KTH ROYAL INSTITUTE
OF TECHNOLOGY

Gas dynamics of exhaust valves

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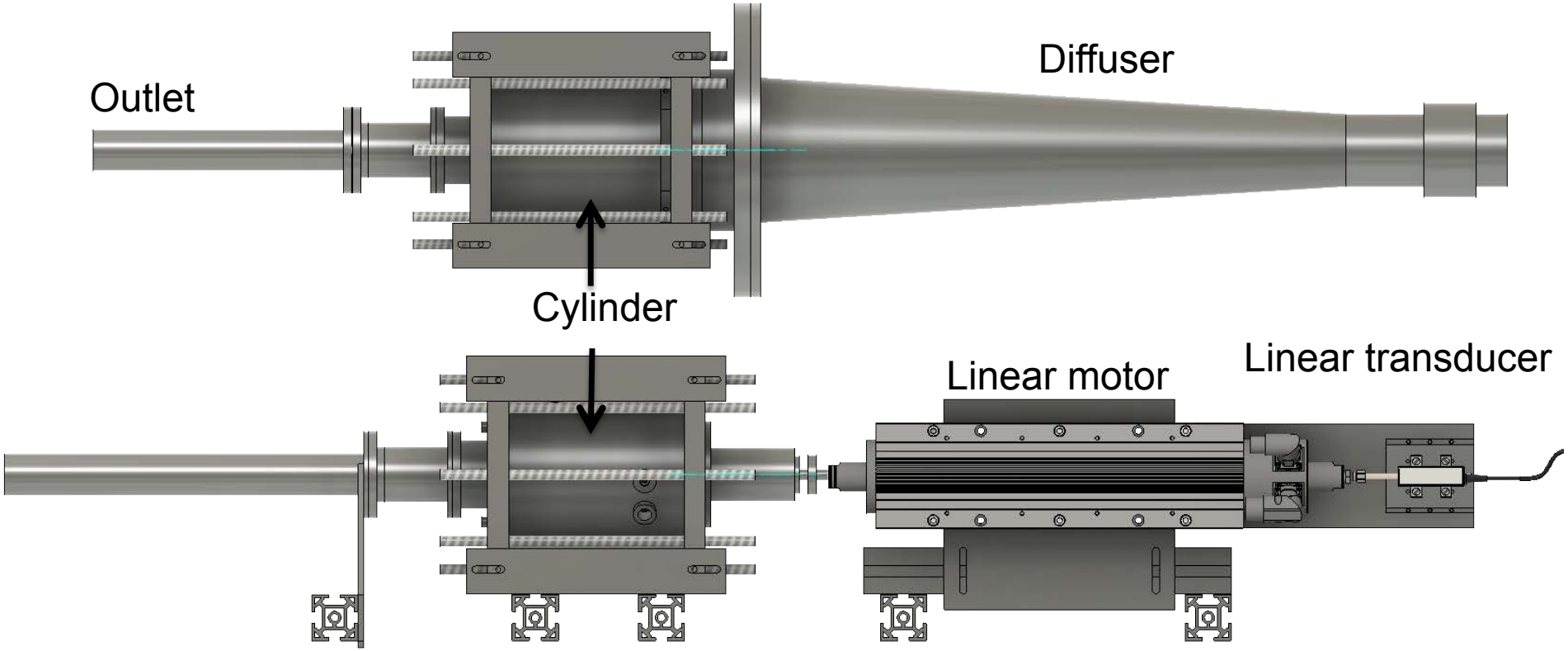
11.10.2018, CCGEx - Research days

