

## APPLICATIONS OF “THREE-THREADS-MEASURING-SYSTEM” IN THE SWIMMING FLUME

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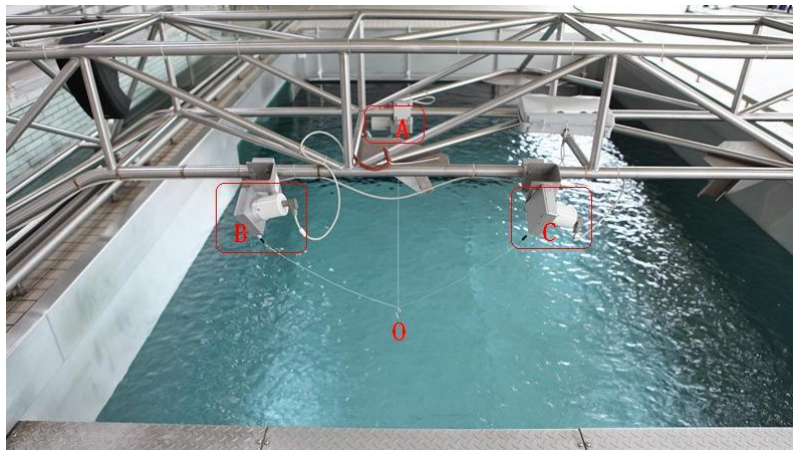
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The purpose of this study was to describe the measurement principles of “three-threads-measuring-system” and its applications. 2 figures show exemplary time histories for 3D velocity during freestyle and breaststroke swimming. More detail parameters can be calculated by a self-developed software. Major parameters, including Max velocity, Min velocity, velocity variation, stroke frequency, distance per stroke, are averaged over 10 stroke cycles. Results indicate: 1)freestyle and breaststroke show different cycle characteristics in the 3D velocity curves; 2)velocity fluctuation(y direction) can be used to determine swimmer’s technique characteristics in freestyle.

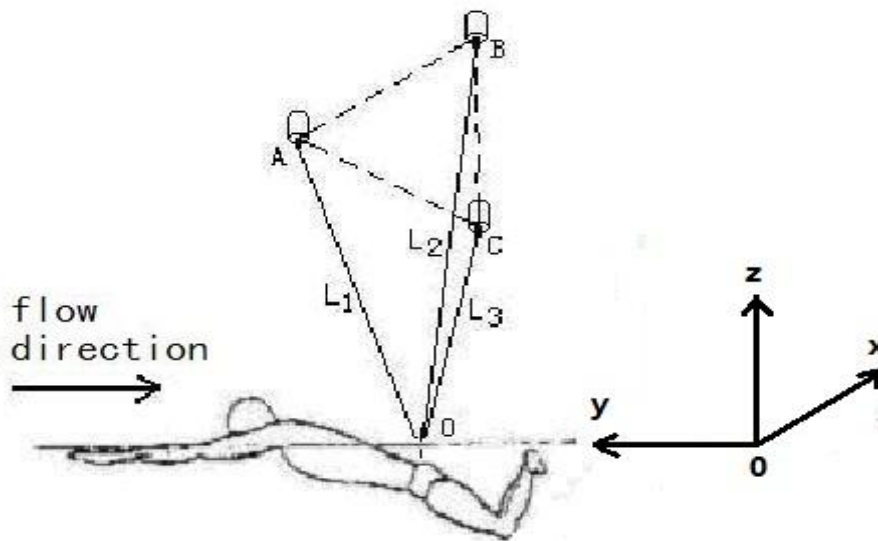
**KEY WORDS:** swimming flume, “three-threads-measuring-system”, application

**INTRODUCTION :** The swimming flume is a typical example of development of the testing system for swimming training. The one (see Fig1) built in Shanghai in 2005 is one of the most advanced swimming flume in the world and provides a variety of flow speeds for training and scientific study. An innovative “three-threads-measuring-system” was developed for measuring swimmer’s velocity, stroke frequency, stroke length and other parameters in the flume. The purpose of this paper was to describe the measurement principles of “three-threads-measuring-system” and its applications.



