

# Observation and Analysis of Particle Image Velocimetry

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## Abstract

The purpose of the work and research conducted during the SURF 2014 program was to evaluate the capability of the THERMOFLOW™ and FLOWCOACH™ setups and the associated FLOWEX™ software recently acquired by the Mechanical Engineering Department at UNH. The experimental setups enabled the visualization and analysis of fluid flows over various objects subjected for testing. This measurement technique is known as Particle Imaging Velocimetry (PIV) and is a useful tool to investigate complex flows, for instance, those which arise in models of artificial organs, MEMS devices, over wind turbines and many other applications.

## Introduction

The study of Fluid Mechanics is a very large branch in the discipline of Mechanical engineering. The aid of visualization paired with the science and mathematics of the subject is essential for a complete understanding and drive to move forward in the field. Common basic studies to this field include the analysis of external and internal flow systems which involves the concepts of fluid dynamics. Some of the most important and highly used concepts in today's use of fluid mechanics studies were derived from experimental observation, including *No Slip Condition Theory* (Carnasciali).

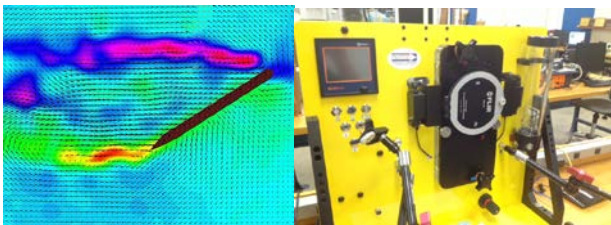


Figure 1: Sample PIV analysis: flat plate; THERMOFLOW™.

The addition of observational tools in today's engineering education would prove beneficial to students studying such practices, as many concepts involved can be abstract when seen strictly through equations. More specifically, the use of PIV equipment will go hand-in-hand with fluid flow studies.

An experimental PIV setup generally consists of fluid flow around particular objects exposed to a dynamic fluid. Typically, the medium used is either air or water (or both). Studies on the velocity of the fluid are taken by multiple still images of the fluid with digital camera devices. Reflective particles, known as seeding particles, are *dissolved* in the fluid and *seen* with the use of lasers and bright strobe lights. The displacement of seeded particles in the test fluid is visualized through the imaging process (see *Figure 2*) and velocity calculations can proceed with the use of computer codes and software.

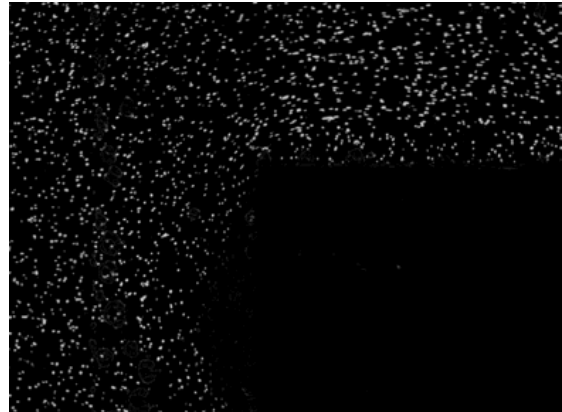


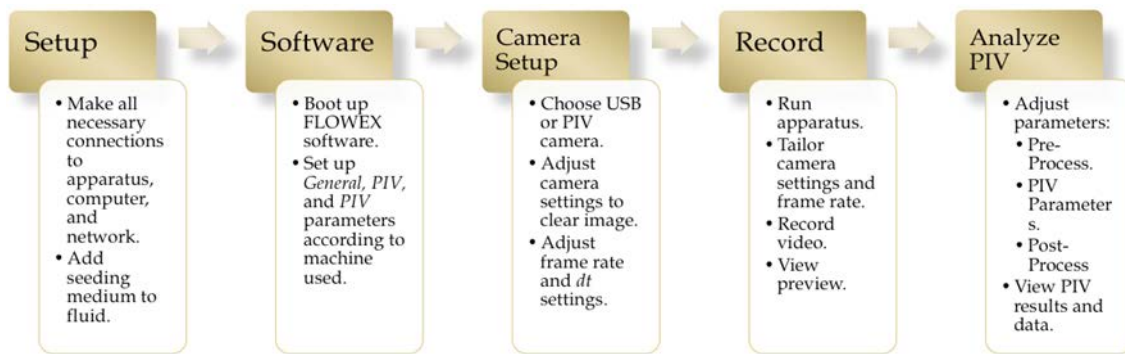
Figure 1: Suspended Microspheres around square geometry – FLOWCOACH™

