A System Modelling Approach to Roots-Claw Pump Performance Prediction

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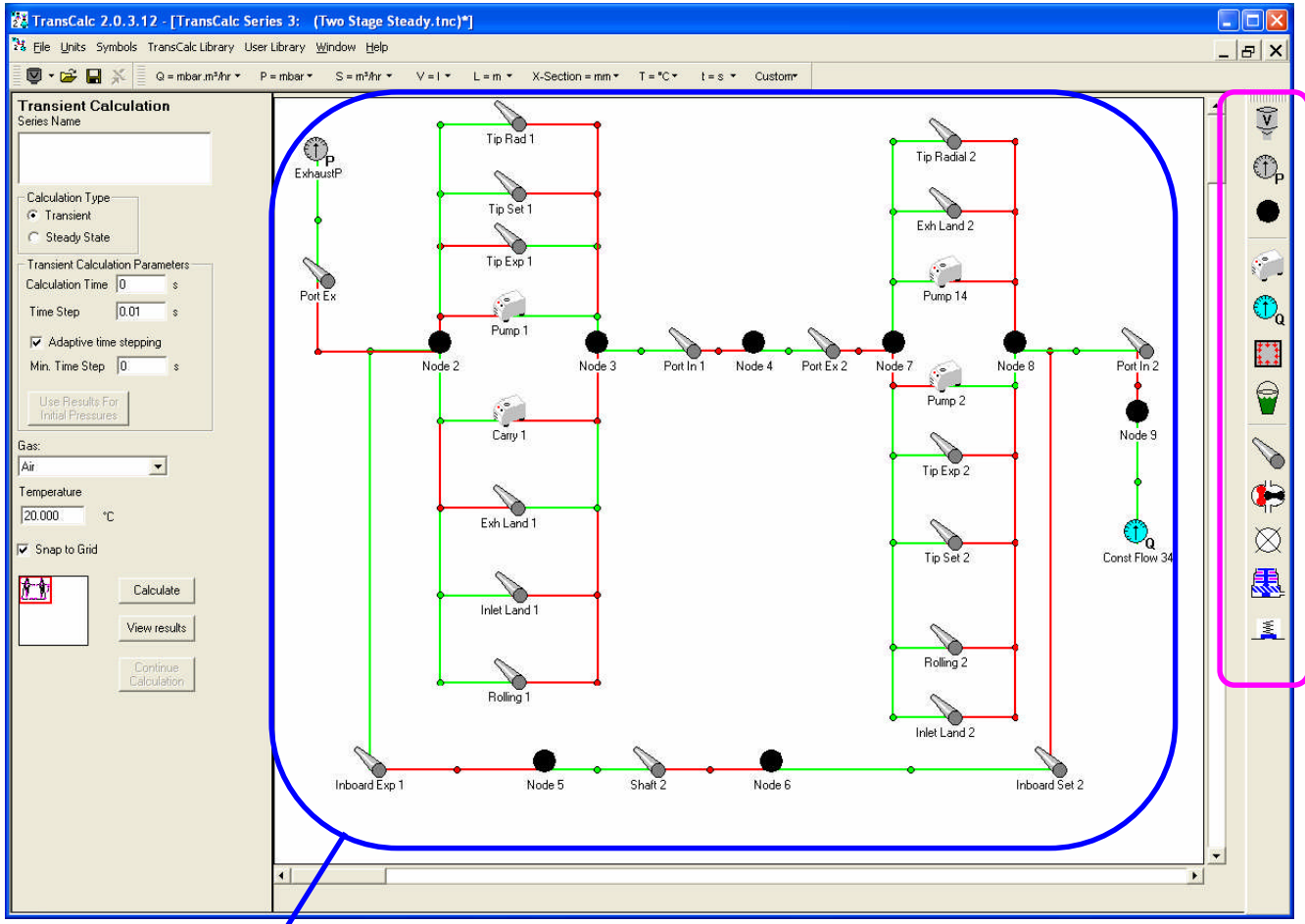
Volumetric Performance Modelling - History

- Roots mechanism successfully modelled within Edwards over last 15 years
- Claw mechanism is more challenging
  - More complex geometry
  - Koss et al. achieved limited success in continuum flow with full thermodynamic treatment.
    - JVST A 13, 3, May 1995, pp.536-539
- Pump developers require easy to use and rapid code to speed up design process

