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Gas dynamics of exhaust valves

Marcus Winroth, Henrik Alfredsson, Ramis Örlü

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Outline

- Background
- Experimental design
- Preliminary results
- Future work

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Background – flow over exhaust valves

- Discharge coefficient

$$C_D = \frac{\dot{m}_{\text{real}}}{\dot{m}_{\text{ideal}}}$$

- Measurements of C_D today:
  - Fixed valve lift
  - Low pressure ratios
  - Typical experiments performed in industry have a maximum M ≈ 0.3 (incompressible)

- LES simulations by Y. Wang show
  - Large pressure ratio dependence on C_D

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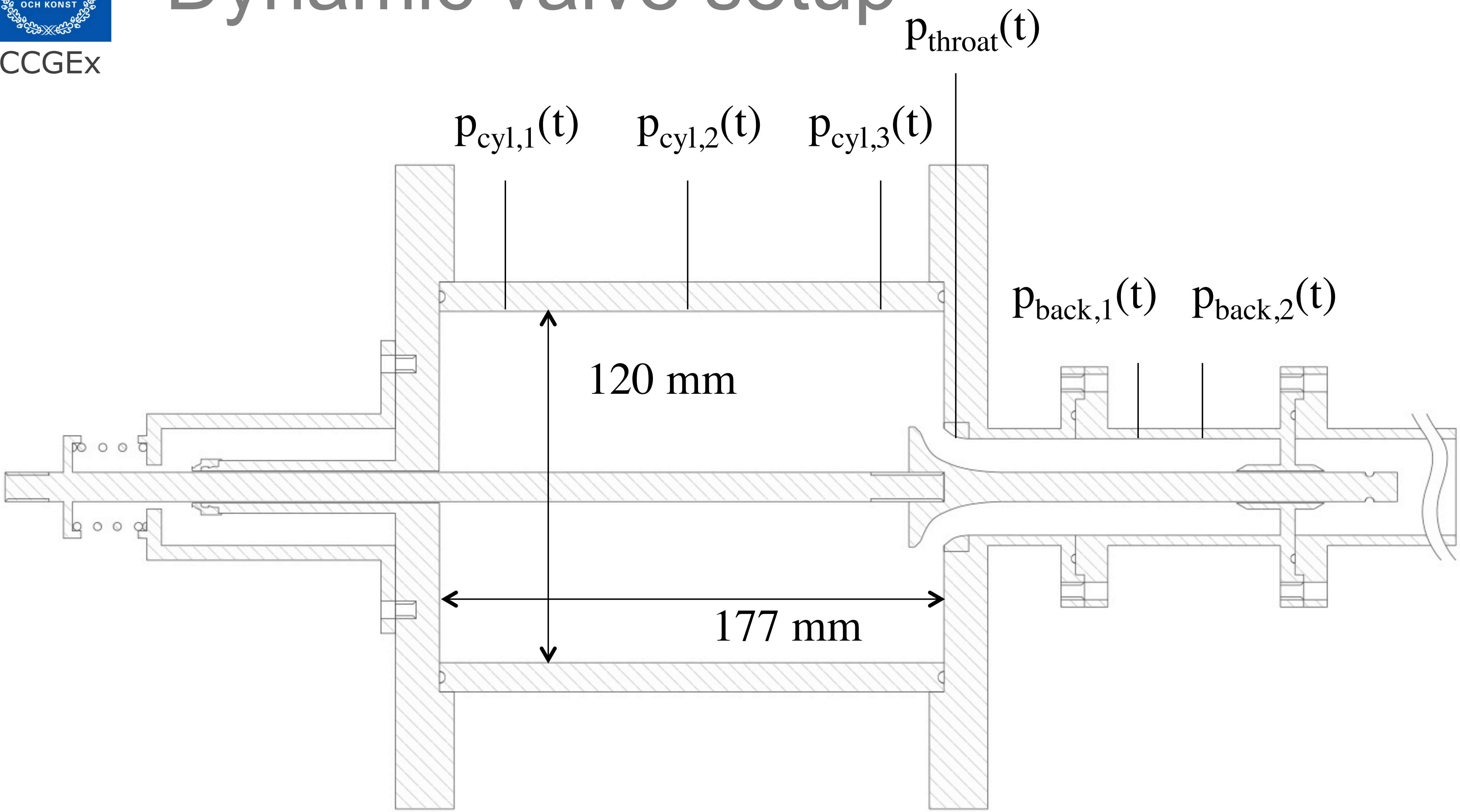
Objectives