## Materials and Methods

The methods used during this research consisted of mapping out the quality of measurements obtained from the PIV setups dependent on geometry and patterns of the testing features. This was done by seeding the test fluid with the very small neutrally buoyant microspheres and tracking their displacement with cameras and lighting. The sample flow inserts tested in the FLOWCOACH™ were provided by the manufacturer while custom geometries were printed out of ABS plastic using the uPrint® 3-D printer and dimensional accuracy was measured using the Galileo™ AV metrology system – both of which are accessible in Buckman 225. For the THERMOFLOW™ (seen in *Figure 1*) setup, samples must be made of a heat resistant material and as such will be CNC machined at the Mechanical Engineering Machine Shop.

## Developing Procedural Guidelines

A large part of this experiment involved writing out procedural outlines for the setup and use of the PIV devices (THERMOFLOW™ and FLOWCOACH™) and running the associated analysis software packaged with both machines. Because little literature was provided with the equipment on specific operation and data receiving procedures and little time had been devoted to using the



**Figure 3** - Graphical Procedure for PIV analysis with FLOWCOATCH™ apparatus.

devices, much of the time utilized during research was experimental trial and error runs to obtain a consistent operating process. A basic graphical process was created for quick reference (seen in *Figure 3*), along with an extensive walk-through procedure taking the user step by step to gain flow data. Schematics for hardware connections were also drawn during this process to allow quick initial setup for flow analysis. To demonstrate the methods used during the experimental process, a summary of the more detailed procedural steps follows:

#### *Software Setup*

- Boot up computer with *FLOWEX™* driver
- Open FLOWEX Web Interface displayed on the desktop.
- Click the image of the PIV device being used to set preliminary equipment parameters automatically. The “General,” “PIV,” and “CFD” settings should automatically be set accordingly.

#### *PIV Camera Setup*

- While in the FLOWEX Web Interface, click the “Acquire” tab on the left hand side.
- With all connections made to the PIV camera, under “Launch Camera Control Software” change “Camera Type” to “PIV” in the drop-down menu.
- Click “Adjust Camera Settings,” a window titled “Select Base Camera Configuration” will appear allowing the user to select the desired camera.
- A new window titled “Sample Viewer” will appear. Click the *eye* icon to bring up a live view window of the camera feed.
- The displayed image will likely be saturated or over-exposed. Click on the *wrench* icon to open the “Controls” window and click the arrow next to it to open the sub-menu. Find the Exposure menu, expand it, and on the value column click on the word “Manual” and change it to “Auto” then click the green check to apply.
- Manually adjust the camera lens focus to gain a sharp image of the flow window.

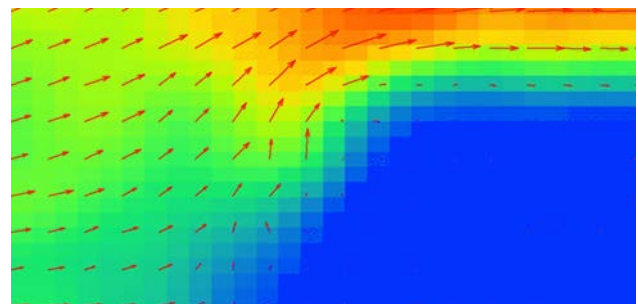
#### *Capturing PIV Video Recording*

- Close the camera “Sample Viewer” if the window is still open. With the machine running and flowing

a steady state, click “Capture Video” and wait for the process to complete.

- The screen will close automatically and return to the “Acquire” page when complete. A preview of the video will be viewable at the bottom of the screen.
- Go to the “Analyze PIV” tab to begin fluid calculations. Go through all parameters desired while reading all information provided on each setting to make necessary adjustments. This includes ‘Pre-Processing,’ PIV Parameters,’ and ‘Post-Processing’ settings to be completed.

