CFD versus PIV

Computational Fluid Dynamics (CFD) is playing an increasingly important role in today's maritime industry. Report explains MARIN's efforts to improve quality levels and outlines the next steps towards full 3D flow understanding.

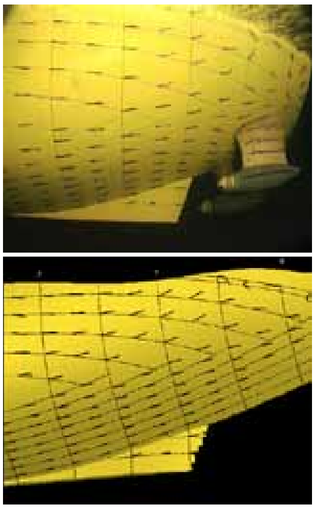

Figure 1: Tuft observation (above) and calculation (below); indication of flow separation

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Nowadays, more complex flows are being calculated and these await comparison and validation with measured data. Guaranteeing and increasing the quality of calculated and measured results becomes an even bigger challenge. For years qualitative data has been obtained from flow visualisation tests using tufts (Figure 1), paint-smearing and dye injection, followed by quantitative flow data from Pitot tube measurements. For general comparison with CFD such techniques suffice. However, these methods have limited applicability and partly obstruct the flow. A flexible system that copes with complex geometries but maintains and eventually increases the quality level, is needed. Therefore, MARIN has taken the next step in the use of Particle Image Velocimetry (PIV).

PIV PIV is a method to determine the velocities in a fluid in an optical, non-invasive way. The flow measurement with PIV is based on measurements of the displacement of a particle in a target plane between two successive light pulses with a time delay. The flow is seeded with micrometre-sized particles and the target plane is illuminated with a laser light sheet. Two digital cameras record the particle positions. Special image-processing software analyses the movements of particles in subsections of the PIV image using correlation techniques. By using two cameras in a stereoscopic arrangement the instantaneous three-velocity components are derived in the measuring plane.

PIV and CFD comparison For the flow around a twin-screw, open-shaft vessel PIV measurements and steady viscous flow calculations (RANS using a SST k-omega turbulence model) have been performed. For the measurements the model was equipped with a full shaft line arrangement with I and V-brackets. Measurements have been carried out at several locations along the shaft line at port and starboard (Figure 2). In the calculation no shaft rotation was modelled and shaft brackets were disregarded because when nicely aligned, no significant effect is expected.
Here we focus on the wake field at port side. Figure 3 shows the comparison of the axial velocity field with and without, shaft rotation in the measurement. The distinct "wake peak" between shaft and hull caused by the shaft shadow is clearly visible. The thickness of the boundary layer is nicely captured and the agreement between PIV and CFD is good.
PIV facilitates a higher spatial resolution compared to Pitot tube measurements, so more flow details can be captured. The influence of the inward rotating shaft is clearly visible and the effect of the V-bracket (yellow-orange contour level) is

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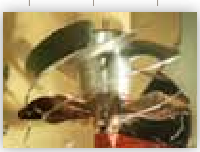

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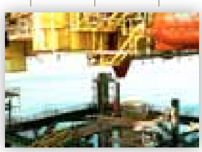