TransCalc Network Solution Tool

- Developed for modelling of complex vacuum systems
  - Network based: no *a priori* knowledge of system layout
  - Transient and steady-state solutions
  - Isothermal modelling
- Widely applicable
  - Enables use for modelling in-pump behaviour as well as system wide behaviour
  - Based on Edwards' GasFlow routines for flow in ducts.
    - Across all flow regimes

TransCalc Network Solution Tool



Large range of tool types

Drag & Drop interface for rapid model creation

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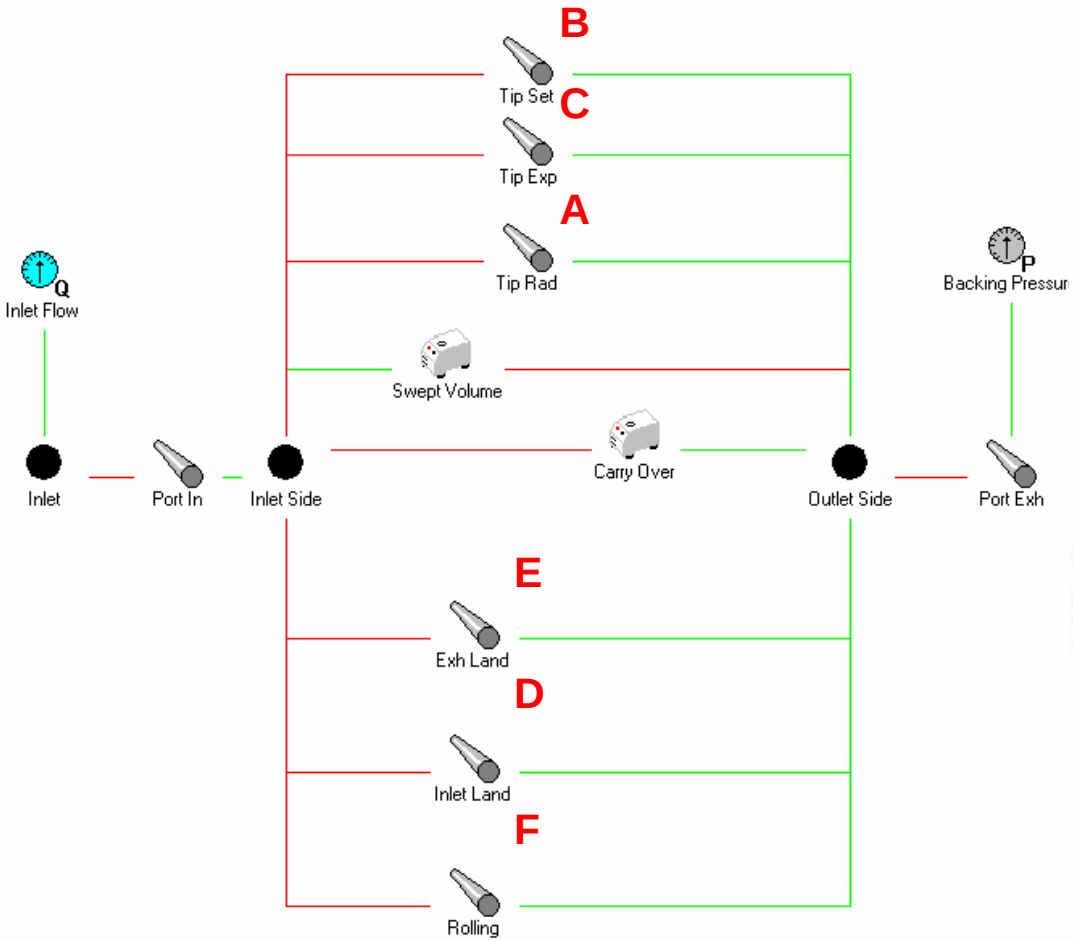
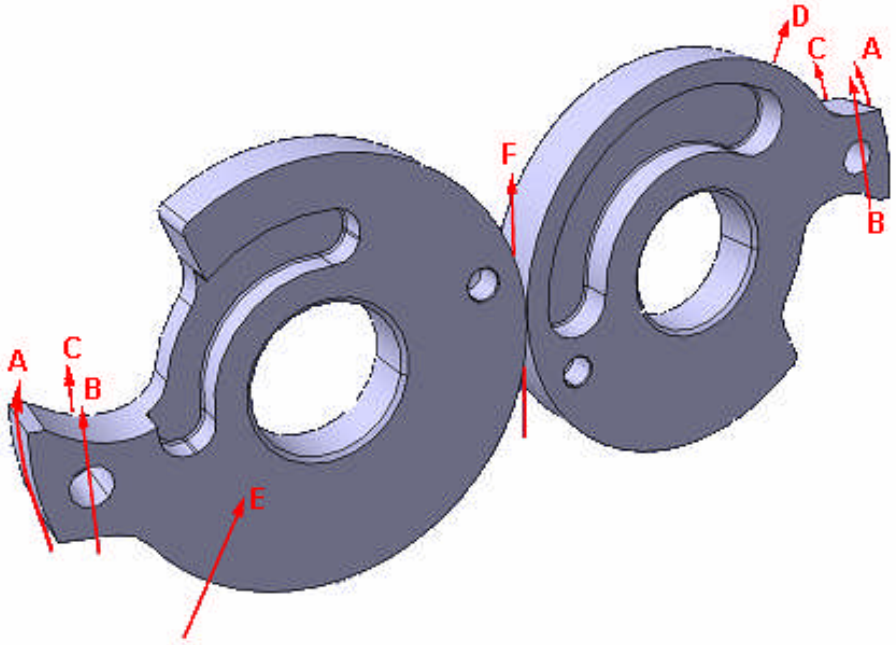
Steady-State Models

