

Aero/hydrodynamic Study of Speedo LZR, TYR Sayonara and Blueseventy Pointzero3 Swimsuits

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Abstract

Aero/hydrodynamics plays a critical role in swimming. Studies estimate that over 90% of the swimmer's power output is spent overcoming aero/hydrodynamic resistance. Recently, swimsuits have been aggressively marketed, principally as a means for reducing the skin friction component of the total drag, thereby conferring a competitive advantage over other swimmers. Some manufacturers have claimed significant reduction of drag, but it is difficult to find independent research in the open literature that supports these claims and counter claims. In fact, it is not at all clear that swimsuits in reality reduce skin friction or other forms of drag. At present, there is no standard methodology for the evaluation of swimsuits performance. The primary purpose of this work is to conduct a comparative study of three competitive commercially manufactured swimsuits.

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1. Introduction

Swimming is one of the major athletic sports and became one of the top 10 new sports technologies that changed the 2008 Olympics in Beijing. The competitive swimming game event consists of different distances from 50m to 1500m. These distance events required excessive energy and speed to achieve best recorded within short winning time margins. Studies estimate that over 90% of the swimmer's power output is spent overcoming hydrodynamic resistances [1-10]. These resistive forces were essentially behind the generation of drag during swimming. Reduced hydrodynamic resistance can significantly improve overall swimming performance [11]. The total hydrodynamic resistance can be divided approximately into three, almost independent components: wave drag, form drag, and skin friction drag. The wave drag is associated with the work required to generate waves, form drag is the resistance to motion due to the shape of the body, and skin friction is the resistance to motion due to the area of the body with the water (the wetted area) [1]. The form drag is believed to be constituted almost 90% of the total drag [2]. All three components are velocity-dependent as the swimmer completes the stroke, and all three components depend on the speed of the swimmer, as well as his/her shape, length, and style.

Modern swimsuits have travelled a long path and gone through a series of changes of styles and designs over the decades [1]. More recently, several commercial swimsuits

manufacturers have claimed and counterclaimed about their swimsuits performance by reducing hydrodynamic resistance forces and enhancing buoyancy. Since the Beijing Olympic Games 2008, almost all major manufacturers introduced full-body swimsuits made of semi- and- full polyurethane combined with Lycra fabrics. Most publicized swimsuits of these categories are Speedo®, TYR®, Blueseventy®, Arena®, Diana®, and Jaked®. In Beijing Olympic, out of 32 events, 21 had world records broken and 66 Olympic records were broken. The manufacturers claimed these suits have features such as ultra-light weight, water repellence, muscles oscillation and skin vibration reduction by compressing the body. Strangwood et al., [12], Chowdhury et al. [13] and Moria et al. [1] revealed that technological innovation in both design and materials has played a crucial role in sport achieving its current standing in both absolute performance and its aesthetics. Currently, swimsuits have been aggressively marketed principally as a means for reducing the skin friction component of the total drag, thereby conferring a competitive advantage over other swimmers however, it is difficult to find independent research in the open literature that supports these claims and counter claims [14]. In order to understand the comprehensive hydrodynamics of swimmer, swimsuits and find answers of many contemporary questions on swimsuits, a large research project on swimsuit aero/hydrodynamics has been undertaken in the School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University. As a part of this large research project, we have undertaken a comparative study of a series of commercially acclaimed swimsuits. The study was conducted experimentally using RMIT Industrial Wind Tunnel and specially developed testing methodology.

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2. Testing Methodology

2.1 Description of Standard Cylinder and Experimental Arrangement

With a view to obtain aerodynamic properties experimentally for a range of commercially available swimsuits made of various materials composition; a 110 mm diameter cylinder was manufactured. The cylinder was made of PVC material and used some filler to make it structurally rigid. The cylinder was vertically supported on a six-components transducer (type JR-3) had a sensitivity of 0.05% over a range of 0 to 200 N as shown in Figure 1. The aerodynamic forces and their moments were measured for a range of Re numbers based on cylinder diameter and varied wind tunnel air speeds (from 10 km/h to 130 km/h with an increment of 10 km/h). Each test was conducted as a function of swimsuit's seam orientation and seam positions (see Figure 2).

