METHOD TO INCORPORATE PORT STEADY FLOW DATA INTO ENGINE PERFORMANCE MODELS

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OBJECTIVES

- Method to represent port flow data from CFD or Flow Bench in GT POWER models.
- Method to comprehend exhaust port flow recovery and steady flow test hardware effects
- Method to treat 0-D cylinder model in port steady flow models
- Notes on area schedule representation.
- Notes on 4V port modeling.
WHY PORT FLOW MODELING? (WHY SHOULD WE CARE)

Engines need air to make power. They cannot mix flow coefficients with fuel, they need air mass flow. Verify inputs describing port, valve and L/D relationship to define mass flow correctly.

Account for 0D/1D/3D/real-world relationships:

- Flow coefficients are 0-D representations of a system.
- GT POWER Cylinders are 0-D, GT POWER flow elements (ports) are 1D.
- CFD/Flow Bench, Engine ports, and cylinders are full 3D and have aerodynamic characteristics beyond the valve discharge.
What discharge coefficients describe:

\[ A + Cd \]

\[ A_{eff} + Cd = 1 \]
PORT FLOW MODELING – SET-UP

- Build steady flow model to verify port flow
- Represent port area schedule.
  - Subtract valve stem area
  - Check if port-manifold face is perpendicular to flow
    - Use appropriate flow area, if different from ‘face opening’
  - Make sure volume, length and area schedule is represented. (Cross check with CAD or fluid ‘cc’ of port)
- Set up reference arrays based on desired value.
  - GM uses L/D and Cdca based on valve head diameter

Do not include Bore Adaptor in model
WHY NO BORE ADAPTOR IN FLOW BENCH MODEL?

- GT POWER Engine cylinder is 0-D, not really a flow element
- GT POWER Engine model’s port to cylinder interface is into the cylinder 0-D ‘low energy state’ with Zero flow recovery
- Potentially different than the bench with bore adaptor.
- Port flow sub model needs to represent where port+valve sub system is used (connected to engine model cylinder)
- Surrogate for a 0-D cylinder in the steady flow model is a large diameter pipe. 1000 mm dia.
PORT FLOW MODELING (INTAKE)

Intake port flow data typically includes entrance bellmouth (machined, clay etc).

- Insert bench coefficients into steady model and check flow match.
- If flow is more than 1% off, check model for errors:
  - Reference array
  - Cd area reference in model and supplied data
  - Valve size in model and in supplied data
- Tune coefficients to match flow if desired (typically not required).

Load port and valve object models into engine model.

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PORT FLOW MODELING (EXHAUST)

Represent port area schedule.
Do not include Bore Adaptor in steady model
If used in testing, represent extension pipe for steady flow simulations, remove when inserting port into engine model.

Extension pipe mimics the effect of exhaust manifold/header on port

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PORT FLOW MODELING (EXHAUST)

Intake ports flow: pipe > orifice > large diameter/low energy
- Orifice losses ‘dominate’
- Bench derived coefficients are quite close.

Exhaust ports flow: low energy > orifice > pipe > extension pipe
- Subsequent pipes in models provide pressure/flow recovery.
- Bench coefficients lump everything at the valve. Valve coefficients need reduction to allow recovery effects from port and extension pipe.

- Adjust coefficients to achieve flow match
- Load port and valve object models into engine model with adjusted coefficients and without extension pipe.
EXAMPLE DATA  2V V-8 EXHAUST

Bench CD plus CD (adj)
(Adjusted for Aeff < Pipe dia)

CD Curves Dialed in.
Ready for Engine Model

- CNC Bench CD
- CNC Bench CD (Adj)
- CNC Dialed in CD
- Base Bench Cd
- Base Bench Cd (Adj)
- Base Dialed-in CD
EXAMPLE DATA  2V V-8 EXHAUST

Flow Bench
Mass Flow vs Valve Lift

- CNC Flow
- Base Flow

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EXAMPLE DATA  2V V-8 EXHAUST

Flow Bench Coefficients (Cdca in this case)

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EXAMPLE DATA  2V V-8 EXHAUST

Bench CD Flow Results
(Adjusted for Aeff < Pipe dia)

Dialed in Port Flow Results

- CNC Bench CD
- Base Bench CD
- CNC Dialed CD
- Base Dialed CD

Valve Lift

Mass Flow g/s

0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20

250

200

150

100

50
EXAMPLE DATA  2V V-8 EXHAUST

Bench CD plus CD (adj)
(Adjusted for Aeff < Pipe dia)

CD Curves Dialed in.
Ready for Engine Model

Cd CA

Valve Lift

CNC Bench CD
CNC Bench CD (Adj)
CNC Dialed in CD
Base Bench Cd
Base Bench Cd (Adj)
Base Dialed-in CD
ENGINE RESULTS

- Effect of port flow change was small.
- Effect of improper flow coefficients cannot be ignored.
PORT REPRESENTATIONS: CROSS SECTIONAL AREA

Simple one-pipe port, length and dia

Port to Represent Area Schedule

Q: I’m lumping the flow losses at the valve, why do I care about cross sectional area?

A: If exhaust port minimum cross section area is represented, the ENGINE model can indicate choked flow during cycle simulation.
EXTRA CREDIT: TRY THIS ON YOUR FLOW BENCH OR 3D CFD FLOW SIMULATION

- Set up a simple orifice flow test.
- Record Data
- Add a length of straight pipe slightly larger than the orifice (use your flow extension pipe).
- Compare Results
4 VALVE PER CYLINDER PORT SETUP NOTES

- 4 part port characterization recommended.
  - 2 Lower Ports
  - 1 Flow Split
  - 1 Upper Port
- Why not simplify and connect flow split to manifold?
  - Connections from manifold runners into flow-splits is more ‘reactive’ to runner geometry than connections into pipes.
- The lower ports’ connection to flow split should be treated as no expansion
REVIEW OBJECTIVES

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- Notes on 4V port modeling.
QUESTIONS?