LDA volume flow rate standard for water using high spatial resolution LDA for traceable measurements in power plants

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Precise volume flow rate measurements are very important for controlling power plants. Due to the current uncertainty of volume flow rate measurement of about 2 % the process is not controlled efficiently. Therefore, the maximum power output is reduced. With a newly developed laser optical volume flow rate standard (LVS) it will be possible to calibrate flow meters on site within the power plant to reduce the uncertainty of the flow rate measurement.

For the LVS, the velocity profile within the pipe is measured with laser Doppler anemometry (LDA). The profile is integrated to calculate the volume flow rate. Since a conventional LDA has a measurement volume length of about 2 mm, the near wall region cannot be resolved. This leads to an offset of the volume flow rate of about 1,3 %. To overcome this limitation a high resolution LDA was developed.

Therefore, a LDA measurement volume with a constant fringe spacing is overlaid with a LDA measurement volume with a diverging fringe spacing. This way, the position of a particle passing the measurement volume can be determined with a spatial resolution of 6 μm. With the high resolution LDA the influence of the near wall region on the volume flow rate was reduced from 1,3 % to 0,14 %. To realise the high resolution LDA it was necessary to overlay the measurement volumes of two LDA probes within the pipe. This requires a very low uncertainty for the positioning of the LDA measurement volumes. Therefore, two positioning systems were developed to reduce the uncertainty from commonly up to 5500 μm to 67 μm. Furthermore, two independent measurement methods were developed to precisely align the LDA probes to the positioning system and to the pipe.

With all of the aforementioned improvements it was possible to achieve an uncertainty of 0,19 % (k=2) for the LVS. A comparison of the LVS with the national primary standard for thermal energy (WZP) at the Physikalisch-Technische Bundesanstalt (PTB) with an uncertainty of 0,04 % (k=2) revealed a maximum deviation of 0,07 % for Reynolds numbers from 10^5 to 10^6.