- Perform a steady calculation on a simple network
  - Swept volume and carry over modelled as constant speed pumps in opposing directions
  - All leakages/ports modelled as ducts.
    - Geometry of openings must be “averaged over a cycle”
- Simple model
  - Quick and easy to set up
  - Can be easily combined to give multiple stages
    - Interstage leakage down shaft modelled
- Gave acceptable predictions for speed
  - Issues over accuracy of averaging, filling efficiency at high rotational speeds
- Poor prediction of powers
  - Doesn’t predict over-compression during and after port closing

Steady-state Model Network





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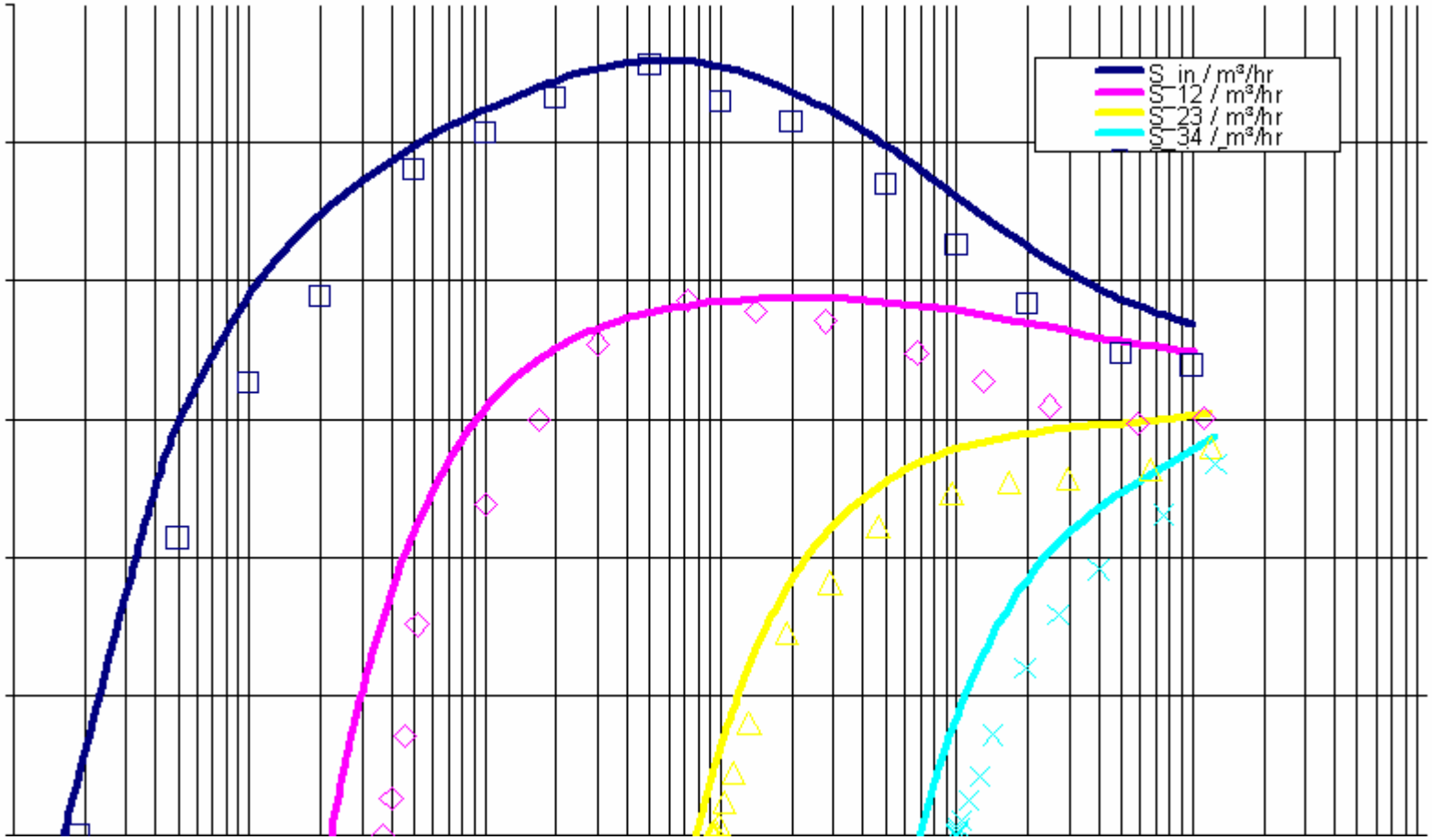
Steady-State Model Results - Speed