Experimentally test the effects of:

- High pressure ratio (including choked flow conditions)
- Quasi-steady valve assumption
- Radial positioning of the valve
- Interaction of two valves
- Exhaust port geometry

Dynamic valve setup



Time resolved mass flow

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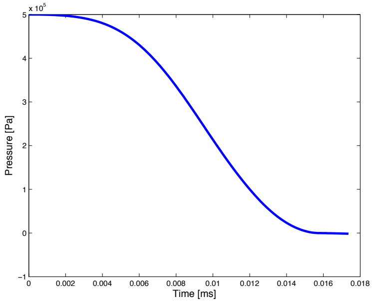
$p(t)$



t

$$m(t) = \frac{V}{R}\frac{p(t)}{T(t)}$$

The expansion in the cylinder may be viewed as isentropic, hence

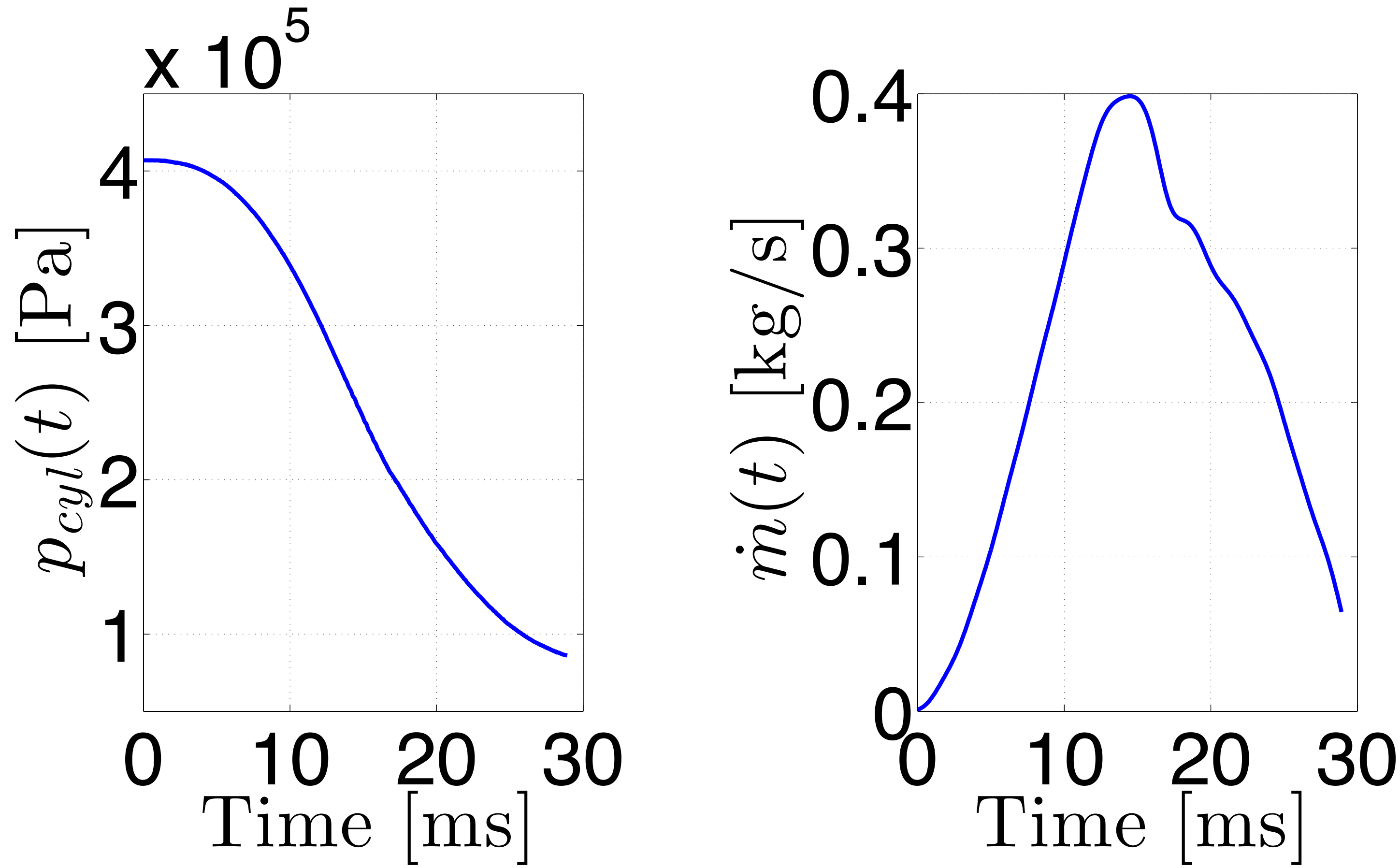
$$\frac{p}{p_0} = \left(\frac{T}{T_0}\right)^{\gamma/(\gamma-1)}$$