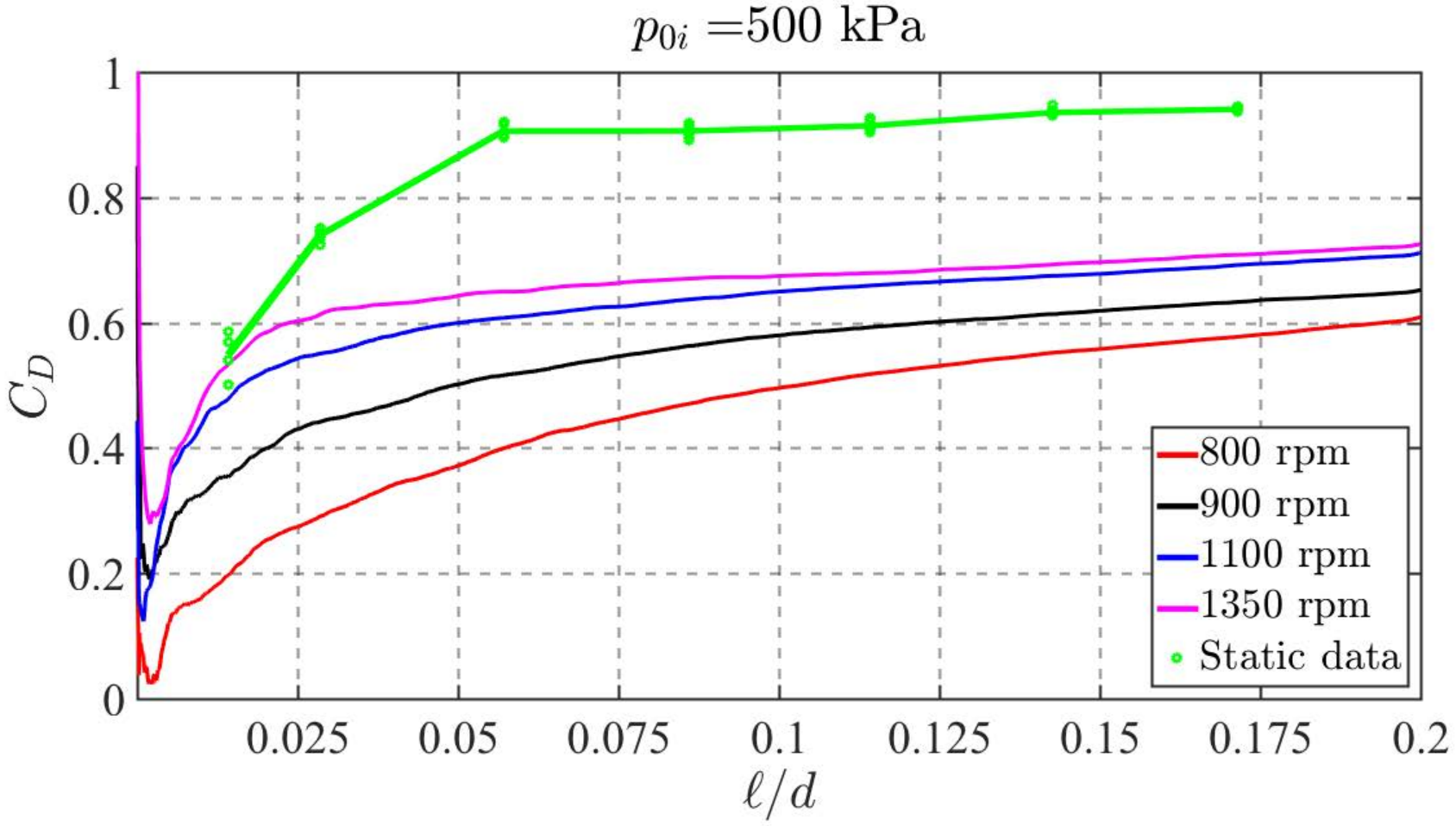
Outline

- Previous experiments – steady state vs dynamic valve C_D measurements
- Gas dynamics during valve opening
  - New flow visualization setup
  - Principle of Schlieren visualization
  - Flow physics in the exhaust port

