PIV for Complex Flow Geometry Using Index-Matching Technique — Application to Water-Jacket Model —

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Background

(1) Very complex flow geometries in engineering applications impose severe limitations on optical imaging techniques such as Particle Image Velocimetry (PIV).

(2) In many cases, more effort & cost are needed for solving/avoiding such limitations than to conducting measurements.

(3) Any solution for this problem can enhance the usefulness of optical imaging techniques.

Index-matching technique for flow diagnostics
Once good optical access is gained, the stereo PIV technique can resolve the flow field with spatial resolution and accuracy comparable to those of CFD.

In index-matching fluid, a full 3-D volume measurement of the flow field is feasible.

Sufficient time resolution is also achieved by using the dynamic stereo PIV technique.
Silicone Model for Index-Matching PIV

Acrylic Model of ICE


JK Joint PIV Seminar (2006)
Materials and Fluids for Index Matching

<table>
<thead>
<tr>
<th>Materials</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrex</td>
<td>1.47-1.49</td>
</tr>
<tr>
<td>Acryl</td>
<td>1.49-1.53</td>
</tr>
<tr>
<td>Urethane</td>
<td>1.51-1.54</td>
</tr>
<tr>
<td><strong>Epoxy</strong></td>
<td>1.55-1.57</td>
</tr>
<tr>
<td>Silicone rubber</td>
<td>1.40-1.43</td>
</tr>
</tbody>
</table>

n=1.33 for water

<table>
<thead>
<tr>
<th>Working Fluids</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycerol solution</td>
<td>1.33-1.47</td>
</tr>
<tr>
<td>Zinc iodine (ZnI₂) Solution</td>
<td>1.33-1.62</td>
</tr>
<tr>
<td>Sodium iodine (NaI) solution</td>
<td>1.33-1.50</td>
</tr>
<tr>
<td>Kerosin</td>
<td>1.45</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>1.48</td>
</tr>
<tr>
<td>Olive oil</td>
<td>1.47</td>
</tr>
</tbody>
</table>

Budwig (1994)

Effect of Index Matching

air  water  IM fluid
Water-Jacket Model for PIV

Photo-fabricated WJ model

Water-Jacket Model in Index-Matching Fluid
Particle Image Acquired

Measured Regions (Blocks 1 & 2)
Define a virtual plane in the measuring location.

Project back the image onto the virtual plane.

Use Gaussian-weighted interpolation scheme.
Back-projected Particle Image (right)

Results for Block 1

Out-of-Plane Components
Heat Transfer Laboratory, Dept. of Mechanical Engineering

Results for Block 1

Bird’s-Eye View

x-axis [mm]

y-axis [mm]

VecLen2D [m/s]: 0.00

Results for Block 2

In-Plane Components

Out-of-Plane Components
Results for Block 2

Bird’s-EyeView

Measured Holes (Gasket Holes ①-⑧)
Close-Up Stereo-Camera Configuration

Results for Gasket-Hole 7

Bird’s-Eye View
Results for Gasket-Hole

Summary

(1) An approach based on rapid-prototyping and index-matching techniques is proposed for efficient PIV measurement of complex flows.

(2) The usefulness and efficiency of the proposed technique is demonstrated in the stereo PIV measurement of an ICE model made by photofabrication method.