which gives

$$\frac{p}{T} = T_0^{-1} p_0^{(\gamma-1)/\gamma} p^{1/\gamma} = C p^{1/\gamma}$$

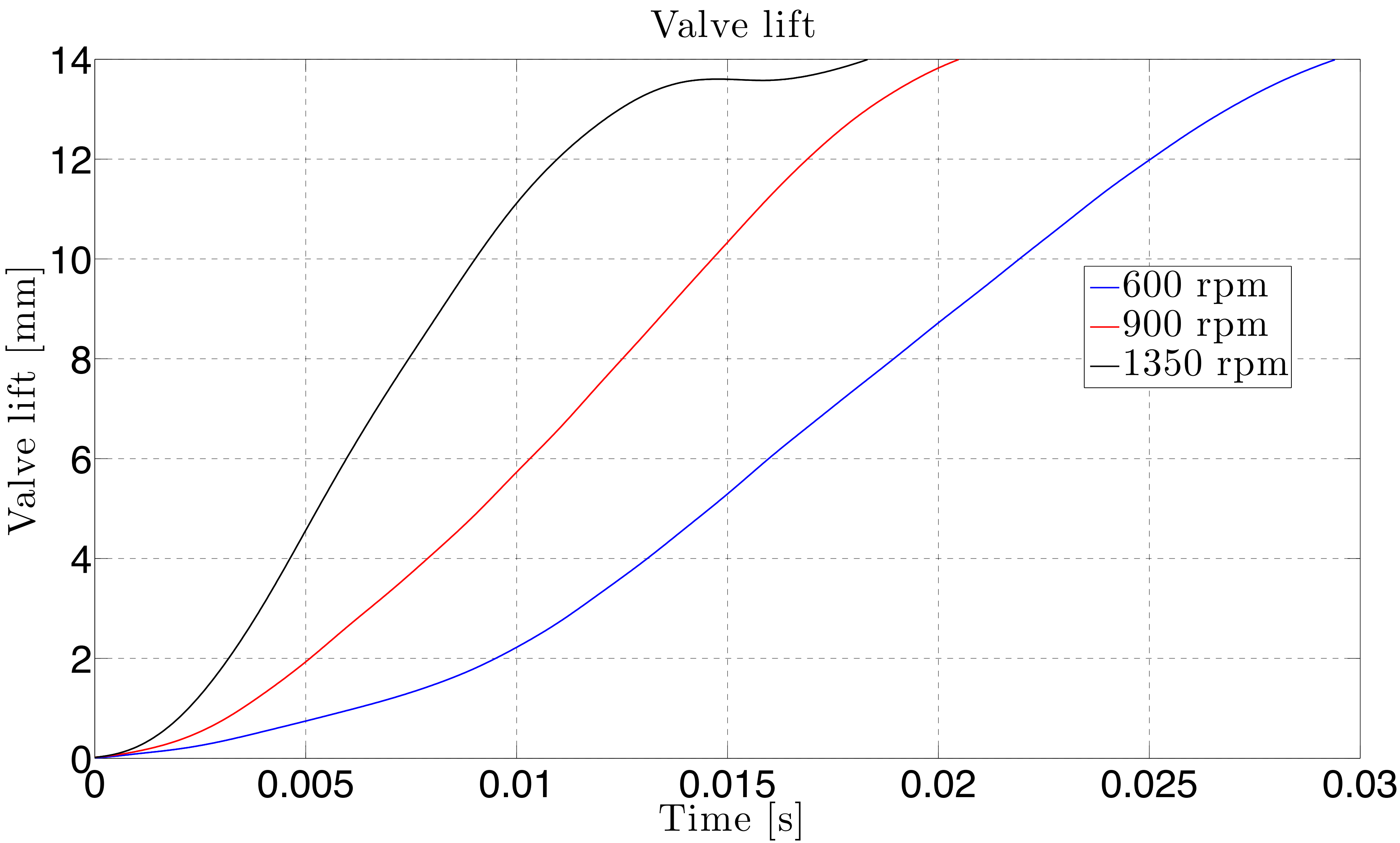
Meaning it is sufficient to measure *p(t)* and *T(t=0)* to obtain the mass flow.