Previous experiments

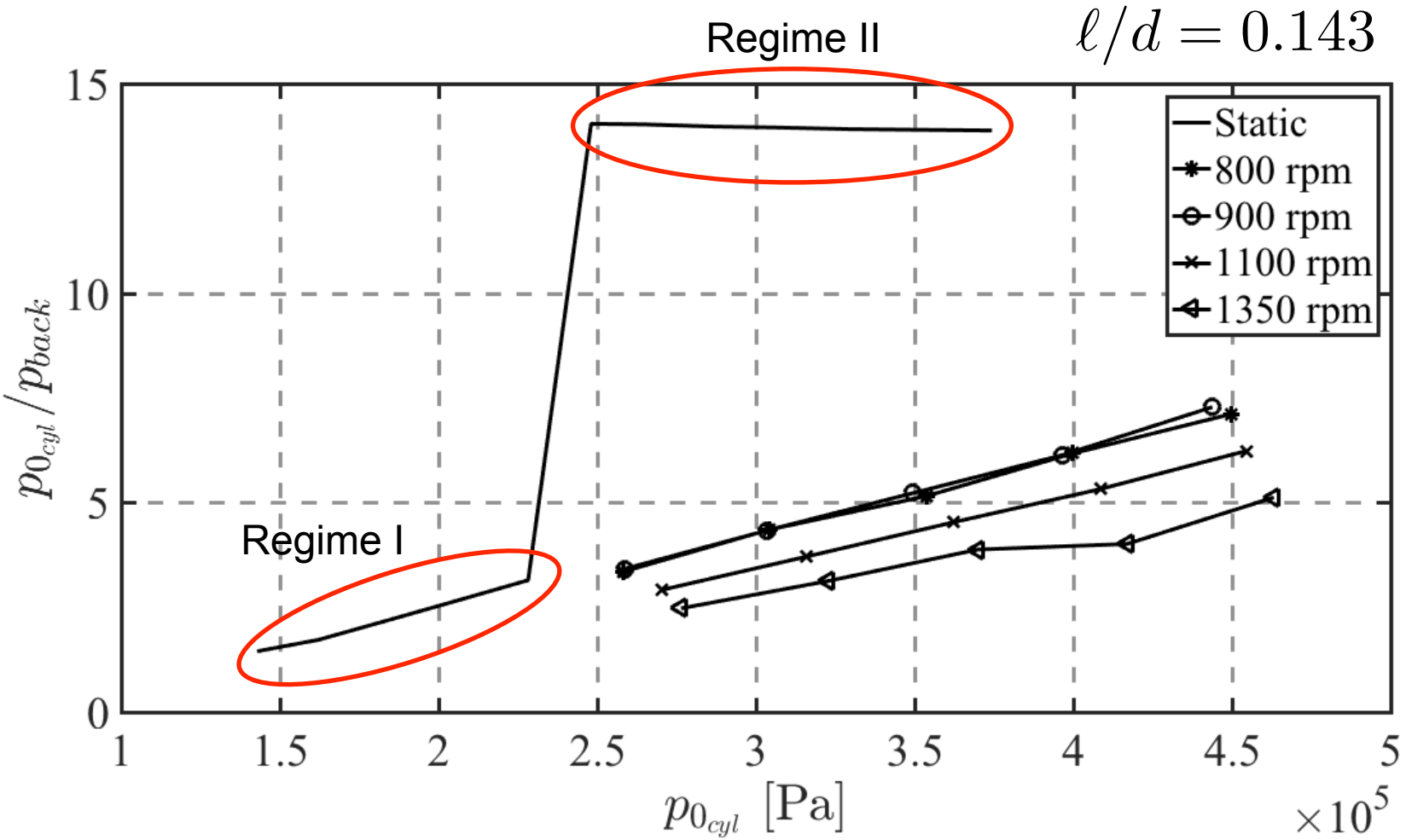


C_D for static and dynamic cases

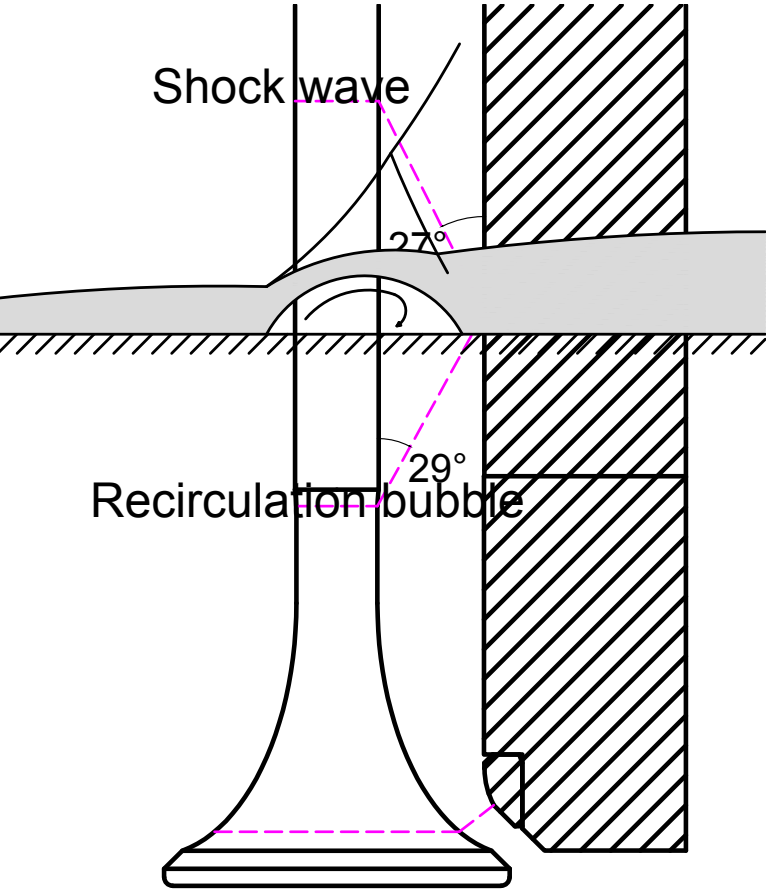


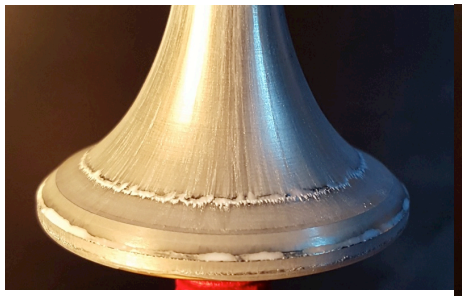
Reference: Winroth, P.M., Ford, C.L. & Alfredsson, P.H. (2018), On discharge from poppet valves: effects of pressure and system dynamics. *Experiments in Fluids*, 59(2), 24