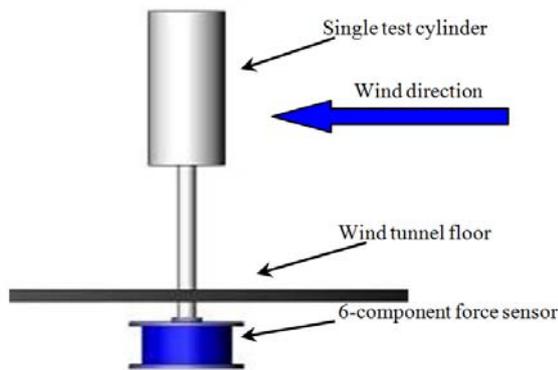


Figure 1. Schematic CAD model of bare cylinder in RMIT Industrial Wind Tunnel [1]

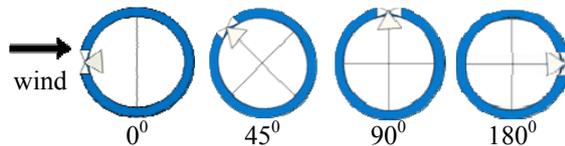


Figure 2. Seam orientation (Bird's eye view)

2.2 Experimental Facilities

As mentioned earlier, the RMIT Industrial Wind Tunnel was used to measure the aerodynamic properties of swimsuit fabrics. The tunnel is a closed return circuit wind tunnel with a turntable to simulate the cross wind effects. The maximum speed of the tunnel is approximately 150 kilometers per hour (km/h). The rectangular test section dimensions are 3 meters wide, 2 meters high and 9 meters long, and the tunnel's cross sectional area is 6 square meters. A plan view of the tunnel is shown in Figure 3. The tunnel was calibrated before and after conducting the experiments and air speeds inside the wind tunnel were measured with a modified National Physical Laboratory (NPL) ellipsoidal head Pitot-Static tube (located at the entry of the test section) which was connected through flexible tubing with the Baratron® pressure sensor made by MKS Instruments, USA. The cylinder was connected through a mounting sting with the JR3 multi-axis load cell,

also commonly known as a 6 degree-of-freedom force-torque sensor made by JR3, Inc., Woodland, USA. The sensor was used to measure all three forces (drag, lift and side forces) and three moments (yaw, pitch and roll moments) at a time. Each data point was recorded for 20 seconds time average with a frequency of 20 Hz ensuring electrical interference is minimized. Multiple snaps were collected at each speed tested and the results were averaged for minimizing the further possible errors in the experimental raw data. Further details about the wind tunnel can be found in Alam et al. [15].

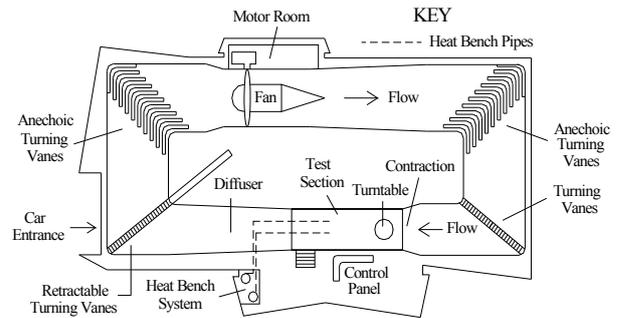


Figure 3. A plan view of RMIT Industrial Wind Tunnel [15]

The bare cylinder was tested initially in order to benchmark the aerodynamic performance as shown in Figure 4. Then the cylinder was wrapped with different swimsuit fabrics to measure their aerodynamic forces and moments. The end effects of the bare cylinder were also considered [13].

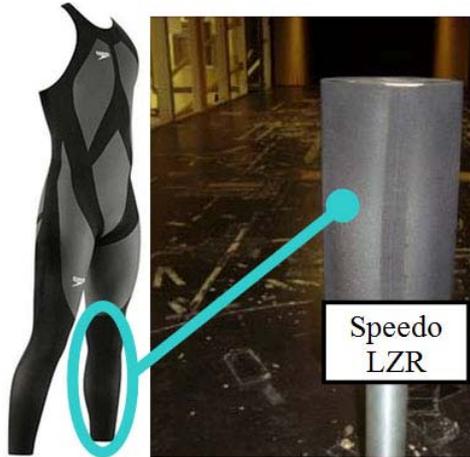


Figure 4. Experimental bare cylinder set up in RMIT Industrial Wind Tunnel

2.3 Description of Swimsuit Fabrics

Three brand new of full-body swimsuit materials have been selected for this study as they were officially used in various competitive events in the World and Olympic Games. These swimsuits are: a) Speedo® LZR, b) TYR® Sayonara and Blueseventy® Pointzero3 (see Figure 5). The Speedo® LZR swimsuit is composed of 70% Nylon (Polyamide) and 30% Elastane (Lycra) and the polyurethane panel was superimposed over some parts on the Speedo® swimsuit while the seam is made by flash joining the two edges using an under layer material (e.g. applying so called ultrasonic weld). The width of the seam is approximately 18 mm. On the other hand, the TYR®

