Simultaneous High Speed Stereo PIV and LDA Measurements in the highly transient vortical wake of an axial fan

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This paper presents the results of simultaneous High-Speed Stereo Particle Image Velocimetry (HS-SPIV) and 1D LDA measurements that took place at a fan test stand at the “Fachgebiet Strömungsmaschinen” at the KIT (see Figure 1).

Fig. 1 Experimental test rig

A highly turbulent ducted swirl flow at a Reynolds number of $Re \approx 166,000$ with the swirl component being six times higher than the axial flow components was measured.

A HS-SPIV and a 1D LDA system were triggered simultaneously to cover a time sequence of almost 3s with about 3000 values to compare from each system. The HS-SPIV system operated at a frequency of 1000 Hz with resolution of 1024x1024 pixels whereas the LDA had a sample rate of 50MHz (raw data). Three different positions within the swirl were compared and analyzed (see Table below).

<table>
<thead>
<tr>
<th>Comparable Points</th>
<th>Cross corr. coeff. [-]</th>
<th>Mean Vel. PIV [m/s]</th>
<th>Mean Vel. LDA [m/s]</th>
<th>Mean Vel. Difference [m/s]</th>
<th>Deviation LDA/PIV [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2674</td>
<td>0.63</td>
<td>0.94</td>
<td>0.49</td>
<td>0.45</td>
<td>91.8</td>
</tr>
<tr>
<td>2680</td>
<td>0.70</td>
<td>7.96</td>
<td>7.27</td>
<td>0.65</td>
<td>9.5</td>
</tr>
<tr>
<td>2682</td>
<td>0.54</td>
<td>8.96</td>
<td>8.55</td>
<td>0.41</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Main problems for a simultaneous measurement were the different seeding requirements of both systems and the nearly identical wavelength of the used laser systems. Approaches for most of the encountered problems are shown.

The analysis showed not only a clear correlation between the time resolve LDA and PIV signals for all measured positions (as shown in Figure 2), but also a good correlation in terms of magnitude (see Figure 3). Sources of errors were analyzed and described.

Fig. 2 Cross correlation PIV-LDA Data

Fig. 3 Superimposed PIV and LDA data

The authors conclude that a well-adjusted HS-SPIV system can resolve flow phenomena as accurate in time and absolute velocity as LDA. Additionally it delivers spatial information of the flow field which is not possible using a LDA system. For a measurement of characteristic turbulent parameters however, it fails since the time between pulses averages out crucial velocity fluctuations.