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# EFFICIENT VISUALIZATION OF THE FLOW FIELD BEHIND A GRID OF CIRCULAR CYLINDERS USING GLVIEW: A COMPARATIVE STUDY BETWEEN NUMERICAL AND PIV EXPERIMENTAL STUDIES

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**Summary.** A study has been carried out at the Department of Marine Technology at NTNU in Trondheim, where both PIV and CFD studies have been performed on a grid of cylinders simulating part of the net structure of an aquaculture cage. The GLview visualization software developed by Ceetron was specially tailored to visualize the PIV and CFD results simultaneously, making comparisons of the results of the two techniques much more efficient and elegant.

## 1 INTRODUCTION

Computational Fluid Dynamics (CFD) has established itself as an important tool in the study and analysis of fluid flows around marine structures. Modern day CFD gives highly accurate time resolved whole field descriptions of the velocity flow field. Similarly, Particle Image Velocimetry (PIV) is an experimental technique that is also able to give the same type of results i.e.instantaneous velocity fields. The two tools, CFD and PIV, complement each other very well and can give a very detailed description of the flow phenomena being studied, especially for viscous flow.

There has been considerable user development in both the CFD and PIV fields around the world, but equally vital, is developing efficient tools for visualizing, presenting, comparing and validating the data generated. Advanced tools for combining, visualizing and inspecting experimental and numerical simulated data, increases the understanding of complex physical phenomena. Combining these two data sets is a time consuming process including handling of very large amounts of data in different formats, time instants, and resolutions. The 3D Visualization tool, GL View Inova, has extended its functionality to deal with combined visualization, and included advanced features for data interpretation which gives us the opportunity to focus on understanding the content of the data.

A study has been carried out at the Department of Marine Technology, where both PIV and CFD studies have been performed on a grid of cylinders simulating part of the net structure of an aquaculture cage. PIV measurements were made of the flow field downstream of a 3x3 grid of circular cylinders, while numerical simulations were also performed. The work presented here will highlight the use of the GLview visualization software developed by Ceetron specially tailored to visualize the PIV and CFD results simultaneously.

## 2 INTERSECTING CYLINDERS

The primary motivation towards studying the flow around intersecting cylinders was influenced by the aquaculture industry, where a simple representation of intersecting cylinders could represent parts of fish aquaculture cages. The cages are situated in open water and are subjected to currents, and thus the vortex shedding behind the individual cage elements would influence the position and structural integrity of the structure. The flow downstream of a single cruciform configuration is characterized by a large cross shaped wake, with the wake then becoming more two dimensional as you move away from the cylinder intersection. An aquaculture cage consists of many such elements, and thus a grid of intersecting cylinders was chosen so as to replicate the effects of these multiple elements. The flow behind the intersections thus is highly turbulent with a combination of horizontal and vertical wakes in the nearfield of the cylinders[1].

## 3 EXPERIMENTAL STUDIES

### 3.1 Towing Tank Facility and Model

The Marine Cybernetics towing tank facility (MCLab) at the Department of Marine Technology was used for these experiments. The facility is a $40m$ long towing tank with a width of $6.45m$, and has a maximum water depth of $1.5m$. The carriage is moved in the X-direction, and has a maximum velocity of approximately $0.8m/s$, but has been tested to run at speeds as low as $0.01m/s$. For the current experiment, a 3x3 grid of cylinders was used.The diameter of the cylinders was $32mm$ and the spacing between cylinder centers was $220mm$. The arrangement was towed down the tank at a speed of $0.1m/s$. This gives us a Reynolds number based on diameter of approximately 3200 (equal to the full scale Re number).

### 3.2 Particle Image Velocimetry (PIV) Technique

PIV is a full field instantaneous flow velocity measurement technique that is particularly well suited to measuring time varying flows. It is a non-intrusive technique (in the measurement plane of interest), and depending of the setup used, can measure all three velocity components of the velocity vector. The water in the tank is seeded with particles (typically spheres with a diameter $< 100\mu m$), and illuminated with a light sheet generated by a laser (see Figure 1). Using two digital cameras, images of the particle field are obtained. By correlating two consecutive images, velocity vector maps of the instantaneous flow field are obtianed as ASCII data and visualized

