Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 147 (2016) 288 – 292

Procedia Engineering

www.elsevier.com/locate/procedia

11th conference of the International Sports Engineering Association, ISEA 2016

# System for flow visualization in swimming

Josje van Houwelingen[a], Willem van de Water[a,b], Rudie P.J. Kunnen[a], GertJan F. van Heijst[a], Herman J.H. Clercx[a]

[a]*Eindhoven University of Technology, Dept. of Physics, Fluid Dynamics Laboratory, P.O. Box 513, 5600 MB Eindhoven, The Netherlands*
[b]*Delft University of Technology, Dept. 3ME, P.O. Box 5, 2600 AA Delft, The Netherlands*

**Abstract**

Understanding the power balance of a swimmer, who needs to overcome power losses to drag and to water set in motion, requires detailed insight into the hydrodynamics of the flow around the swimmer. This will be done from a hydrodynamic point of view with techniques familiar from fluid mechanics. One of our objectives is to develop a system to visualize the flow around a swimmer in practice. Currently, the visualisation system is designed and built and we will present the underlying ideas of the experimental setup.


Peer-review under responsibility of the organizing committee of ISEA 2016

*Keywords:* swimming, hydrodynamics, flow visualization

## 1. Introduction

The goal of a swimmer is to swim the race distance in the shortest amount of time, thus to swim as fast as possible. To achieve this the swimmer has to convert his mechanical power into forward motion by pushing-off against the water. The power balance of a swimmer can be written as $P_s = P_d + P_p$, where $P_s$ is the mechanical power produced by the swimmer, $P_d$ is the power loss to drag (related to the speed of the swimmer), and $P_p$ is the power loss related to the push-off against the water. Compared to terrestrial sports the aquatic sports (swimming, rowing, etc.) are unique. While in most sports a term like $P_p$ can be neglected, this term is relevant in the description of swimming, [1,2]. With the push-off water is set in motion. It is not possible to swim without setting the water in motion. Kinetic energy will always be transferred towards the ambient water. Of course, a technique exists whereby this term is minimized. That does not mean that all generated flow motions, such as vortices, produced by a swimmer are a waste of energy. Vortices are of importance in gaining propulsion. That flow visualization helps in understanding the principles behind propulsion has been shown by studies like reported by Takagi et al. [3]. In this study the propulsion of two front

* Josje van Houwelingen. Tel.: +31-(0)40-247-3241
*E-mail address:* j.v.houwelingen@tue.nl

1877-7058 
Peer-review under responsibility of the organizing committee of ISEA 2016
doi:10.1016/j.proeng.2016.06.286

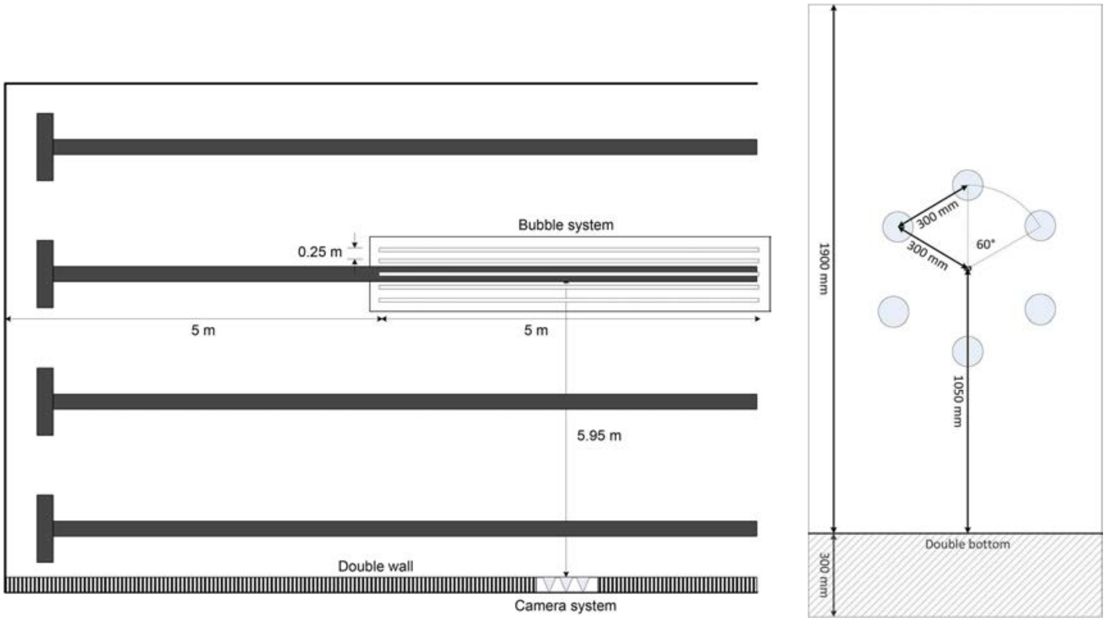


Fig. 1: (a) Schematic plan view of the bubble system placed in the swimming pool. (b) Schematic side view of the camera system.

crawl techniques was investigated by flow visualization using PIV (Particle Image Velocimetry). This study is very illustrative about how lift- and drag-based propulsion arises during the arm stroke, understood from the water motion.

One of the goals of the present study is to develop a system to visualize the flow (i.e. vortices) around the swimmer. The system is inspired by experimental techniques applied in the fluid dynamics community like PIV. For operation use, the system was placed in a regular swimming pool, which entailed a number of challenges.

## 2. Experimental setup

### 2.1. Bubble system

Since the visualization system is placed in a regular swimming pool, neither the use of tracer particles is allowed nor the use of lasers to illuminate the tracer particles. Therefore, as alternative small air bubbles have been chosen as tracers. They are not harmful for the swimmer and the swimming pool, disappear from the pool by themselves and they can be produced continuously and in sufficient amount. The air bubbles, with a diameter of approximately 4 mm, are produced by a 'bubble system', consisting of a set of five parallel tubes of 5 m length with a series of small holes at separation distances of 2 cm along its length. The tubes are placed 25 cm apart. Locally, the double bottom in the swimming pool has been adjusted, allowing the bubble system to be implemented inside the bottom of the swimming pool. In this way the experimental setup can meet the safety requirements of the swimming pool. With a pump and a flow meter for each tube the flow can be set for the appropriate amount of bubbles needed in the measurement volume. Figure 1 shows a schematic view of the bubble system.

### 2.2. Camera system

Another challenge is related with the camera system. Most components have to be resistant to (chlorine) water. Furthermore, a large field of view is necessary to study the flow around the whole swimmer. The cables define the bandwidth of data transfer and thus the particular choice of cameras that can be used. Finally, the chosen camera system consists of six 2 mega pixel cameras with a frame rate of 50 fps. All cameras have a 16 mm lens and are placed