PIV measurements of the flow through an intake port using refractive index matching

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The design and operation of a test bench to measure the flow inside the model of an intake port of an automotive combustion engine by means of optical methods is presented.

Different model materials and matching fluids are discussed with respect to their ability to be used in the test bench. The main requirements for the combination of fluid and model material are to match the refractive index, offer the ability to manufacture the very complex shape of the flow channels of the intake port and maintain Reynolds-number identity.

For the material cured Epoxy resins as created by rapid prototyping machines are very interesting, especially since transparent resins for stereolithography became available recently. However, the refractive index is rather large (n≈1.51) and cannot be matched with any feasible liquid. Therefore PMMA is the better choice, although model manufaction is much more challenging for complicated shapes. Finally, the model was machined by means of 5-axis CNC milling.

The discussion of different liquids reveals that aqueous solutions of sodium iodine (NaI) or zinc iodine (ZnI2) are most interesting. The latter one—in principle—offers the advantage of a larger refractive index range. However, it was found that the strong solutions discolorate quite intensively and thus this advantage cannot be used. NaI on the other hand was found to discolorate only slightly and can be maintained almost fully transparent by additional chemicals. To match PMMA a mass-based solution of approximately 62.5 % of NaI in deionized water is used, which has a similar kinematic viscosity as water and thus with a 1:1 scale model of the intake port full Reynolds number identity can be established.

Exemplary PIV measurements of the flow through the intake ports are presented to highlight the success of the test bench design. The results from two different measurements are presented and compared: A simple 2C2D-PIV measurement in a specific plane as well as section-wise scanning of the whole flow field by means of a 3C2D-Stereo-PIV setup. The data from the latter measurements has been compiled into a reconstructed volume database and thus offers similar abilities for analysis as numerical data.

The 2C2D measurements gave very convincing results, resolving detailed flow structures inside the intake port, around the valves and the valve seats and also in the cylinder. For this setup almost no limitations of optical access were experienced. The 3C2D-experiments suffered from some problems in distinct areas, e.g. around the valves. Still the data that was acquired offers a more than valuable database for the validation of numerical tools, giving detailed insight into the flow fields, the built-up and decay of tumble and swirl and the accompanying flow structures.