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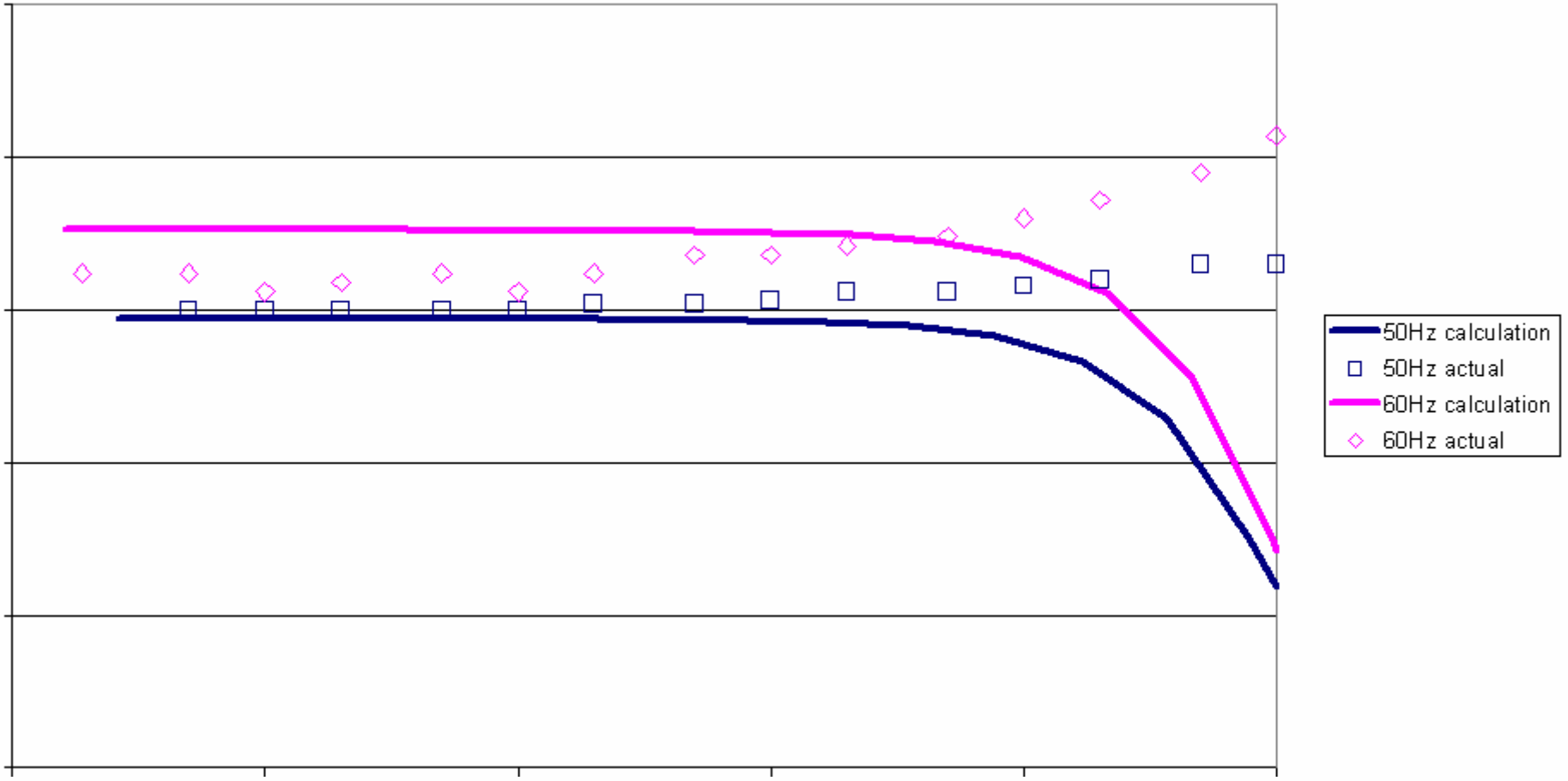
