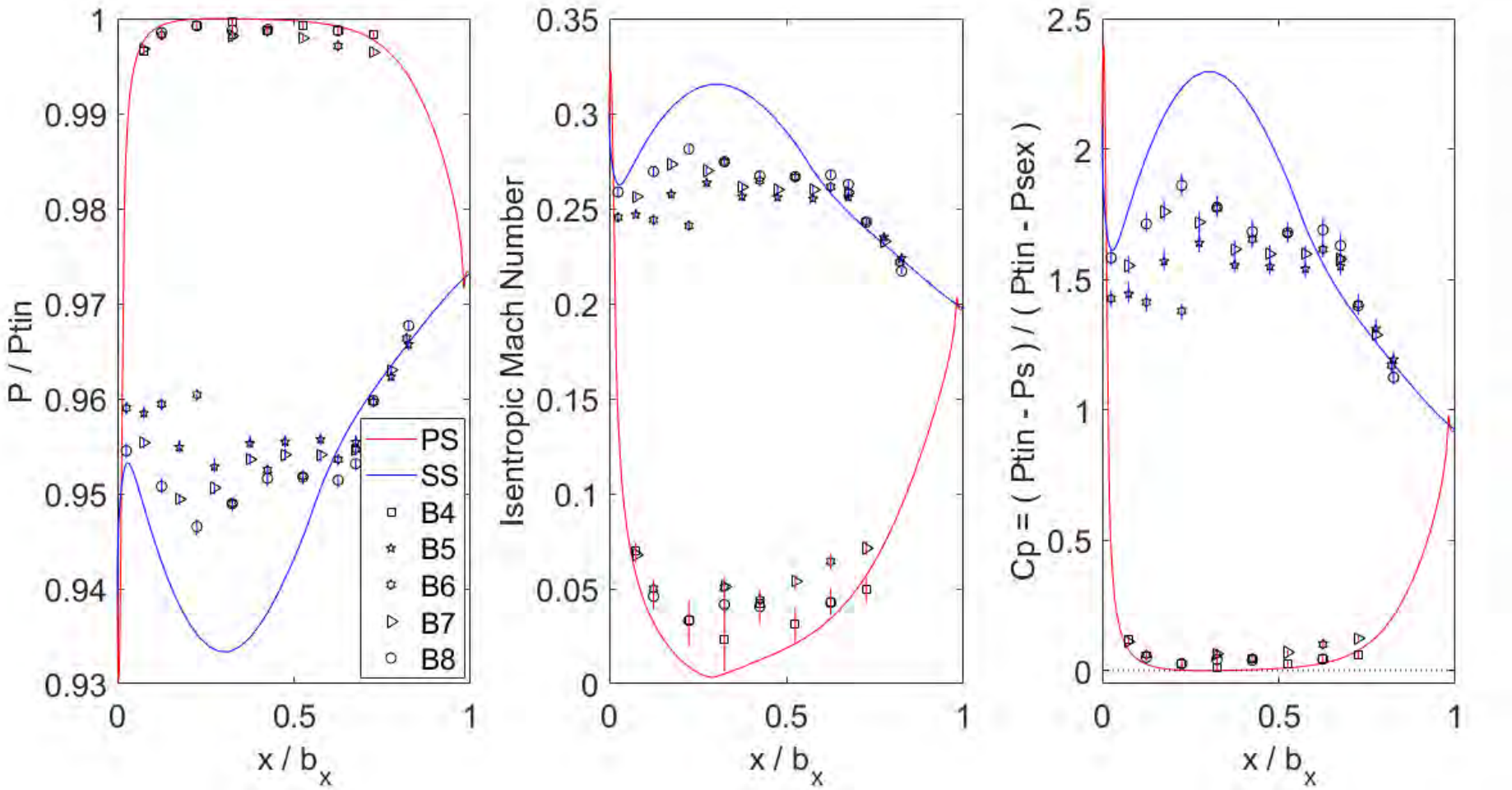
(incompressible)

