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METHODS OF IMPLEMENTATION PIV SYSTEM IN THE WIND TUNNEL OF THE DEPARTMENT OF AIR TRANSPORT

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Abstract

In the early days of aviation, wind tunnels were developed to investigate whether an aircraft is capable of flying, and how capable it was of doing so.They are mainly used as a part of research of aerodynamic forces applied to a model of an aircraft or its parts. There are several methods of measuring the airflow inside a wind tunnel, however this manuscript is concerned with implementation of Particle Image Velocimetry (PIV), especially the software part, in the conditions of the wind tunnel of the Department of Air Transport.

The functions of the software were investigated on the basis of a simple experiment. The poppy seeds were blown on white paper and the images were captured by the camera in slow motion as it moved from side to side and then the images were processed and analyzed. The amount of poppy seeds used varied.The results showed successful use of PIV software and it's application directly in the wind tunnel of the Department of Aviation for research of the effects of aerodynamic forces in aviation, but also in other areas.

Keywords

Wind tunnel, PIV, Implementation, Software

1. INTRODUCTION

Since the beginning of aviation, it was necessary to know the characteristics of the aircraft in the air. The designers realized that if they wanted to build a machine that would be able to fly, they must first understand how the air bypassed its surfaces. Although the first machines were built based on the flight of birds, these attempts were never successful. They did not provide the data they needed to build a flight-capable aircraft. To obtain the necessary data, they had a choice of 2 options, either to get their test aircraft at the required speed, or to blow a static model through the air. The Wright brothers have already used a wind tunnel to study the properties of the various wing profiles of their first Wright Flyer aircraft [1].

A wind tunnel is a device used to measure the aerodynamic properties of bodies. It is currently used not only in aviation, but also in the automotive industry, construction, ecology and the like. By suitable shaping of bodies, we can reduce resistance, energy consumption or design buildings more resistant to adverse weather conditions. The basis of every wind tunnel is also the technique of visualizing the flowing air. The most important techniques used are tufts, smoke, oil paint, Schlieren photography and laser sheet / PIV [2]. The main advantage of PIV is the non-invasiveness of the measurement system and its reliability.

PIV is an optical method for measuring the direction and velocity of a fluid. This method is relatively new and suitable for use in research and education. We insert indicator particles, or particles small enough to follow the dynamics of the fluid flow, into the examined liquid. The liquid with the flowing particles is illuminated by a laser so that the particles are visible in it. We then monitor these particles and, according to the change in their direction and velocity, we can calculate the direction and velocity of the investigated liquid [3].

A typical PIV device consists of a camera, a laser, optics that create a plane of light, a synchronizer that acts as an external trigger to control the camera and the laser, indicator particles and the fluid being examined. The PIV software and a suitable computer are then used to process the generated images [3].

All these things would be useless if we had nowhere to use them. The wind tunnel at the Department of Air Transport in Žilina should have been used for this purpose

"Fig. 1" [4]. Instead, the measurements were made at home, because the tunnel of the Department of Air Transport was in the process of being completed at the time of writing, and the results were processed and evaluated using PIVlab software.

Figure 1: Wind tunnel of the Department of Air Transport.

2. MATERIALS & METHODS

2.1. Equipment

The experiment required at least 15 grams of poppy seeds, an accurate weight, a camera stand, slow-motion camera, white paper of A4 format , PIVlab software and computer. The camera stand was built from Lego and served as a camera holder in a position over the white paper. Little adjustment were added to the camera stand to hold the paper in a fixed position and to protect it from being blown by the air. As a slow-motion camera, iPhone X was used.

2.2. Setup

The camera stand together with white paper were placed on a wooden table. The sight of the camera had to cover the whole white surface. Poppy seeds were put at the bottom of the paper “Fig. 2”.

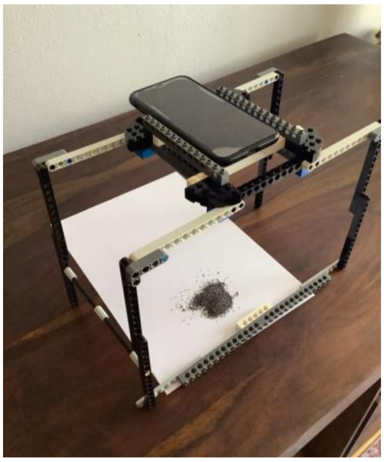

Figure 2: Apparatus setup.

2.3. Measurment methodology

The amount of poppy seeds was first weighted and then divided into 3 groups according to weight: 5 grams, 10 grams and 15 grams group. The experiment proceeded as follows. Each group of poppy seeds was placed separately on the paper to be displayed at the bottom of the camera display “Fig. 3”. Slow-motion mode on the camera was chosen and recording started. Stream of air was applied to the amount of poppy on the paper. After application of the air recording stopped. The videos recorded in this way were further edited and analyzed in PIVlab software.

Figure 3: The amount of poppy seeds. 5g (left), 10g (center), 15g (right)

2.4. Data preprocessing and processing

Each recorded video was cut to only show the starting position and the process of poppy seeds being blown away. To maintain the same conditions, 300 frames of video were determined for processing, with the first frame capturing the initial blow. The coordinate system had its origin in the lower

left corner, where the x-axis increased to the right and the y-axis increased upwards. Every group was supplemented with a calibration image of the ruler placed on the corner of the paper to determine the same scale in the program. Image adjustments were set the same, adding CLAHE, Auto contrast stretch and Subtract mean intensity. Speed limits were not adjusted. The 150th image of the vector “Fig. 4”and velocity magnitude “Fig. 5” was selected for comparison.