Time resolved mass flow

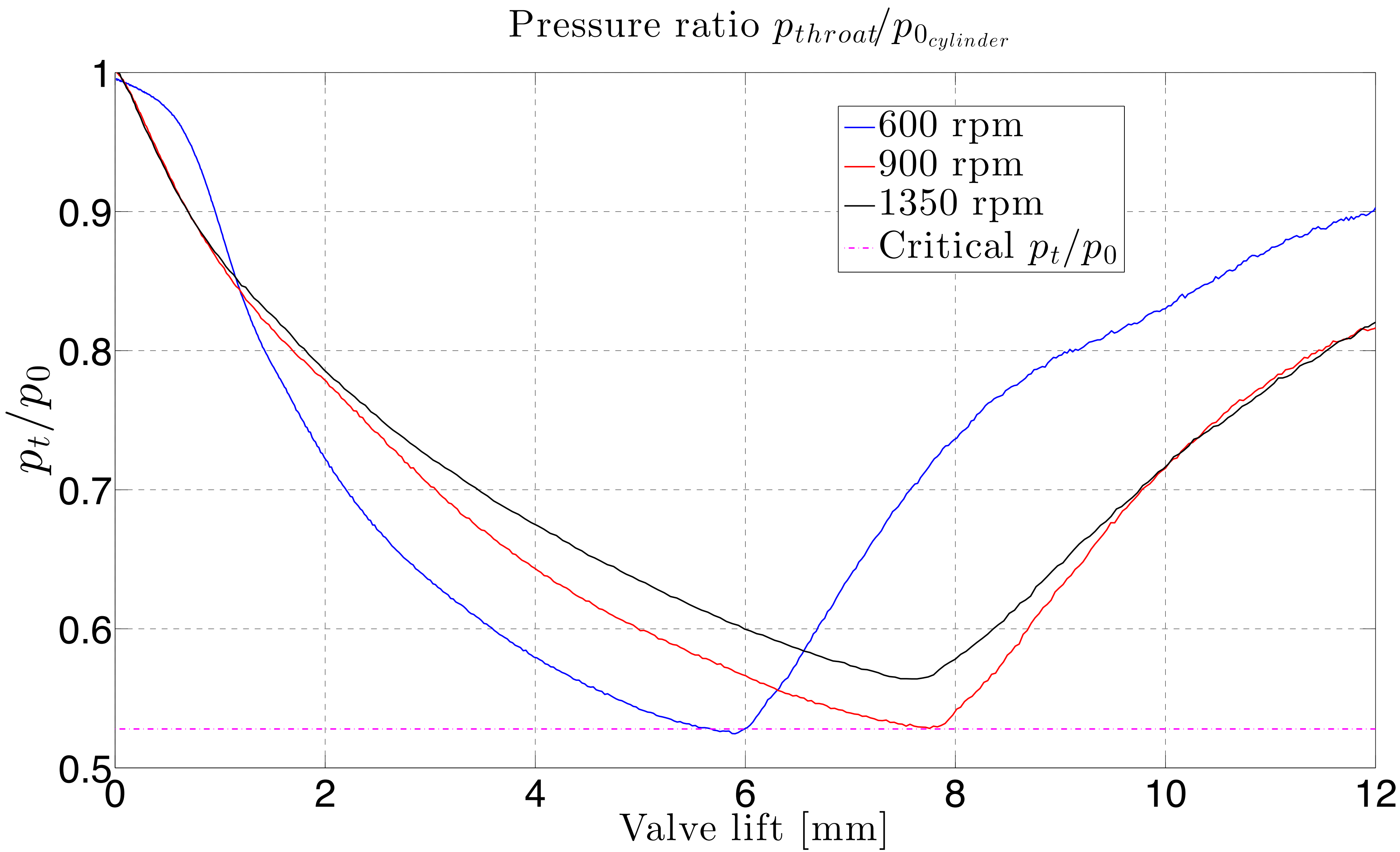


$$\dot{m} = \frac{\mathrm{d}m}{\mathrm{d}t} = \frac{V}{\gamma R T_0} \left(\frac{p_0}{p} \right)^{(\gamma - 1)/\gamma} \frac{\mathrm{d}p}{\mathrm{d}t}$$