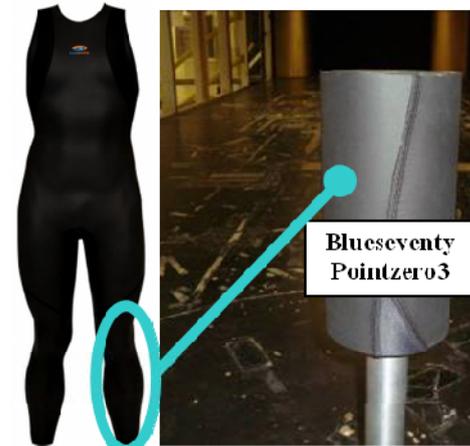
Sayonara swimsuit is made of 55.5% PU-Chloroprene, 40.5% Nylon and 4% Titanium Alloy; and the Blueseventy® Pointzero3 is made of 75% Nylon and 25% PU-CR. The seams of TYR® Sayonara and Blueseventy® Pointzero3 swimsuits are made using four-way flat lock method. The seam has 18 stitches per inch (25.4 mm) length. The width of the seam is approximately 6 mm.



a) Speedo® Swimsuit's Seam



b) TYR® Swimsuit's Seam



c) Blueseventy® Swimsuit's seam

Figure 5. Speedo® LZR, TYR® Sayonara and Blueseventy® Pointzero3 swimsuits used in this study

3. Results and Discussion

In this paper, only drag force data and its dimensionless quantity drag coefficient (C_D) are presented. The C_D was calculated by using the following formula:

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 A} \quad (1)$$

Where, D , V , ρ and A are the drag, wind speed, air density and cylinder's projected frontal area respectively.

Also another dimensionless quantity the Reynolds number (Re) is defined as:

$$Re = \rho V d / \mu \quad (2)$$

Where, d and μ are the diameter of the cylinder and absolute air viscosity respectively.

The drag (D) versus wind speeds and the C_D as a function of Re for a range of seam positions for the tested swimsuits are presented in Figures 6 to 12. In order to compare the results of swimsuits materials, the drag force and dimensionless parameter C_D of the bare cylinder were also shown in all figures. The drag forces and the C_D values for the Speedo® LZR swimsuit with four seam orientations (0° , 45° , 90° and 180°) are shown in Figures 6 and 7. Figure 6 shows that the drag for the bare cylinder is continuously increasing without any abrupt changes as expected. However, a sudden drop in drag forces in between 90 and 110 km/h speeds is evident for the Speedo® LZR suit at all seam angles.

The C_D variation with Re (shown in Figure 7) clearly indicates that the Speedo® LZR material has undergone a rapid drag crisis (transition effect from viscous or frictional drag to pressure or form drag at speed range of 90 and 110 km/h) for all seam positions except the seam position at 45° . The transitional effect starts much earlier at 70 km/h compared to 90 km/h for other seam positions. The seam position at 45° enhances the favorable pressure gradient more and delays the separation by increasing the turbulent boundary layer compared to other seam positions. In general, the rougher surface of swimsuits extends the turbulent boundary layer by reducing the length of laminar boundary layer and ultimately delays the flow separation in comparison with the smooth surface of bare cylinder. As expected, there is no noted difference in drag or C_D for the seam positions of 0° and 180° at all speeds tested (Re). Nevertheless, minor variations in drag and C_D were noted for the seam angle at 90° compared to other seam positions. The 90° seam position is not favorable for the drag reduction as it triggers the earlier flow separation compared to no seam at 0° situations.