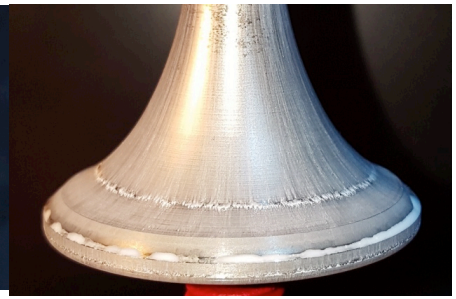
Cylinder to back pressure ratio



Surface flow visualisation







Regime I

Regime II

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- Previous experiments – steady state vs dynamic valve C_D measurements
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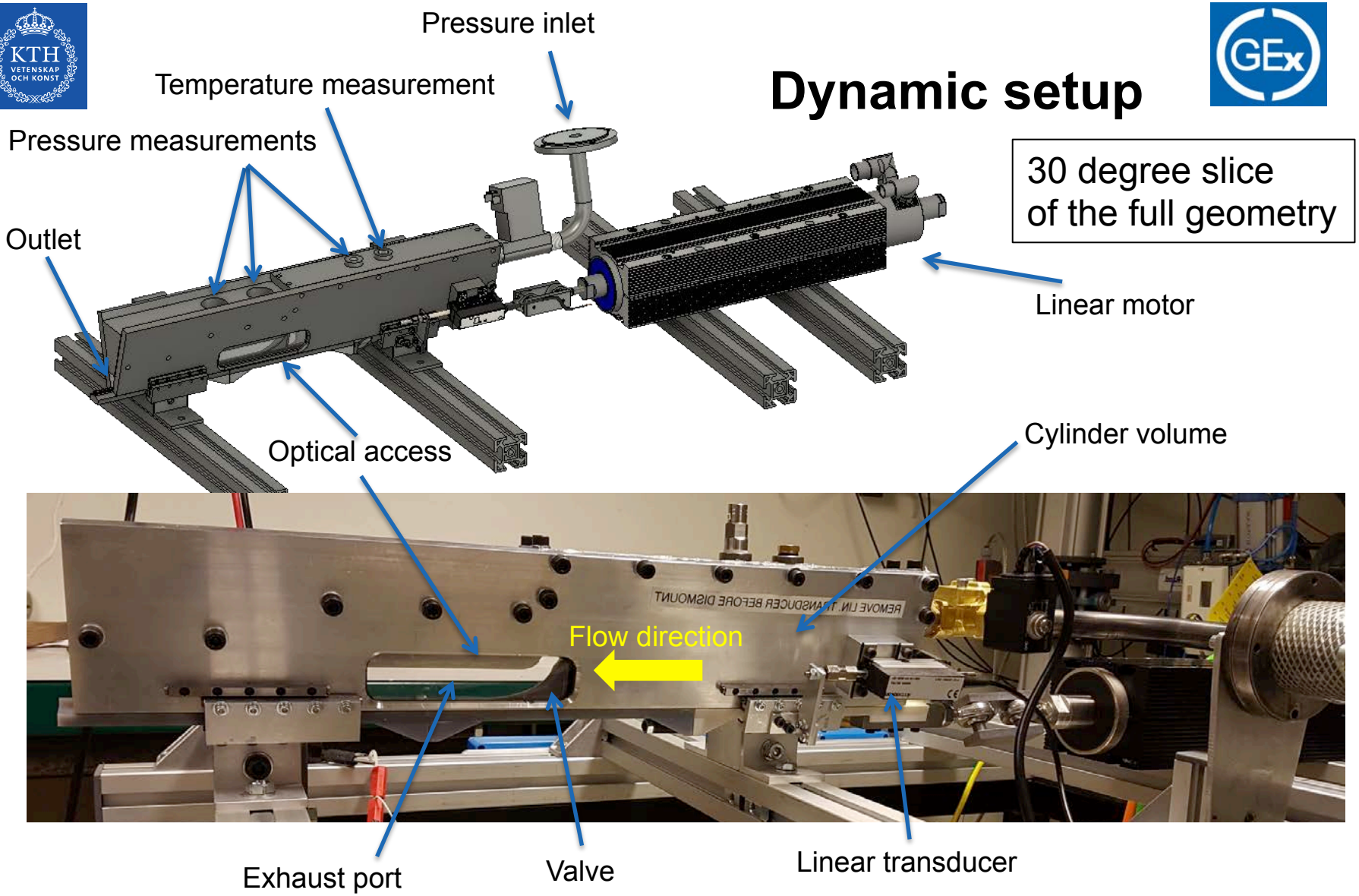
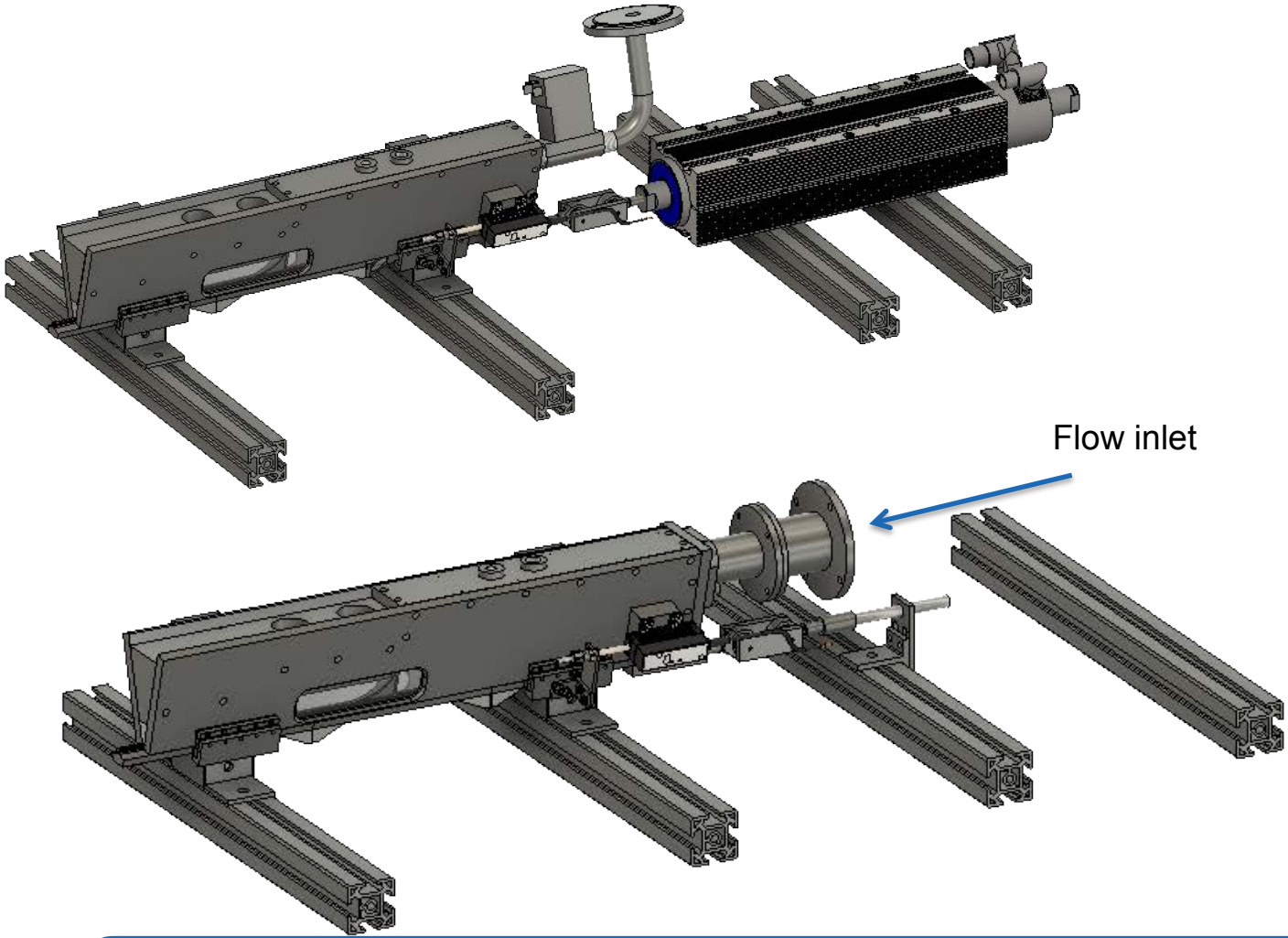
  - Principle of Schlieren visualization
  - Flow physics in the exhaust port