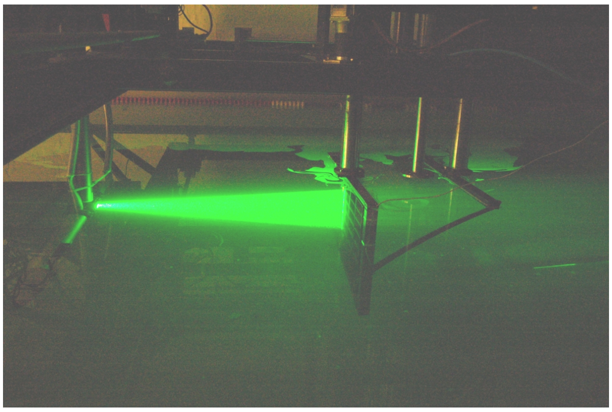

Figure 1: Laser Light sheet used to illuminate the flow field behind the grid of intersecting cylinders. The carriage moves from right to left in the picture, and cameras pointing normal to the light sheet take pictures at a rate up to 10Hz

using any standard visualization package as shown in Figure 2. As can be seen in Figure 2 the velocity vectors are similar to that which can be obtained from numerical simulations of flow fields. In the case of the PIV results, images were obtained at a rate of $10Hz$ thus giving us 10 vector maps per second.

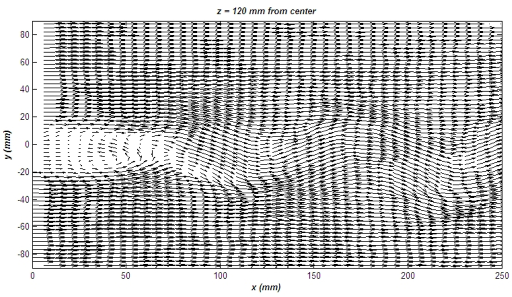


Figure 2: Velocity vectors downstream of the grid of circular cylinders as obtained from PIV experiments and visualized using the commercial Matlab® software package. Here the flow is from left to right and the cylinder is at $(x, y) = (0, 0)$

## 4 NUMERICAL STUDIES

### 4.1 Computational Method

The computational results were obtained using the open source Gerris Flow Solver[2]. An adaptive mesh of quadrilateral cells is utilized. The Reynolds number based on diameter was 1250 for the simulations, and no turbulence model was applied to the computational scheme. The challenge that then arises is how to compare the two data sets (experimental and computational) efficiently and effectively.

### 4.2 GLview: Visualization Tool

The data sets from the experiments and computations are in two different formats, and time steps. The usual method of comparing data sets would be to convert the sets into a common format that can then be visualized in a whatever manner one chooses. However, the quantity of data involved is quite large, and thus the procedure is very time consuming when trying to obtain comparisons. To that effect, Ceetron AS have developed their GLview visualization program to very quickly and efficiently read both the PIV and CFD data and provide comparisons both visually and quantitatively in an easy user friendly package. A screen shot of the tool can be seen in Figure 3. Visible in Figure 3 is a comparison between the experimental (top) and computational (bottom) results highlighting the differences and similarities of the flow field.

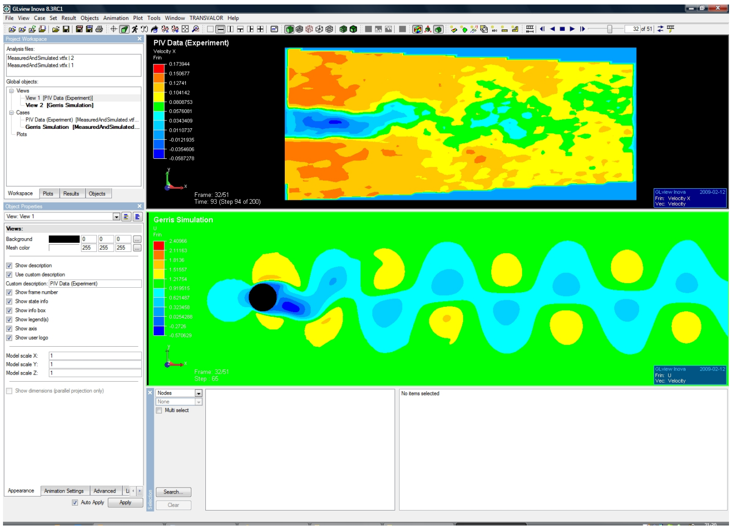


Figure 3: GLview Inova Visualization Tool screenshot showing the comparison between experimental (top) and computational (bottom) results.

## 5 CONCLUSIONS

The use of an advanced visualization tool such as GLview Inova has improved the efficiency of interpreting the combination of PIV and CFD data. The presentation will focus on demonstrating an effective interpretation process using GLView to efficiently and elegantly visualize and compare experimental and computational results.

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