Valve dynamics



Valve dynamics



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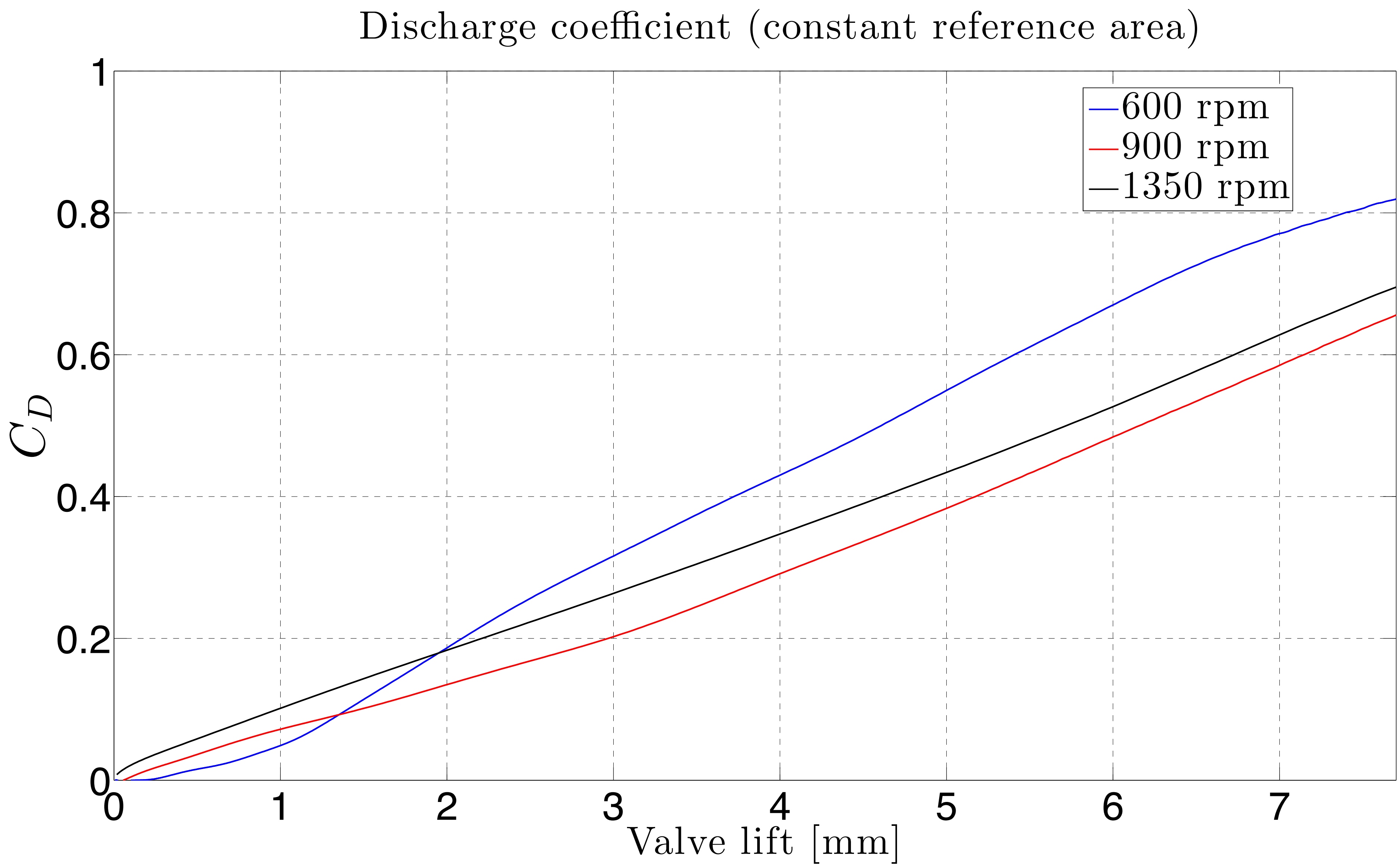
Valve dynamics