Dynamic setup

30 degree slice
of the full geometry



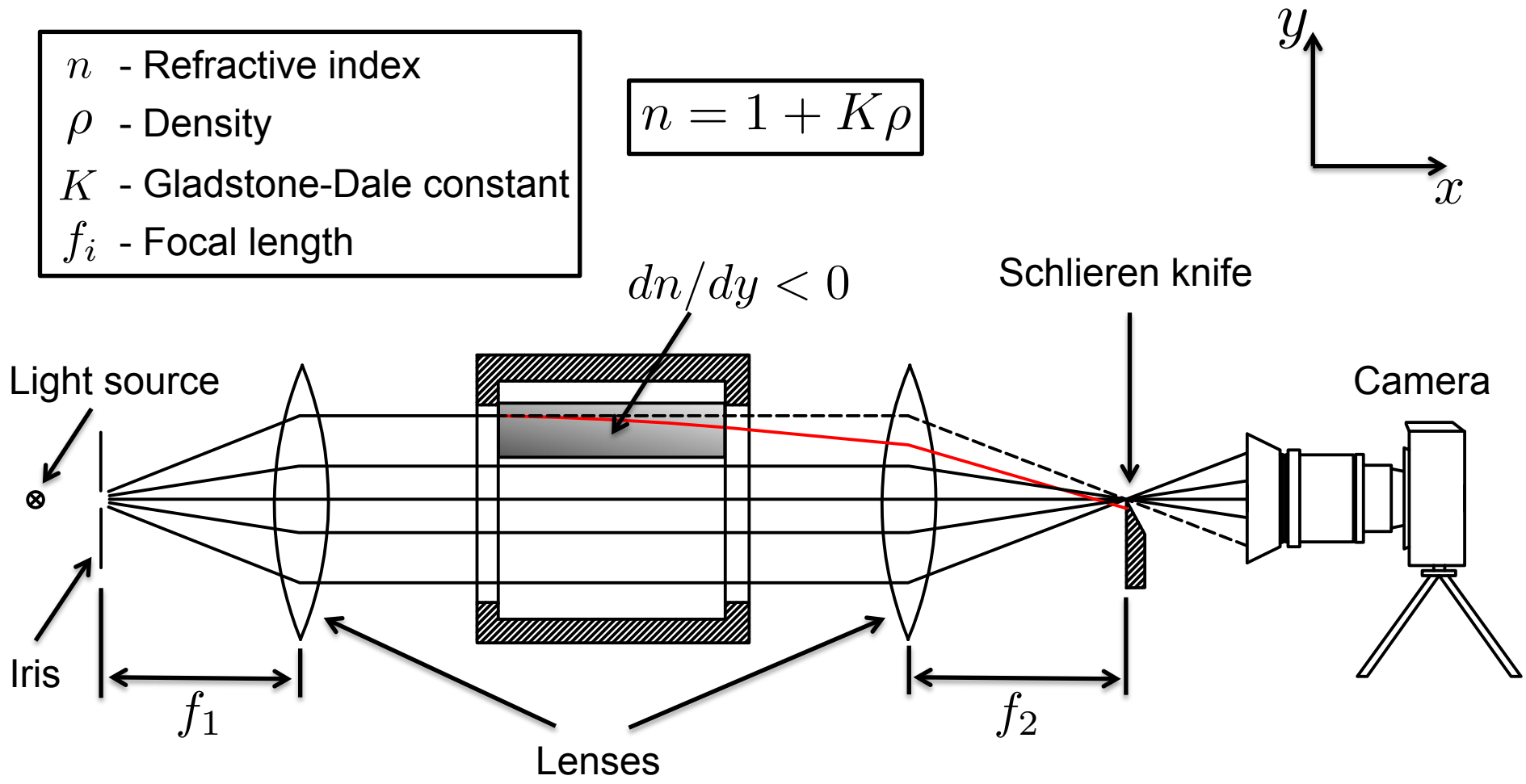
Static setup



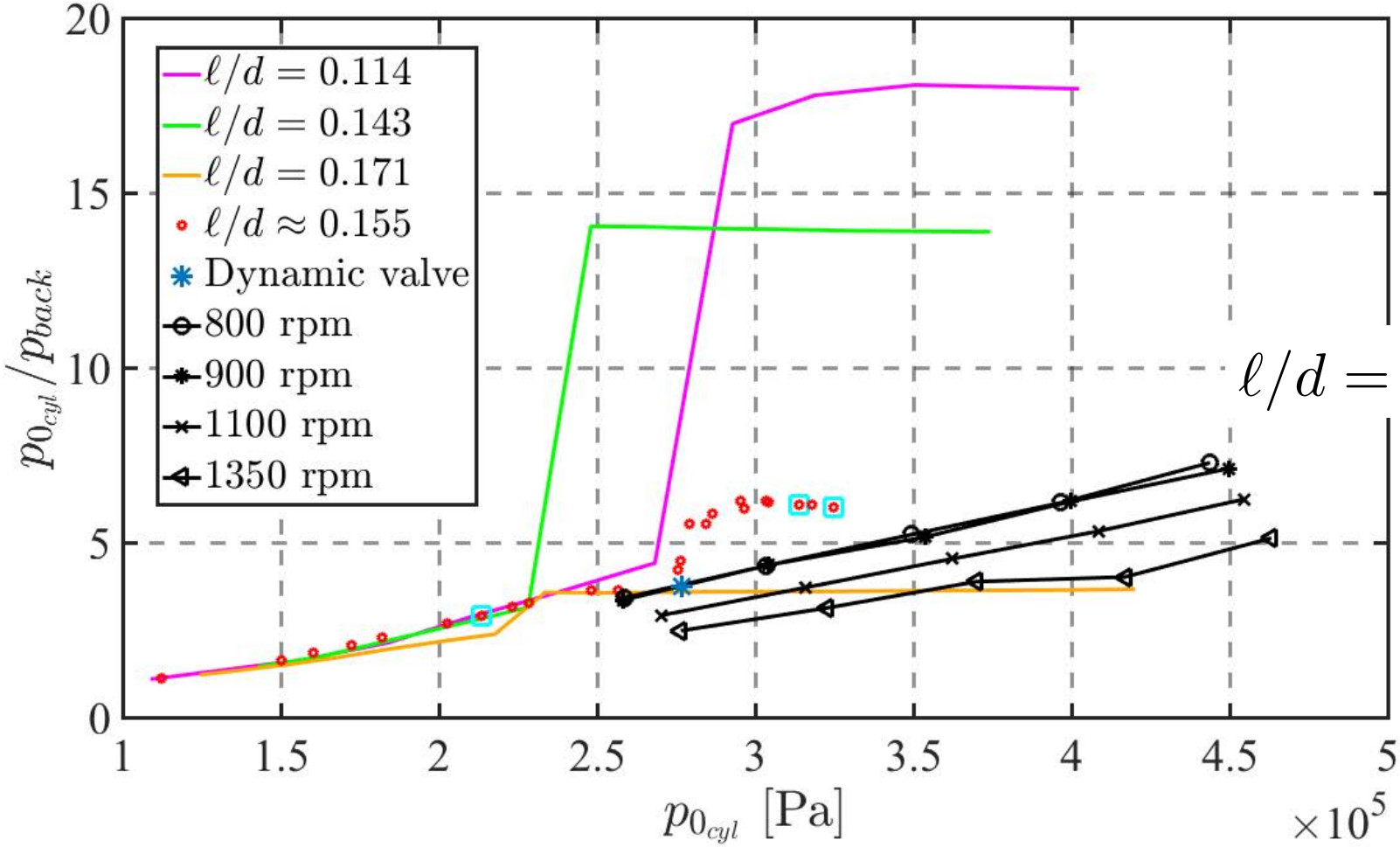
Schlieren setup

n - Refractive index
ρ - Density
K - Gladstone-Dale constant
f_i - Focal length