Start Trials & Monitoring activities

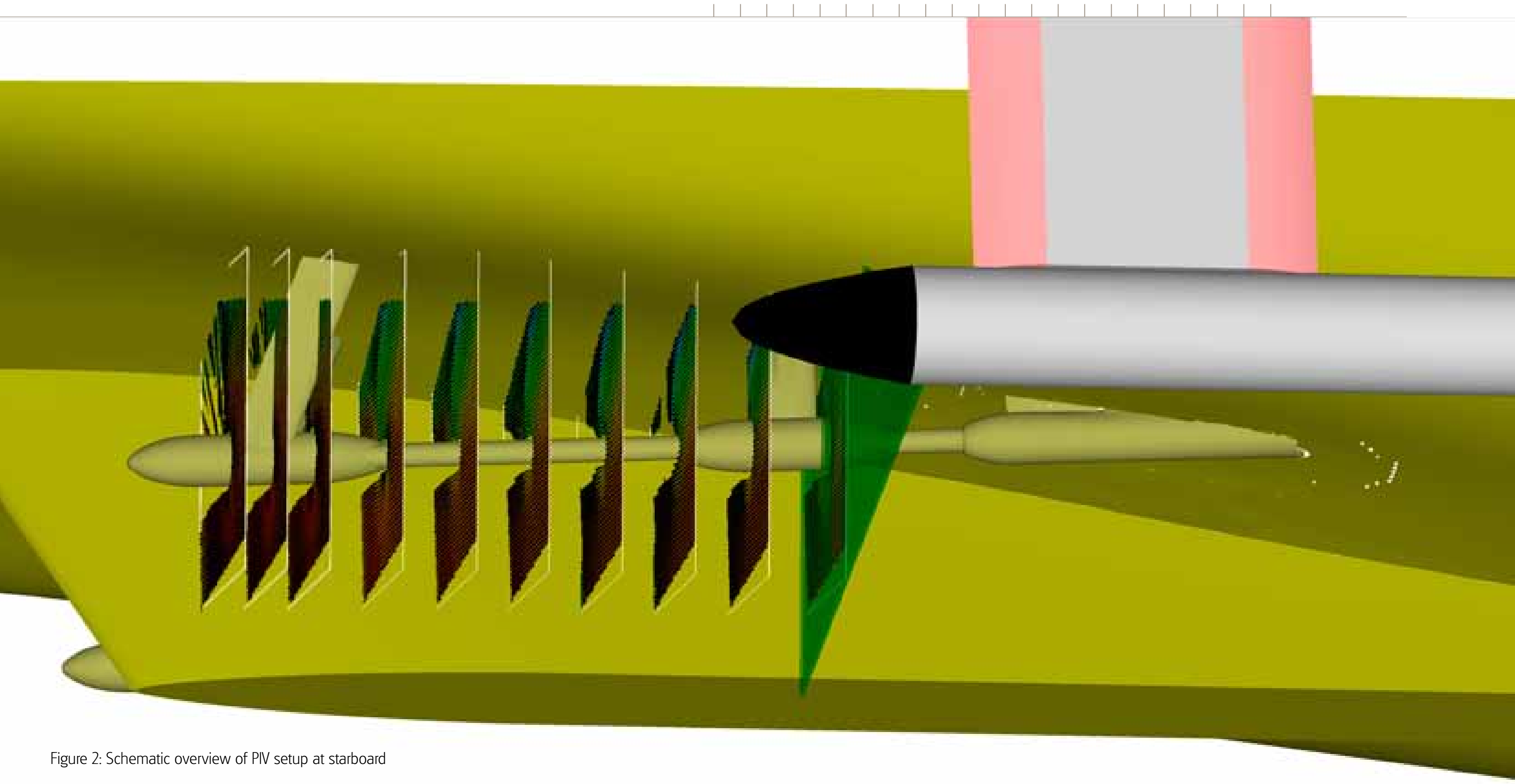
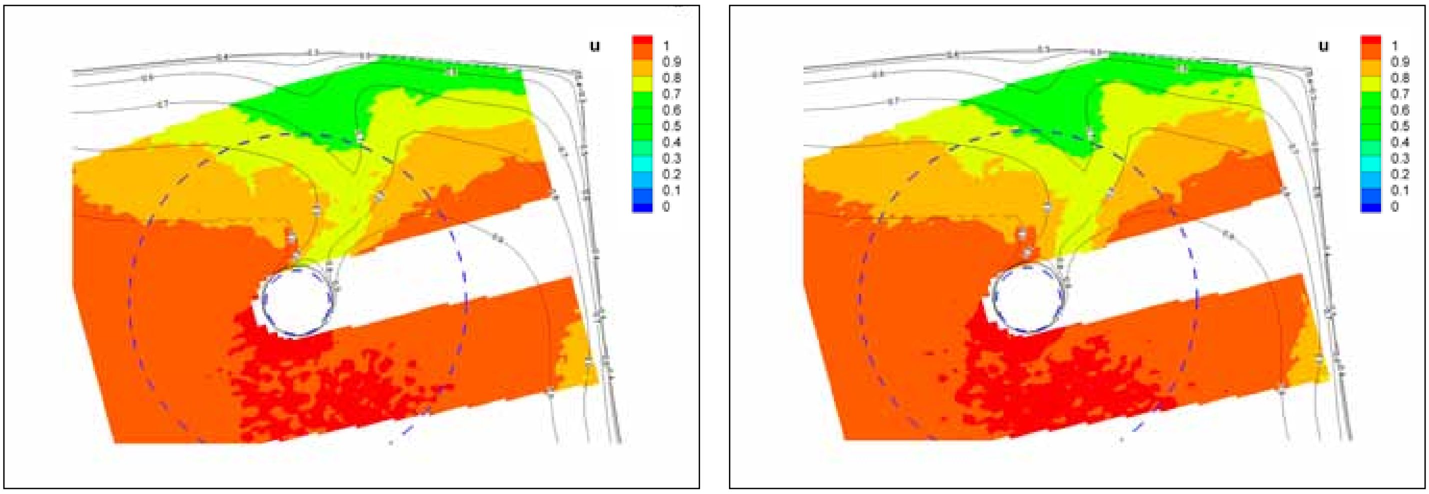


Figure 2: Schematic overview of PIV setup at starboard

visible in the measurements. However, the CFD results show a smooth axial velocity contour because the bracket was not modelled. The effects of both shaft rotation and V-bracket wake in the propeller wake field are small and will not influence an actual propeller design.
However, for other ships, hence other geometries, such effects can increase significantly and this necessitates modelling of these details in the CFD calculations. Comparisons of results along the rest of the shaft line provides more insight and it is possible in regions where no comparison was done before.
The quality and complexity of CFD is increasing rapidly and we are getting very close to a full-appended hull. However, there is always a trade-off. MARIN is constantly assessing the correct level of detail necessary to provide high quality results. It is now even more important to compare CFD with measurements and PIV can provide the necessary high quality data. Finally, this brings a full understanding of the 3D flow field within reach.

Figure 3: Comparison of CFD and PIV results for the axial velocity in the propeller plane; left: without shaft rotation in model test, right; with shaft rotation. Colours represent results from PIV, black lines from CFD.



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First software delivered for PC/DOS

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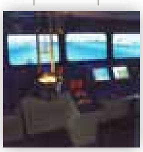

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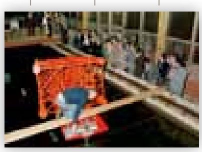

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