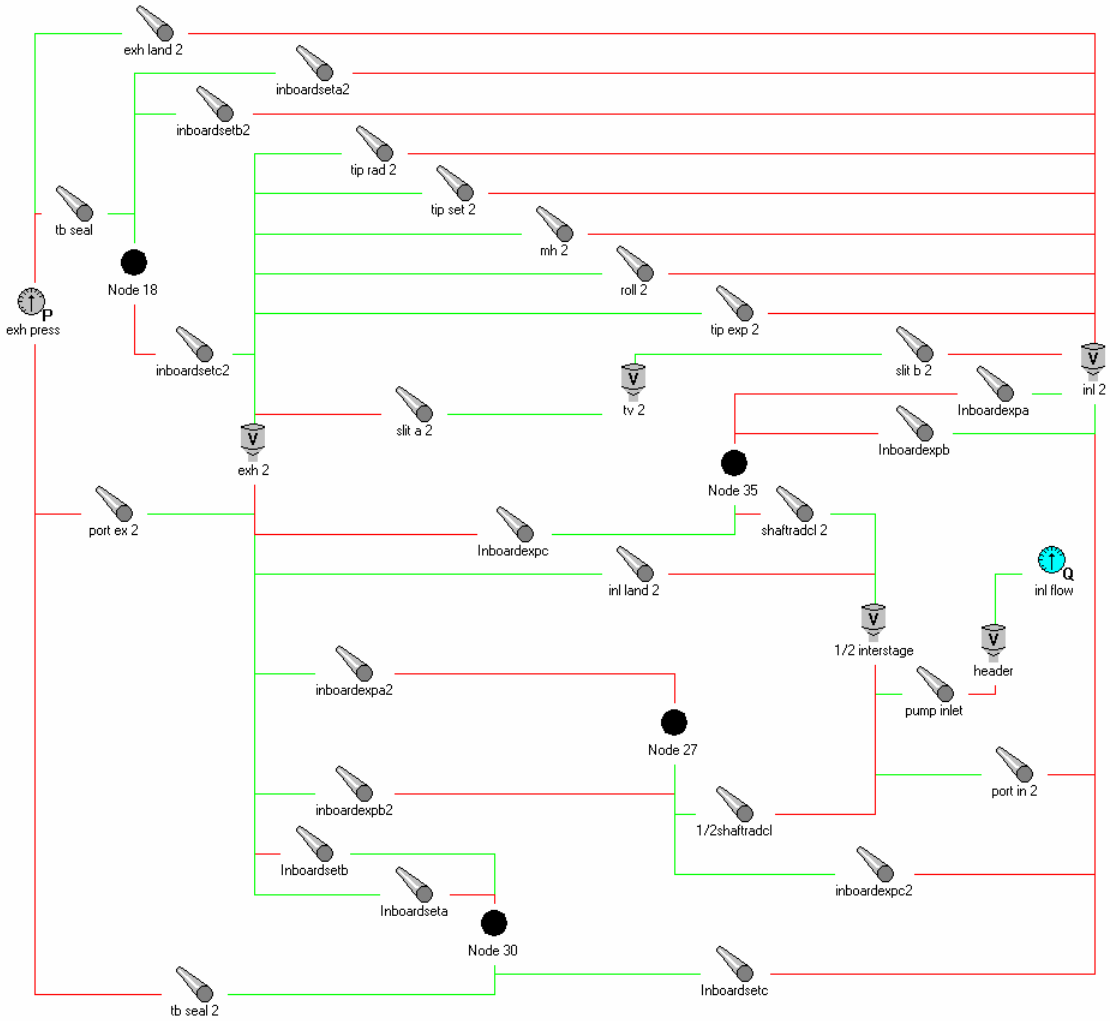
Steady-State Model Results - Power