$$n = 1 + K\rho$$

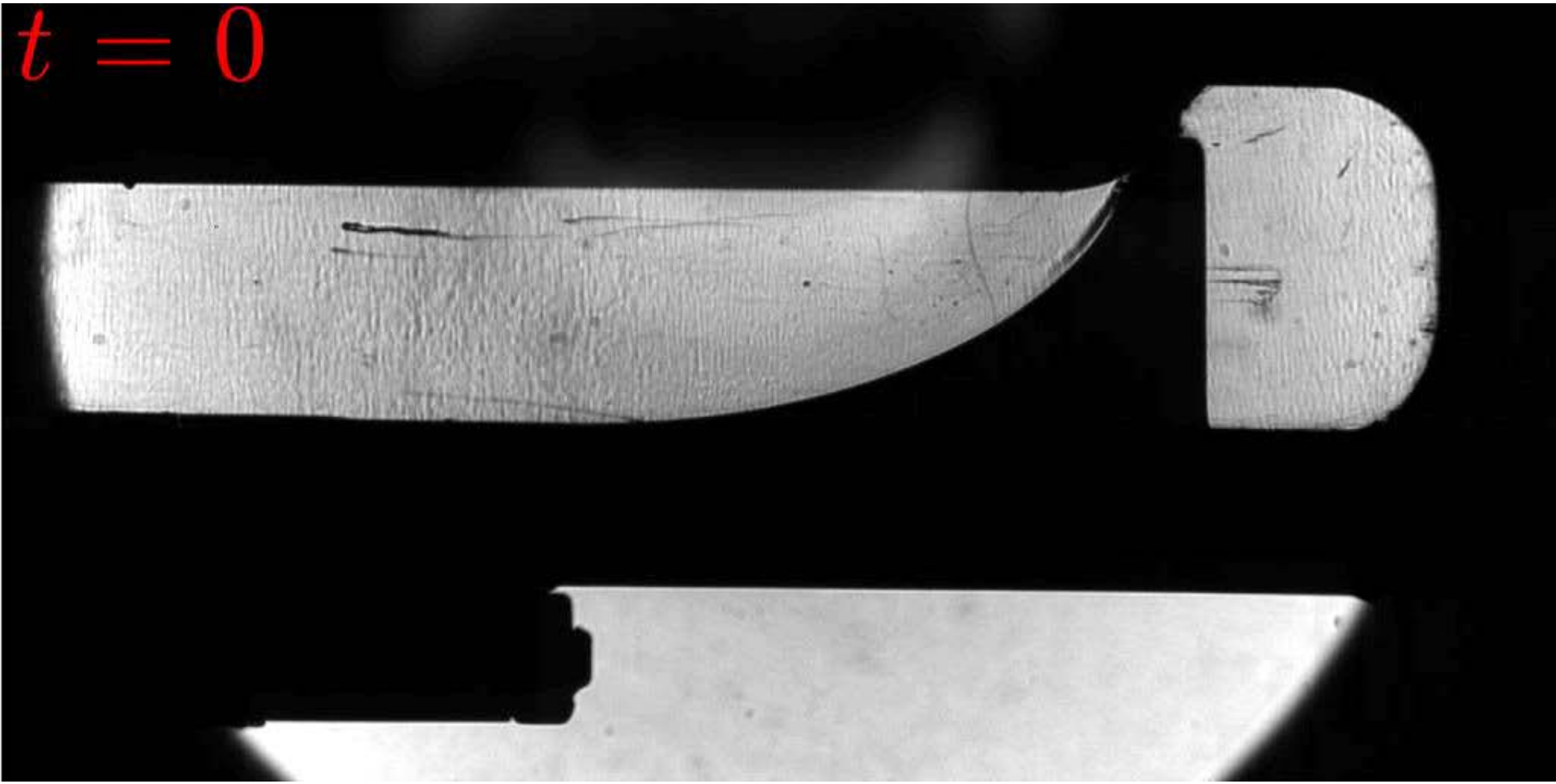


Pressure ratio

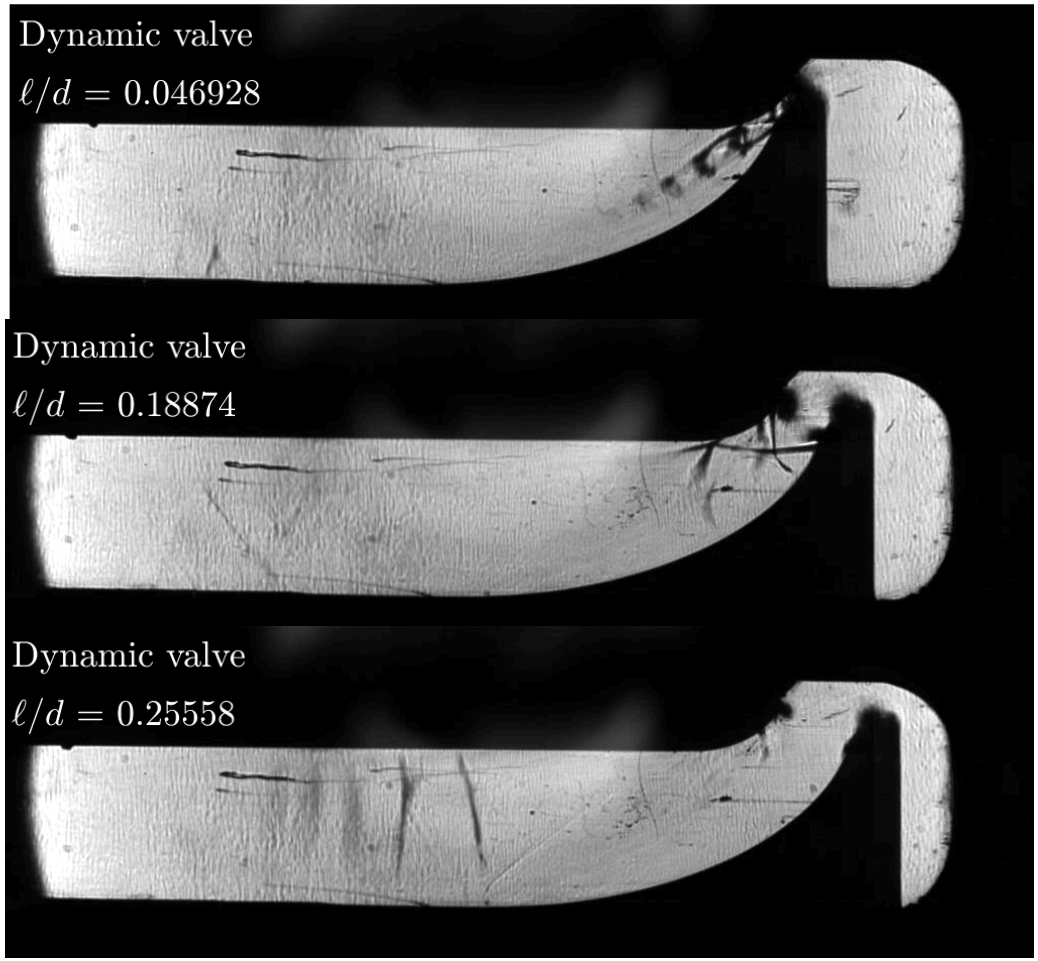


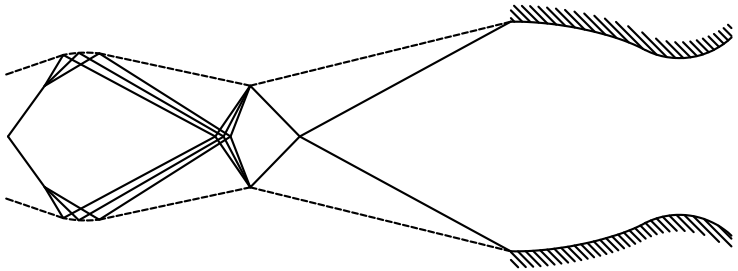
$\ell/d = 0.143$

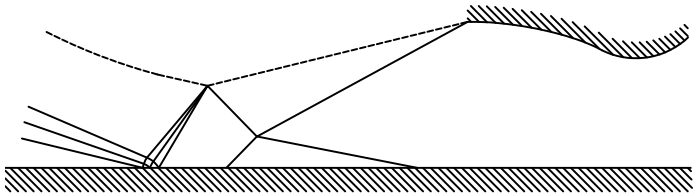
Dynamic process (n = 1350 rpm)