**Fig1.** The swimming flume and “three-threads-measuring-system” in Shanghai, China

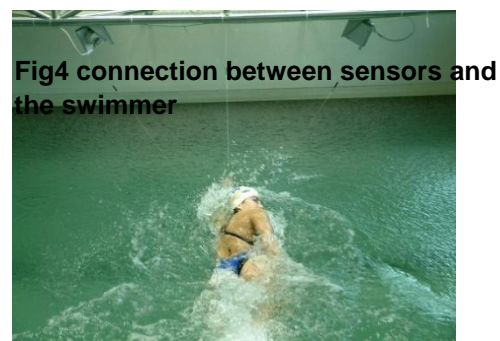
**METHODS :** Three steps are followed to obtain the velocity curve:1) a 3D coordinate is defined with three non-collinear points; 2)a displacement curve was obtained from a displacement sensor.3) a velocity curve was calculated by finite difference of displacement .(See fig2)



**Fig2. Schematic diagram of “three-threads-measuring-system”**

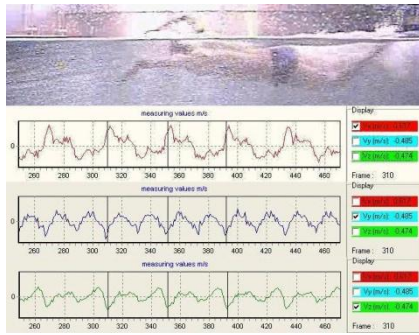
As Shown in Fig2, three displacement sensors were installed at A, B, C sites respectively. The point O, the intersection of three threads was connected to the athlete’s Lumbar Region. Equilateral triangle ABC is parallel to the horizontal plane. The lengths of L1, L2, L3 were measured by the displacement sensors and the three dimensional coordinates of the point O were determined. The three dimensional velocities of the point O were calculated by using finite difference method. Therefore, the measurement of the “three-threads-measuring-system” is based on displacement. The definition of 3D coordinate axis are as following: X direction (namely the lateral direction) is located on the horizontal plane and is perpendicular to y; y direction (namely the forward direction) is located on the horizontal plane and is opposite to the flow, direction z (namely up-down direction) is perpendicular to the horizontal plane.

A video camera was added to the system to record swimmer’s motion. The displacement sensors were made by German ASM and the accuracy is 0.05m/s after computation process.

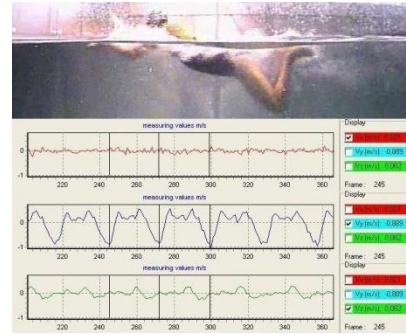


During testing, swimmer wears a custom-made brief which was connected to three displacement sensors installed on a movable frame, as shown in Fig3 and Fig4. When swimmer started to swim, signals from sensors and video from camera were synchronously recorded in a computer. After data processing, velocity curves and corresponding pictures were generated by the system. 56 swimmers were recruited to participate in the testing. The results were used to demonstrate the applications of “three-threads-measuring-system”.