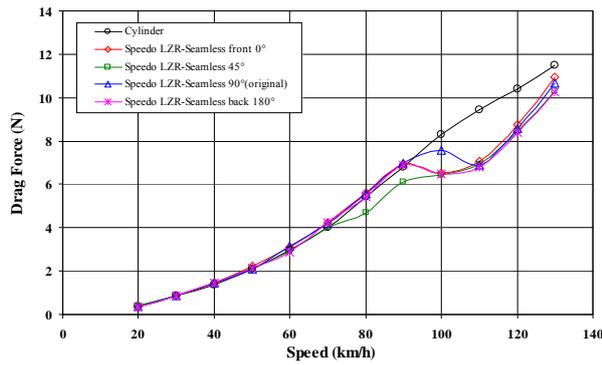


Figure 6. Drag variation with speeds of Speedo® LZR suit

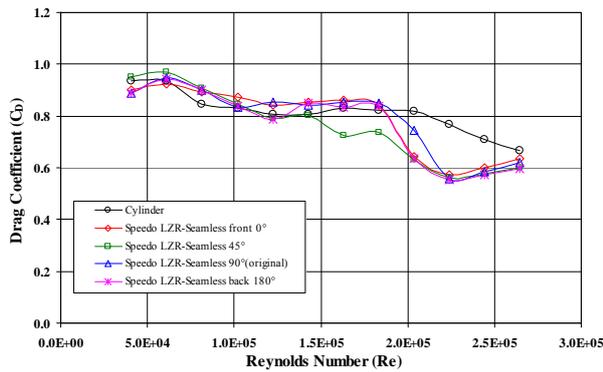


Figure 7. C_D variation with Re of Speedo® LZR suit

The drag and the C_D values for the TYR® Sayonara swimsuit are shown in Figures 8 and 9. There is no clearly noted transitional effect on the drag and drag coefficient (C_D) except the seam position of 45°. The seam position TYR® Sayonara swimsuit at all other angles tested has the higher drag and C_D values compared to the bare cylinder (see Figures 8 and 9). A close inspection has revealed that the surface of the material is very smooth compared to Speedo® LZR swimsuit. The relatively smooth surface does not assist the flow to have transitional effect.

A very similar effect was also noted for the Blueseventy® Pointzero3 swimsuit (see Figures 9 and 10) in comparison with the TYR® Sayonara swimsuit. However, due to the complexity of seam position on the suit, the seams were positioned on the test cylinder simultaneously at 45° and 90°; and at ±45°. The average drag and C_D values at these seam positions are around 13% less compared other seam positions (±90°, 0° and 180°). A close inspection has also revealed that both TYR® Sayonara and Blueseventy® Pointzero3 swimsuits are made of several layers, thicknesses of which are 0.3 mm and 0.5 mm respectively. The Speedo® LZR is made of single layer and the thickness is less than TYR® Sayonara and Blueseventy® Pointzero3 as mentioned above.