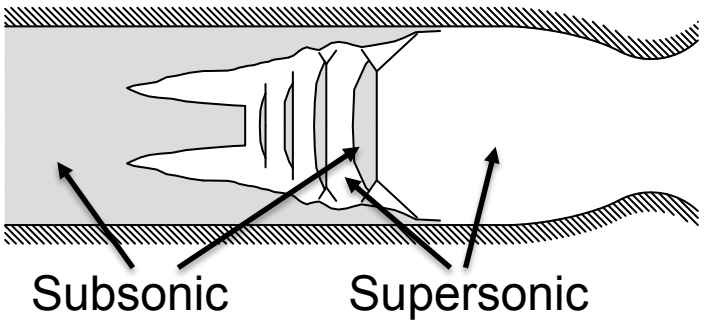


Flow states in the dynamic process









Comparing dynamic & static operations

Dynamic

$\ell/d = 0.154$

$\mu = 42.8°$

$M = 1.47$

Static

Regime I

$\ell/d = 0.155$

$\mu = 52.1°$

$M = 1.27$

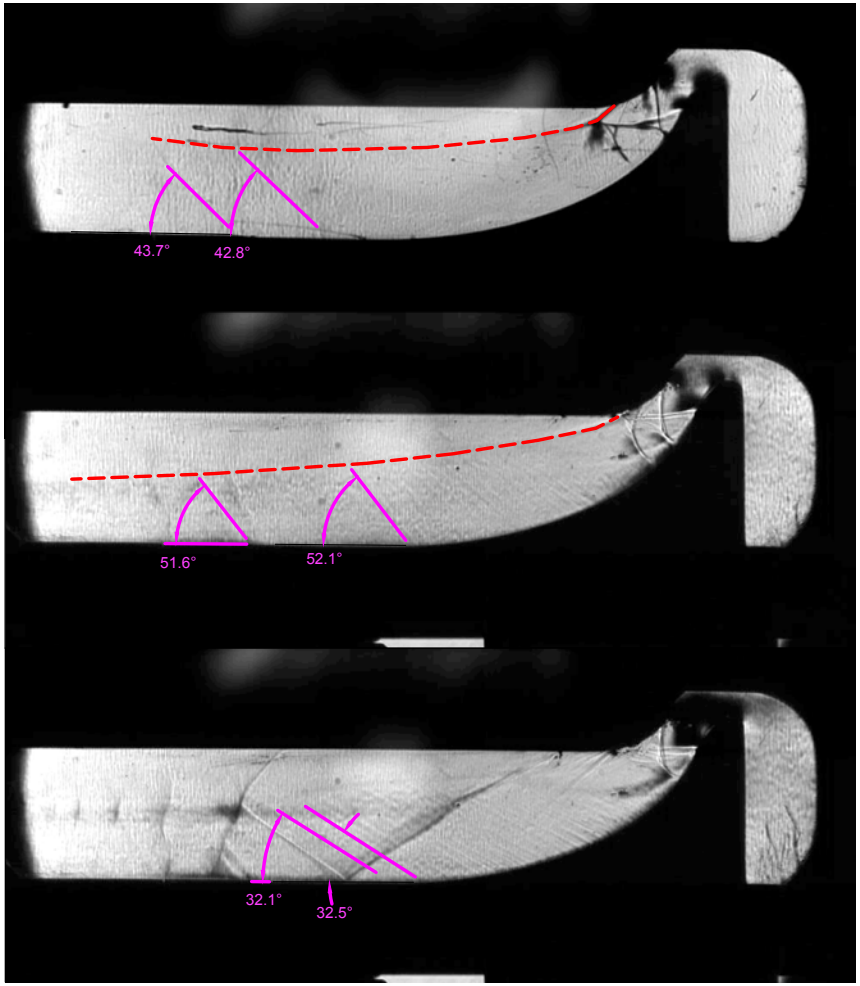
Regime II

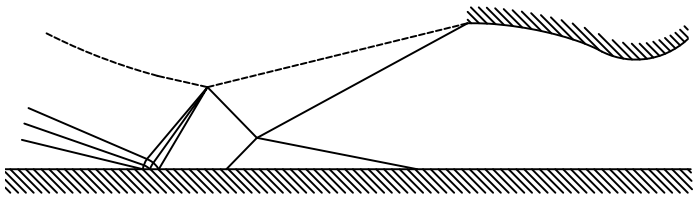
$\ell/d = 0.155$

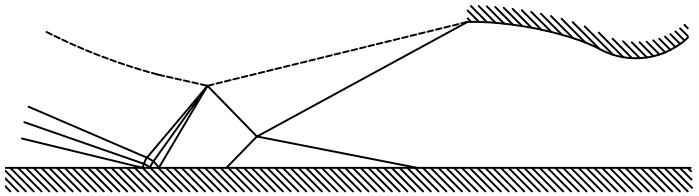
$\mu = 32.1°$

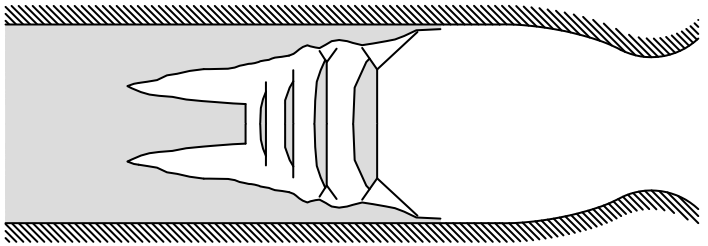
$M = 1.88$

$$M = \frac{1}{\sin \mu}$$









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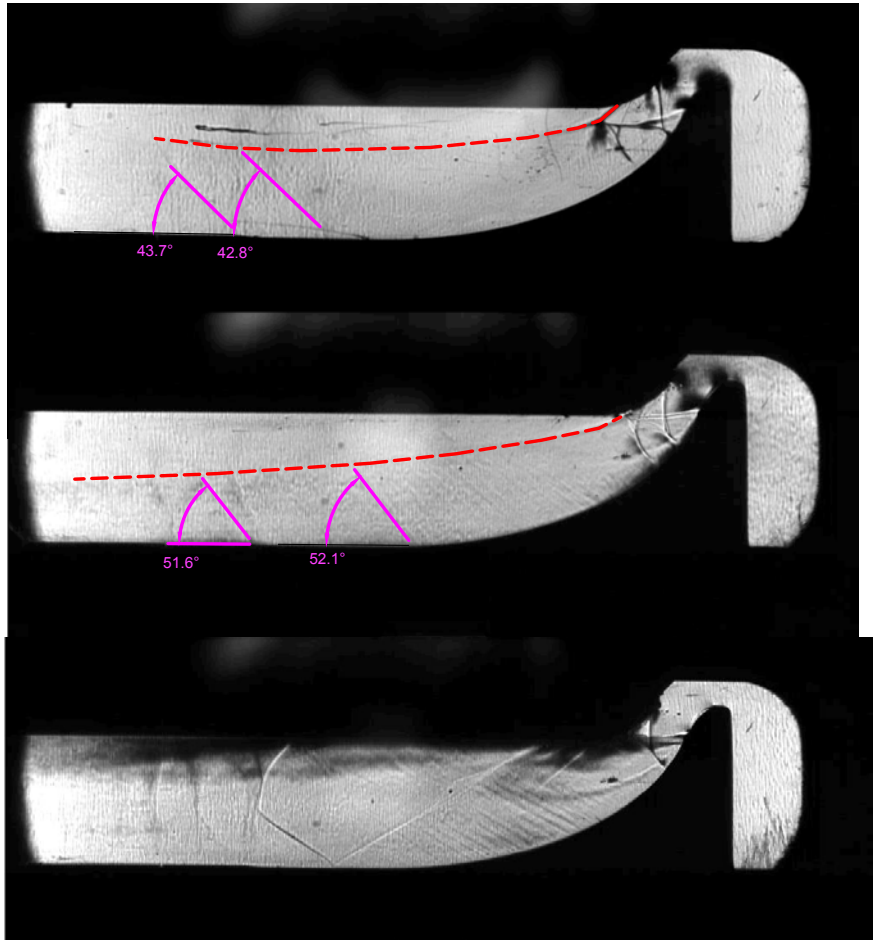

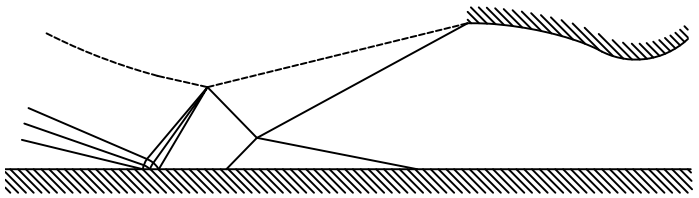

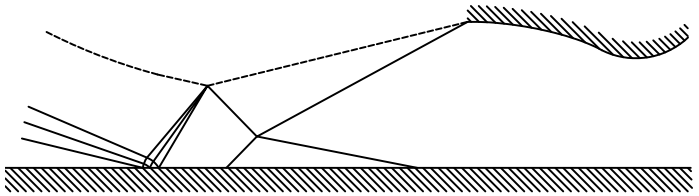

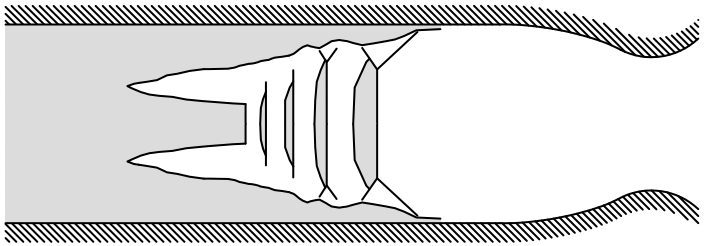

$$M = \frac{1}{\sin \mu}$$

Conclusions

- The exhaust port flow has three distinct flow states:
  A. Overexpanded jet with free boundaries (small l/d)
  B. Overexpanded wall bounded jet with one free boundary (medium l/d)
  C. Fully expanded flow terminating in a normal pseudo-shock (large l/d)
- The dynamic discharge process goes through flow states A - C, showing mainly a dependency on l/d.
- The steady flow process show a transition from flow state B. (regime I) to flow state C. (regime II) (function of cylinder pressure) at lower l/d compared to the dynamic process.
- The characteristics of the state B jet (shock pattern, shape, Mach number) differs between dynamic and static operations.

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