**RESULTS :** Fig5 and Fig6 show exemplary time histories for velocity during freestyle and breaststroke swimming.

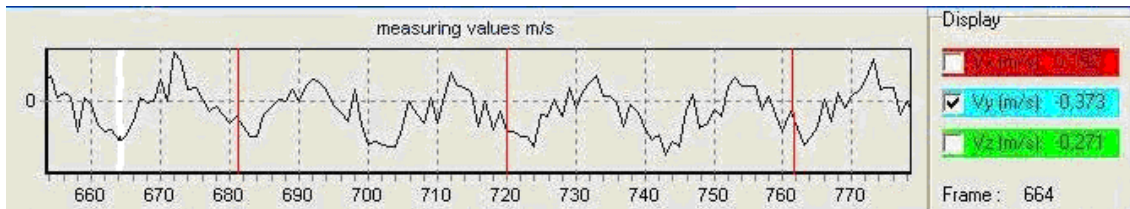


**Fig5 3D velocities during freestyle**

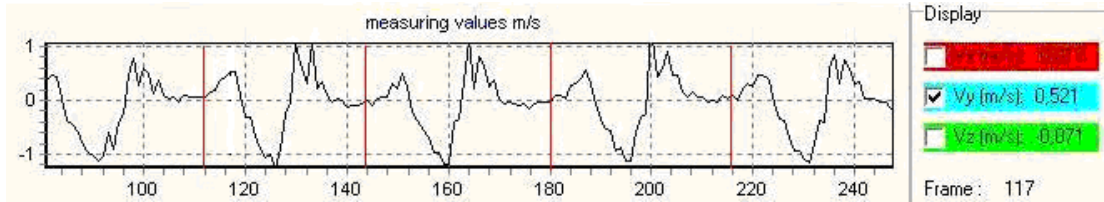


**Fig6 3D velocities during breaststroke**

Fig7 and Fig8 show velocity curves on the Y direction (the forward direction) during a freestyle and a breaststroke swimming. When velocity value is greater than zero, the swimmer's velocity is greater than flow and vice versa. Therefore, the system provides the relative velocity over the flow. The curves of elite swimmers are characterized with smaller burrs, smaller fluctuations and less variability.



**Fig7 cycle characteristics of velocity curve during freestyle on the forward direction**



**Fig 8 cycle characteristics of velocity curve during breaststroke on the forward direction**

More detail parameters can be calculated by a self-developed software. Major parameters, including Max velocity, Min velocity, velocity variation, stroke frequency, stroke length, are averaged over 10 stroke cycles. Table1 shows detail technique parameters during freestyle swimming under 5 different flow speeds.

**Table1 A freestyle player's characteristics under 5 setting speed in flume (Y diction)**

item	1	2	3	4	5
setting speed(m/s)	1.45	1.5	1.55	1.6	1.65
actual average speed(m/s)	1.445	1.502	1.543	1.591	1.631
average frequency (stroke/min)	46.512	48.105	48.673	50.847	52.381
average lap distance(m)	1.864	1.874	1.902	1.877	1.868
average lap time(s)	1.290	1.247	1.233	1.18	1.145
max average speed(m/s)	1.611	1.683	1.725	1.746	1.802
min average speed(m/s)	1.247	1.283	1.324	1.373	1.382
velocity fluctuation (m/s) =max-min	0.364	0.400	0.401	0.373	0.420

**DISCUSSION:** Combines with the video technology and displacement sensors, the "three-threads-measuring-system" provides an innovative velocity measurement and analysis. 1) Freestyle feature (See Fig7): Freestyle speed curve for the forward direction shows "Two-Peaks Two-Valley" features, generated two peaks in the stage of pushing water by right and left hand, and produce the trough in the stage of holding water. The curves of elite swimmers are characterized with smaller burrs, smaller fluctuations and less variability. So it has a direct role in guiding in technological improvements.

2) Characteristics under different flow rate (See Table1): with the increase of flow rate, the "three-threads-measuring-system" speed change range has no significant increase. Results show that the velocity fluctuation and variability did not increase significantly with the increased flow rate. The max and min of velocity fluctuation is 0.420m/s and 0.364m/s separately. It indicated that player had good dynamic stereotype with consistency and stability.

**CONCLUSION :** Freestyle and breaststroke show different cycle characteristics in the velocity curves. Velocity fluctuation can be used to determine swimmer's technique characteristics.

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