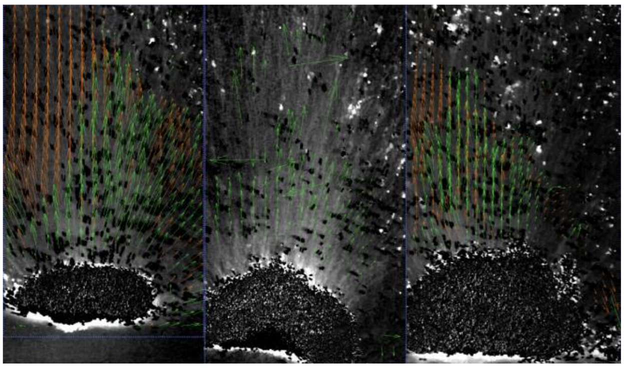

Figure 4: Displayed vectors in groups of poppy seeeds 5g (left), 10g (center), 15g (right) in the 150th image.

Analysis of images with more poppies took more time to process. For every extra 5 grams, it lasted about an extra 2-4 minutes, with a calculation time of about 11 minutes for a group of 5 grams. Based on that a larger number of particles requires more computational operations and this equates to a larger total time.

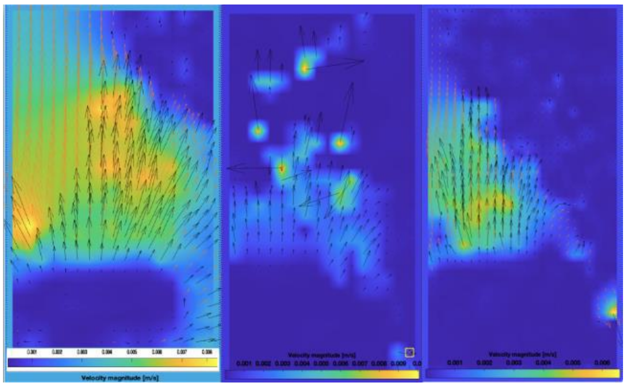

Figure 5: Velocity magnitude in groups of poppy seeds 5g (left), 10g (center), 15g (right) in the 150th image.

The software had trouble correctly determining the vectors of some particles if they were already somewhere on the paper in the initial images. The software had the most troubles in determining directional vectors in a group of 10 grams. In the group with the largest or smallest amount, similar problems did not occur.

3. RESULTS

results showed that the most suitable group for processing is group of 5 grams. The particle saturation ratio of the area and the distance of the camera from the paper was the most ideal for this option. The option with the largest amount of poppy came in second, but it is likely that a measurement error occurred with this option. With such a large amount of poppy, only the particles on the surface of the total amount shifted during the blowing, and therefore there was less surface saturation and better processing than in the case of the 10-gram option.

Therefore, in a wind tunnel, it should be taken into account that with the camera fitted from the test part, a smaller amount of particles will be better for the overall capture and subsequent processing. When analyzing in the software, make sure that the images are edited from the very beginning. Processing in the middle of the sequence can cause incorrect determination of vectors and thus affect our entire research.

4. CONCLUSION

The main goal of the presented manuscript was to investigate the effect of the amount of particles on the processing and analysis in the software PIVlab. Due to the completion of the wind tunnel of the Department of Air Transport, the practical part was carried out at home.

The results of the practical part showed that a higher number of particles meant a longer time for the overall processing. At 10 grams, the software had trouble determining the directional vectors of some poppy grains. The reason was the high saturation of the area in relation to the placement of the camera from the area of paper. This problem did not occur at 15 grams because a large amount of poppy prevented some particles from passing onto the paper during blowing.

It follows from the above that, when researching in a wind tunnel, care must be taken not to overflow with particles. Smaller quantities are easier to analyze and faster to process. Processing may also be affected by the time of initial analysis. For more accurate measurements, it is important to adjust the images from the very beginning.

Although the practical part did not take place in a wind tunnel, it can be concluded that the PIVlab software is sufficiently capable of research and suitable for use in it.

The goal of the work however would lose its meaning if the software was not applied to the wind tunnel. Due to the financial demands of the individual components of the system, the laser was not yet available at the Department of Air Transport at the time of writing. After its delivery, it is planned to connect it together with the camera and the computer and place it so that it illuminates the test part "Fig. 6" of the wind tunnel. Testing of the system will take place first by selecting suitable indicator parts, which must meet the conditions for working with them and will be easily accessible. The conditions are their size so that they can properly follow and copy the air stream and not disturb it, and the ability to reflect light so that the particles are visible on the camera. Additional conditions may be encountered during system implementation. We can verify the functionality of the system by comparing the already existing results of airflow bypass on different wing profiles from other wind tunnels with a wind tunnel at the Department of Air Transport. The comparison determines if the system is set up correctly. Once an agreement has been reached, it can be stated that the PIV has been applied successfully.

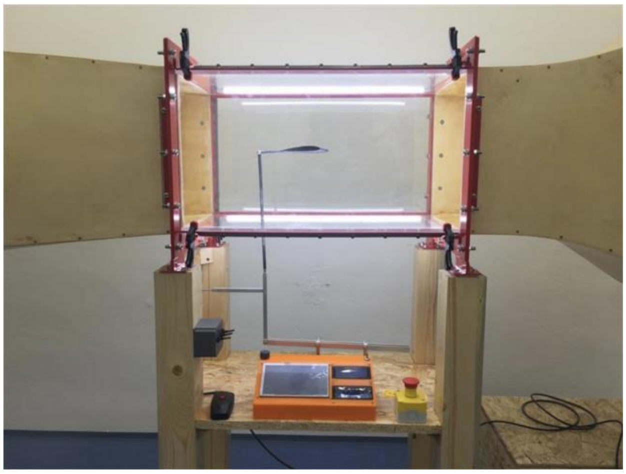

Figure 6: Test part of the wind tunnel at the Department of Air Transport.

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