Transient Modelling

- TransCalc modified to allow volumes, ducts etc to change with time.
- System modelled dynamically over a number of revolutions.
- More complex model to set up
  - Full pump model is very large
  - More economic to model stage by stage
    - Interstage leakages reduced to leakage back to inlet
      - Real case has leakage to inlet of previous stage
- Still gives results in acceptable times
- Good agreement for speed and power
  - Model extracted into specific model for pump performance
  - Speed and power curves for multi-stage pumps calculated in ~15 minutes on a PC

Transient Stage Model Network – Single Stage



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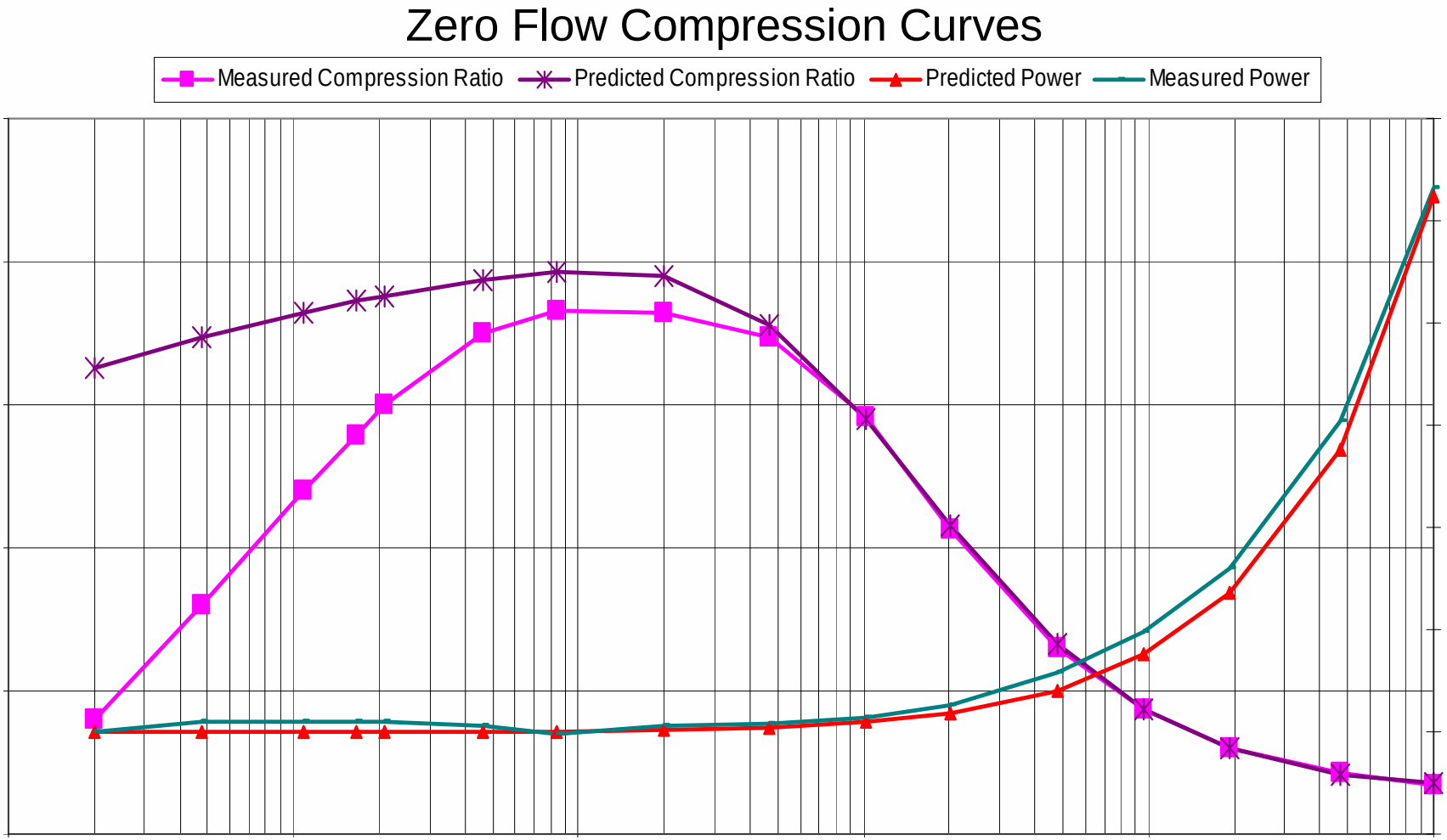
Transient Model Results – Single Stage