Pressure ratio dependence

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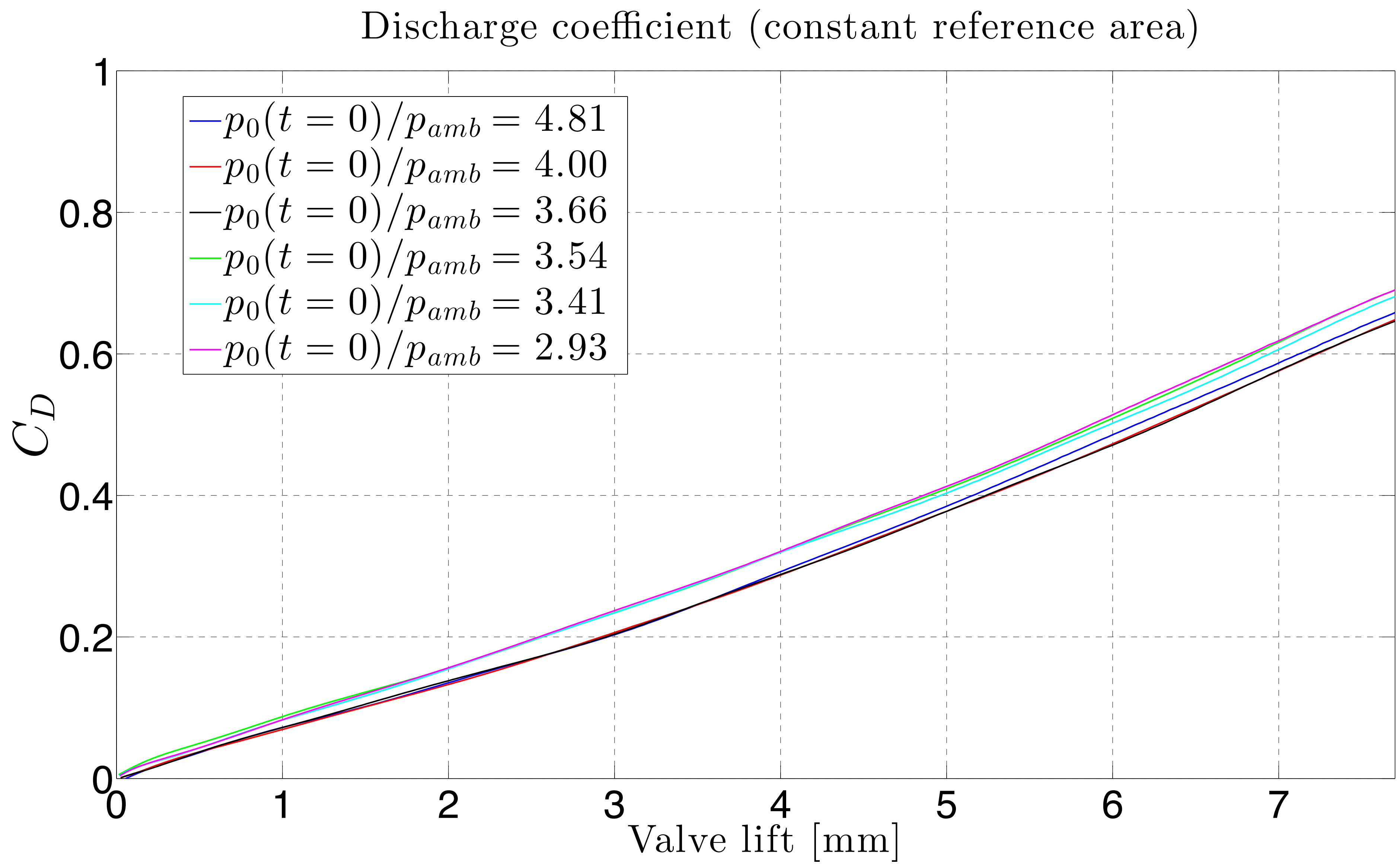