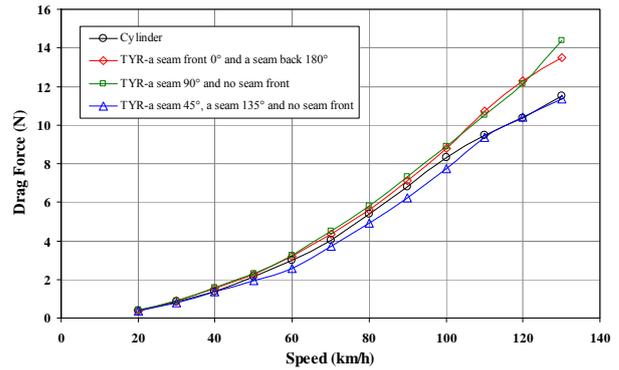


Figure 8. Drag variation with speeds of TYR® Sayonara suit

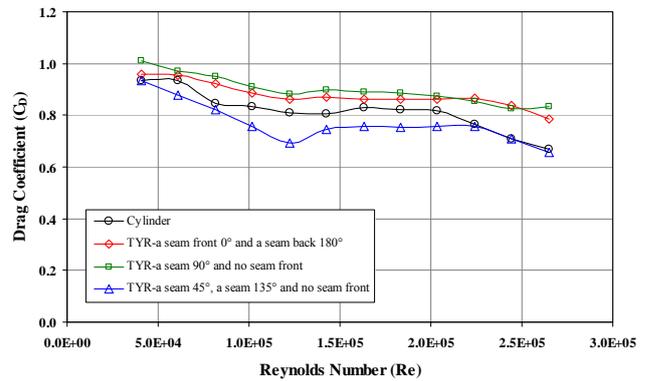


Figure 9. C_D variation with Re of TYR® Sayonara suit

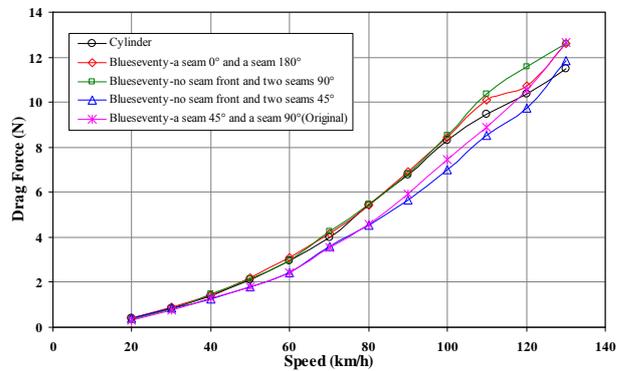


Figure 10. Drag variation with speeds of Blueseventy® Pointzero3 suit

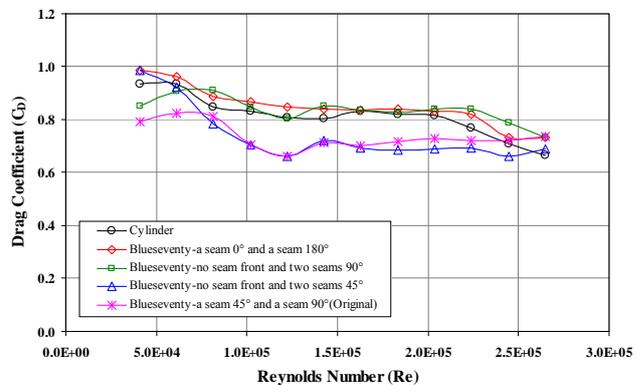


Figure 11. C_D variation with Re of Blueseventy® Pointzero3 suit

A comparison of C_D values for the Speedo® LZR, TYR® Sayonara and Blueseventy® Pointzero3 swimsuits for the seam position of 45° is shown in Figure 12. It is clearly evident that the seam of the Speedo® LZR swimsuit has the lowest value of the drag coefficient after transition to two other swimsuits' seam positions (TYR® Sayonara and Blueseventy® Pointzero3). Although the two other suits have earlier transition, they have relatively higher C_D values at high speeds. These suits have relative advantages at lower speeds compared to Speedo® LZR. The Blueseventy® Pointzero3 swimsuit possesses lower C_D values compared to the TYR® Sayonara swimsuit as these suits do not have much effect on flow transition.

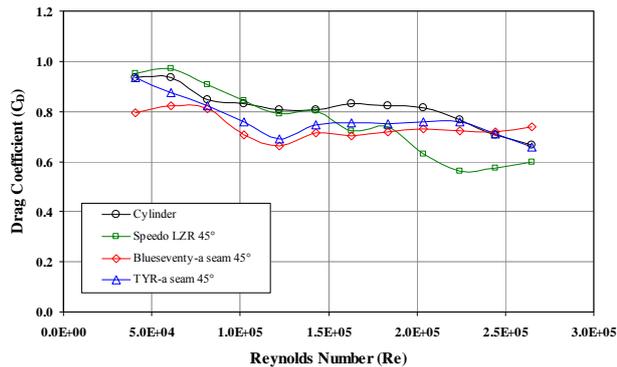


Figure 12. Comparison of C_D variation with Re of Speedo® LZR, TYR® Sayonara and Blueseventy® Pointzero3 swimsuits

4. Conclusions

The following concluding remarks have been made based on the experimental study presented here:

The surface structure (surface roughness, seam and its orientation) of the swimsuit has significant effect on the aero/hydrodynamic drag.

The seam orientation at 45° has the potential to reduce the drag up to 15% depending seam geometry.

The TYR® Sayonara and Blueseventy® Pointzero3 swimsuits have relative advantages due to lower C_D values at speeds below 80 km/h wind speed or equivalent speeds in water.

The Speedo® LZR has relative advantage at speeds over 80 km/h wind speed or equivalent speeds in water compared to other two suits as it has significantly lower C_D values at high speeds.

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