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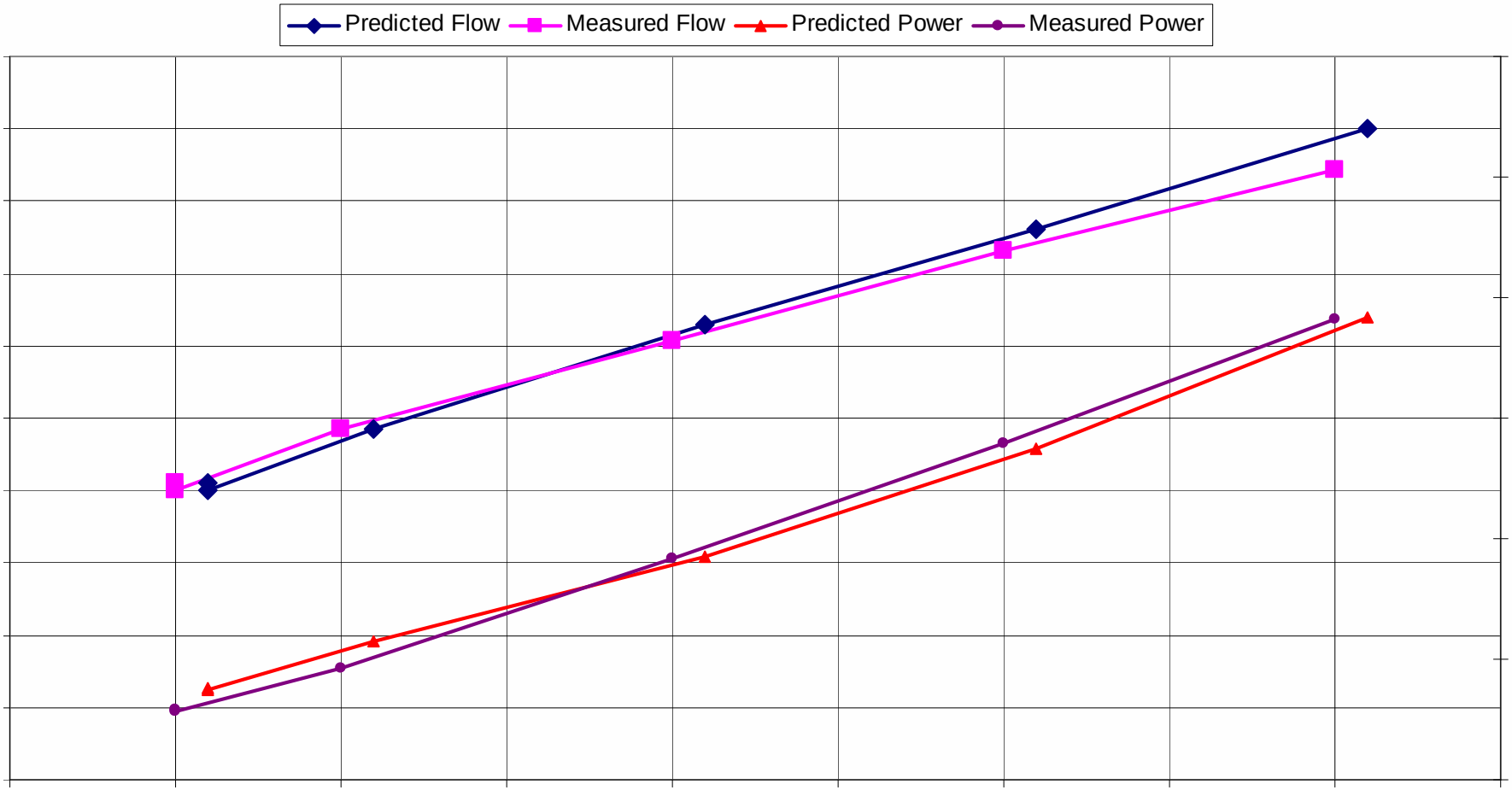
Transient Model Results – Single Stage

