EXPERIMENTS ON TURBULENT FLOW UNDER COMPRESSION

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In order to make future combustion engines more efficient, basic flow studies of various processes are needed [1]. Here confined turbulent flow under strong compression is studied in order to mimic the flow in the cylinder of an internal combustion engine during the compression stroke. The flow inside the cylinder before compression depends on the flow through the inlet port (manifold and valves, see e.g. Ref. [2]). During the intake of the air-mixture flow fluctuations as well as specific type of overall fluid motion (usually denoted swirl and tumble) are introduced in order to ensure efficient mixing between the fuel and the gas. As the valves close and the piston compresses the gas in the cylinder, the flow structures and turbulence in the cylinder change. The flow development is apparent from the right hand side of the vorticity transport equation (1)[1] and are due to vortex stretching, time dependent compression, baroclinic effects and viscous diffusion.

$$\frac{\partial \omega_i}{\partial t} + u_j \frac{\partial \omega_i}{\partial x_j} = \omega_j \frac{\partial u_i}{\partial x_j} - \omega_i \frac{\partial u_j}{\partial x_j} + \frac{1}{\rho^2} \epsilon_{ijk} \frac{\partial \rho}{\partial x_j} \frac{\partial p}{\partial x_k} + \frac{\mu}{\rho} \frac{\partial^2 \omega_i}{\partial x_j^2} \quad (1)$$

The time dependent compression term (second term on the RHS) can also be written (with the help of the continuity equation)

$$-\omega_i \frac{\partial u_j}{\partial x_j} = \frac{\omega_i}{\rho} \left(\frac{\partial \rho}{\partial t} + u_j \frac{\partial \rho}{\partial x_j} \right) \quad (2)$$

clearly showing the influence of the compressibility (change of density).

A unique flow apparatus has been developed which allows for large volume compression ratios, up to almost 1:20. A schematic figure as well as a photograph of the set-up is seen in the figure. In order to not produce too high pressures in the glass cylinder during the compression stroke, the gas is first expanded to a low pressure before initiating the compression stroke. The turbulence and flow structures can either be introduced by a grid connected to the piston during the expansion stroke or through nozzles in the cylinder head and suction through its centre. In the first situation near isotropic turbulence is generated, in the second swirl and or tumble together with turbulence. In the second case the cylinder head can be rapidly changed pneumatically to a glass head that allows optical access also close to the top dead centre (TDC). The movement of the piston is done with a linear motor and the compression stroke takes less than 1 second. Measurements are done using Laser Doppler Velocimetry and 2D time-resolved PIV. Also the influence of various piston bowls can be studied in this setup.

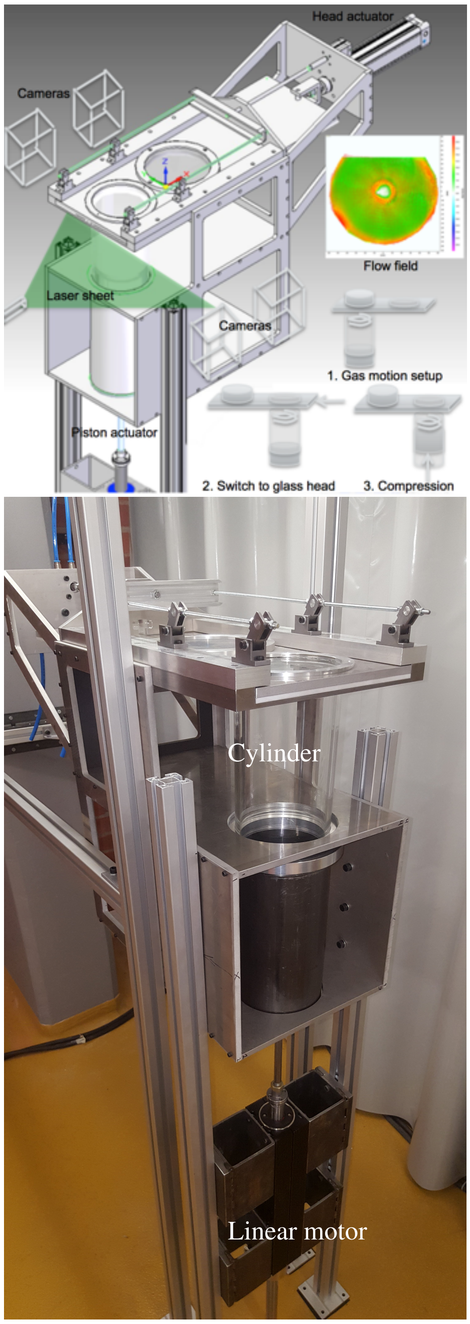

Figure 1. Drawing of the newly developed flow system (upper) and photograph of the setup (lower).

References

[1] Manley, D.K., McIlroy, A. & Taatjes, C.A. 2008 Research needs for future internal combustion engines. *Phys. Today* **61** (11), 47–52.

[2] Miles, P.C. 2009 Turbulent flow structure in direct-injection, swirl-supported diesel engines. Chapter 4 in *Flow and Combustion in Reciprocating Engines*, series: Experimental Fluid Mechanics (Eds. C. Arcoumanis & T. Kamimoto), Springer, pp 173–256.

[1] In Eqs. 1, 2, ω_i and u_i are the i:th vorticity and velocity components, respectively, ρ the density, p the pressure, μ the dynamic viscosity, and ϵ_{ijk} the permuation symbol.