Total Pressure Loss Across L2FHW Cascade

$$L = \frac{P_{t_{in}} - P_{t_{ex}}}{P_{t_{in}} - P_{s_{ex}}}$$

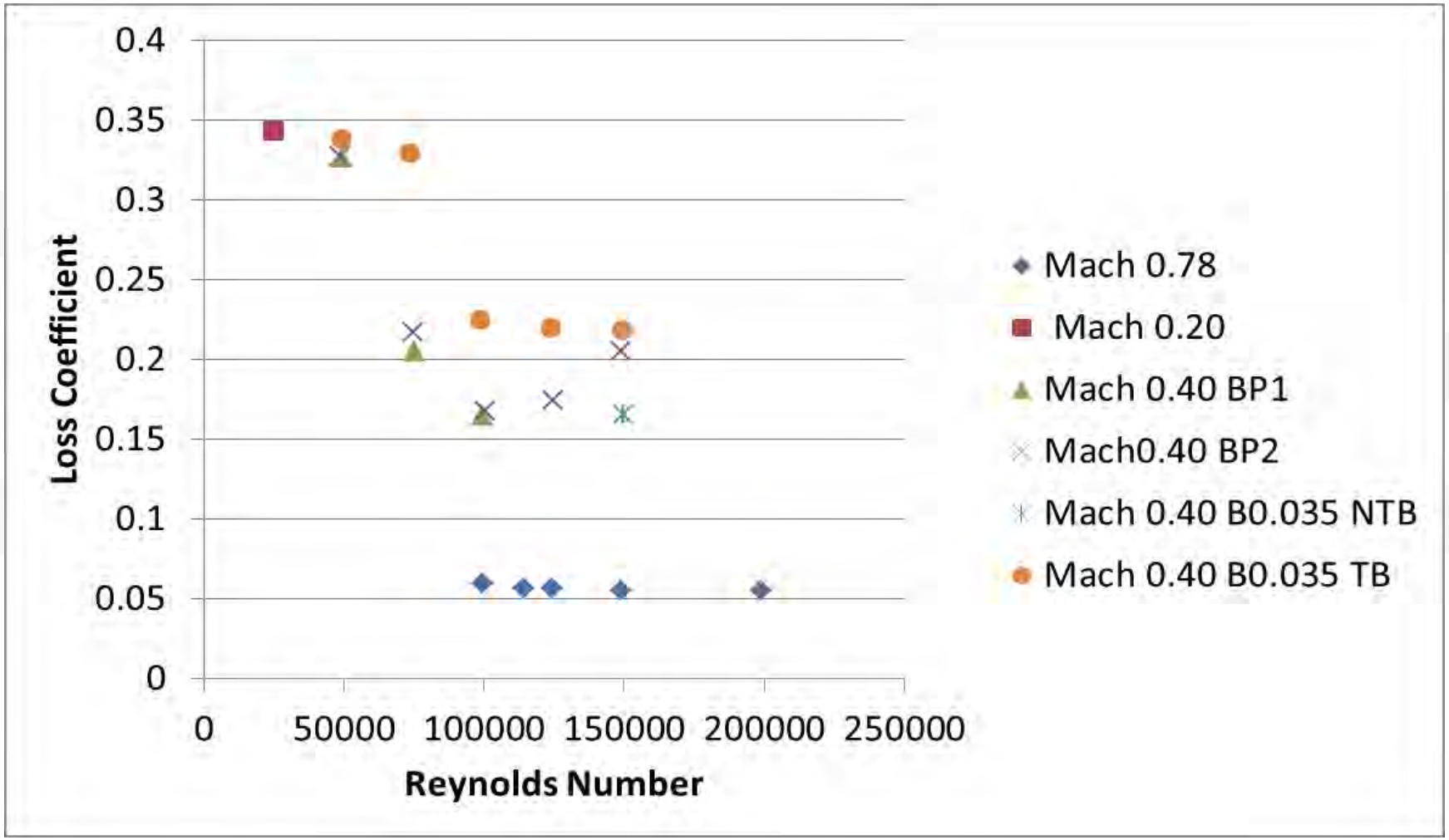


L2FHW: Flow Separation and Reattachment at Exit Mach 0.2 Reynolds Number 23,300

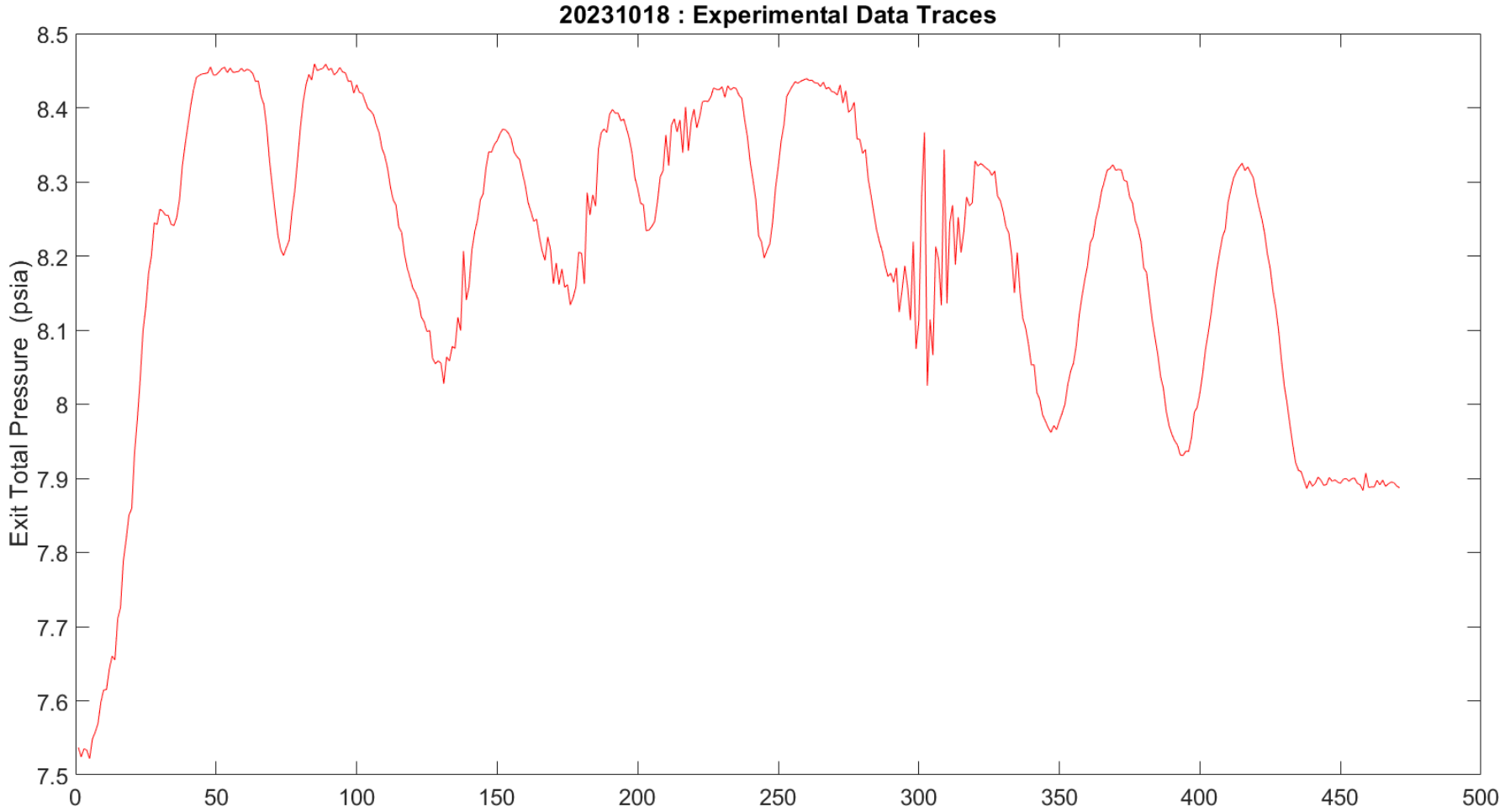


Preliminary Total Pressure Loss Across L3FHW Cascade

$$L = \frac{P_{t_{in}} - P_{t_{ex}}}{P_{t_{in}} - P_{s_{ex}}}$$



L3FHW: Initial Lack of Flow Periodicity At Low Mach numbers: Mach 0.397 Re 12400



L3FHW: Initial Lack of Flow Periodicity At Low Mach numbers

- Blades reordered in cascade– 10/18
  - Marginal impact on performance
- Addition of full Tailboards – 11/6
  - Low Subsonic velocity prevents shocks to assist in flow turning
  - 24 Inch tailboard installed on lowest blade
  - 12 inch tailboard installed on highest blade
  - Greatly Improved Flow characteristics
- Collection of Performance Data – 11/14