Effect of Rotational Speed on Roughing Performance



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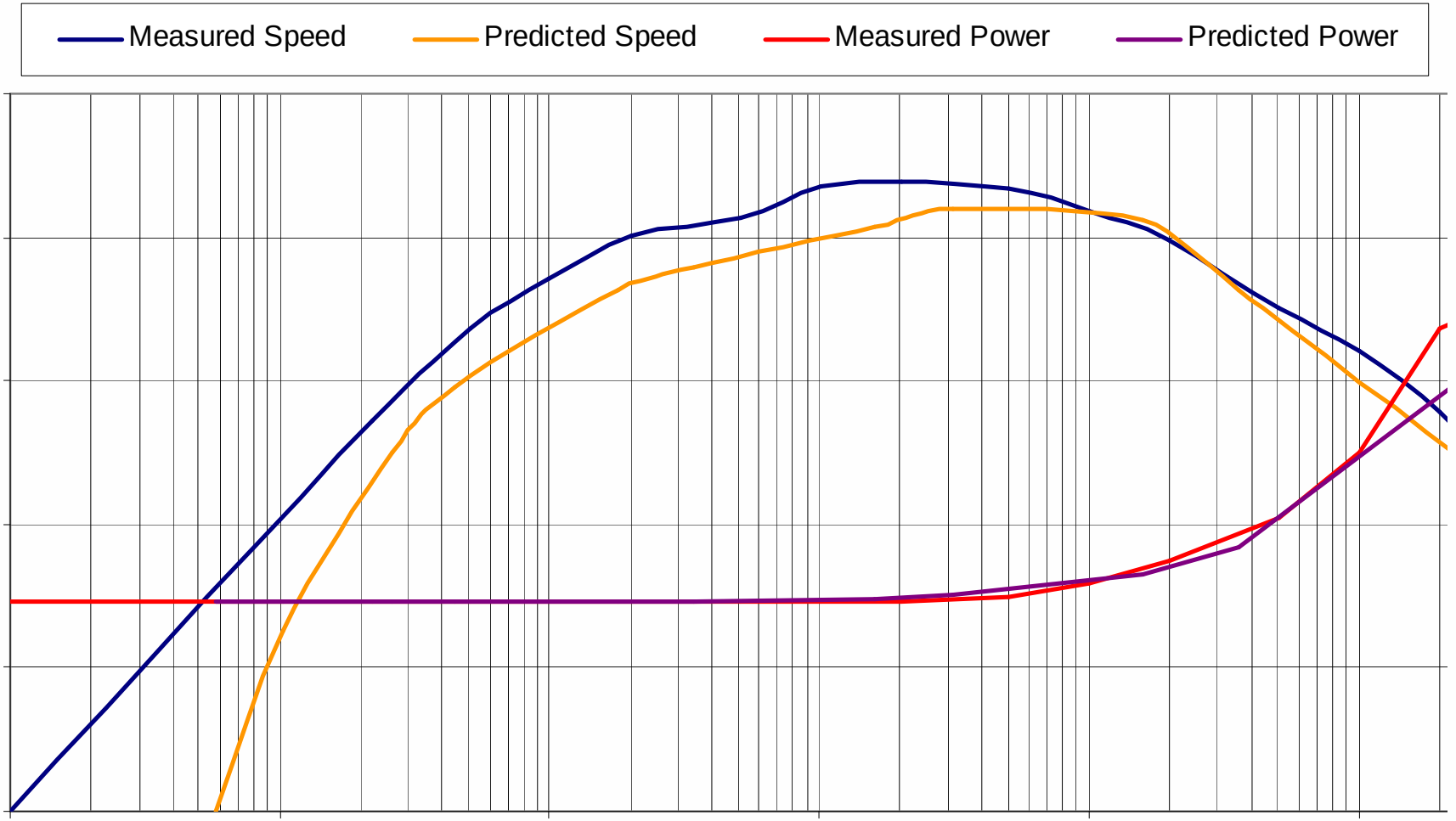
Transient Model Results – Multistage Pump



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Future Development

- Thermal Modelling
  - Similar lumped-parameter network approach takes power and pressure data from isothermal modeller
  - Good agreement with measured pump temperatures
  - Future integration to calculate clearances dynamically
- Gas Mixtures
  - Pumping of light gases strongly affected by N_2 purge
  - Need to handle changing mixture composition through pump

Conclusions

- Isothermal models capable of giving good speed and power predictions
- System modelling tools allowed rapid development of complex model
  - Approx 1 man month
- Pump modelling tool used for new pump development
  - Significantly shortening NPI process