The result of running through the procedure explained above allowed for visual and quantitative data based on each recording trial. This gives the user the ability to view original and filtered flow recordings, a color-coded vector field within the PIV window (seen in *Figure 4*), analytical graphs at a desired point within the PIV window representing fluid velocity versus frame of the recording, and an entire library of all data points processed, all frames stored, and all stills captured.



**Figure 2** - Visual vector field from PIV over square geometry - FLOWCOATCH™

#### *Designing Custom Inserts*

The other major process involved during the research was designing and manufacturing custom inserts. The need for laminar flow during early stages of research was necessary in order to create basic procedures for running the machinery. Complex inserts would create too many variables in flow analysis when simple obtaining consistent data from the software was the objective. For this to occur, a flat plate was developed to take the place of the provided inserts with extruded geometries. This allowed for



**Figure 5** - Flat plate insert after cold acetone bath.

no obstructions in the flow path, creating linear flow, the simplest for computing purposes.

Several options were available to create the flat plate. Because the rapid prototyping machine was readily available, it was decided to make the insert (and eventually other custom inserts) out of 3-D printed ABS plastic. However, these inserts could only be used in the FLOWCOACH<sup>TM</sup> device as opposed to the THERMOFLOW<sup>TM</sup> where heat is transferred to the insert, which would result in damage to the ABS plate. In order to print the plate insert, it was first drawn using Solidworks<sup>TM</sup>. The drawing file is converted to an STL file making it readable by the 3-D printing software and convertible to tool-path code.

Through several printing attempts, it was discovered the best surface finish results were produced by orienting the build in a vertical position. By doing so, only the ABS layering produced the texture on the flow surface. In order to obtain as close to laminar flow as possible, a finishing technique was used to smooth the flat surface. A process known as a cold acetone bath used acetone fumes to melt the layers into each other, creating a glossy finish (seen in *Figure 5*) (Kraft). The inserts were then primed, painted black, and wet-sanded to further the finishing process. It was necessary to have the inserts a dark color in order to contrast the bright microspheres illuminated by the strobos and become visible during filming.

Several issues were encountered during the printing process. Inserts that contained extruded geometry off the flow surface had the tendency to tip over during printing. The only way this was avoided was by orienting the insert so the center of gravity was relatively low, and choosing a support material configuration that created a larger footprint on the print board.

## Results

At the end of the time allotted for the summer research experience, there was success in utilizing the FLOWCOACH<sup>TM</sup> setup and obtaining flow data from several inserts. It was clear, however, there was room for improvement. Because much of the early stages of research involved setting up and finding appropriate settings to the software and equipment, it left only simple flow tests to be analyzed, certainly not the extent of the equipment's capabilities.

## Conclusions and Future Work

It became clear during research that it was critical to apply the correct settings in both the software and camera parameters to obtain consistent and accurate results. Much of the research consisted of running tests changing one parameter at a time to see the deviation in results computed by the PIV software. The capabilities of the equipment and software used were seen to the extent the SURF time frame allowed for.

There is the potential for continuation of the research. Various samples will be designed and built using the same processes to gain further data. Other elements will be added as well, including the addition of heat to the flow inserts in the THERMOFLOW<sup>TM</sup> device. The use of lasers and strobos synchronized with the camera will also be an added feature. Finally, a brief instructional operator's manual will be created for the setup of the equipment and provided to future users in laboratory or classroom environment. This, in itself, is a substantial contribution.

## References

- Carnasciali, Maria-Isabel, "Fluids in Motion," University of New Haven Spring 2014. Lecture
- IFS – Interactive Flow Studies*. Interactive Flow Studies Corporation, 2014. Web. 4. March 2014. <<http://www.interactiveflows.com/>>
- Interactive Flow Studies. "THERMOFLOW Heat Transfer and Fluid Mechanics." Interactive Flow Studies Corporation, 2012. 1-6. Print.
- Kraft, Caleb. "Smoothing Out Your 3D Prints With Acetone Vapor." Sept. 24, 2014. Maker Media Inc. 2004-2014. Makenzie.com. Web. July 2014.

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## **Biography**

Ethan Makuck is currently a junior at the University of New Haven studying mechanical engineering. The 2014 SURF program was his first experience with research-based work. Ethan plans to continue his experience with work in the field as a mechanical engineering student by fulfilling his internship requirement in the months to come.