Pressure ratio dependence

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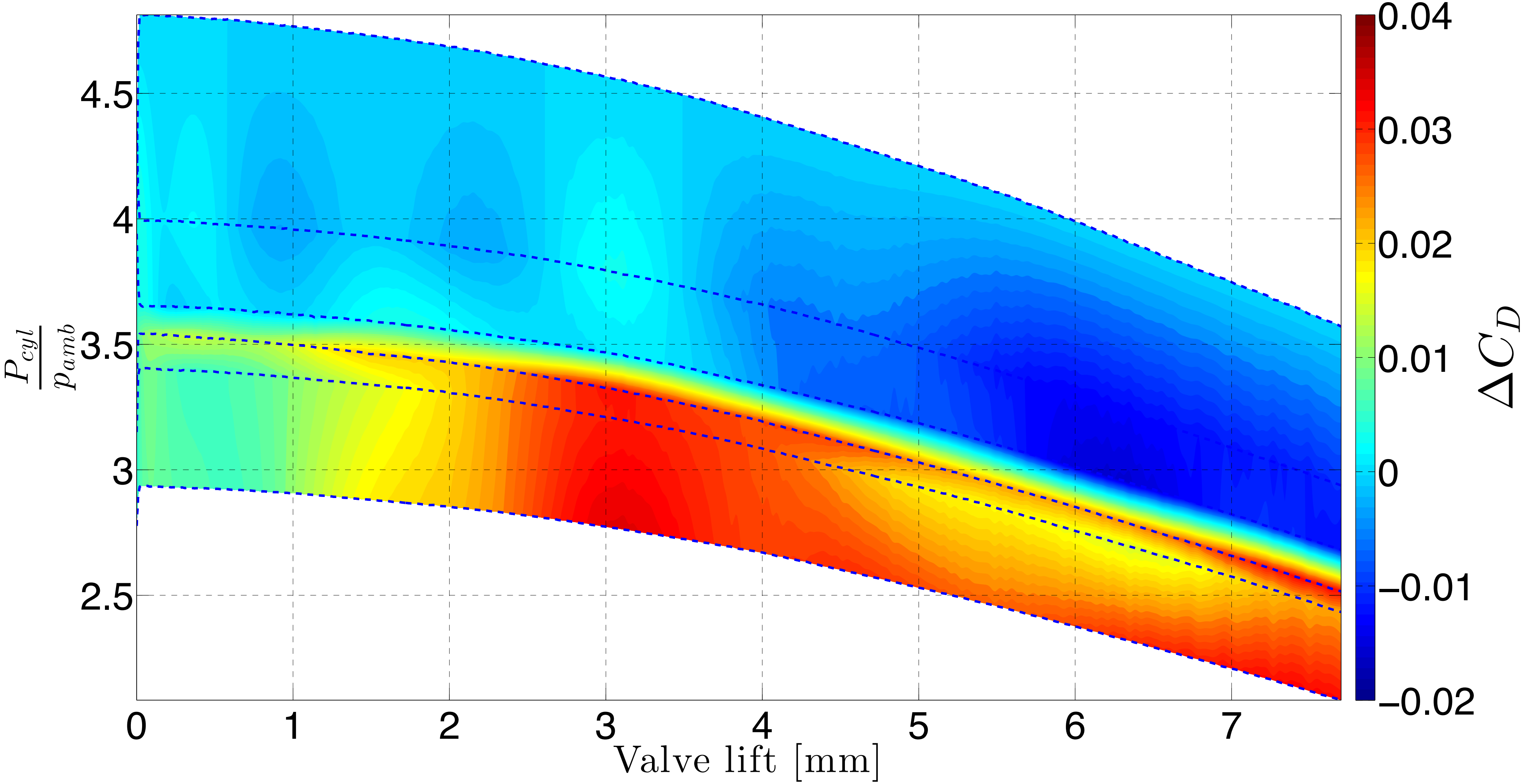
$$\Delta C_D = C_D - C_{D_{ref}}$$



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Future work

- Dynamic valve experiments at

  - different pressure ratios @ different valve opening speeds
  - different radial position of the valve
  - different pressure ratios @ different radial position of the valve
  - different valve lift profiles
  - different exhaust pipe geometries
  - two-valve combination

- Static valve measurements using the CICERO flow facility
- Compare the mass-flow results with the vortex-shedding flow meter

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Thank you!