The Permeability and Performance of Competition Swimsuits

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Permeability of a swimsuit refers to how well water can flow through the fabric. Permeability plays an important factor in the performance of a competition suit by affecting the buoyancy of the swimmer; if the suit has a low permeability, water cannot easily get in and air remains trapped inside the suit, which increases the buoyancy of the swimmer. A higher buoyancy leads to better performance because the swimmer is placed higher in the water, decreasing the hydrodynamic drag [1]. Factors that affect the permeability include the porosity, the percent stretch, the orientation angle, and the number of layers. Porosity is the area between yarns, so a higher porosity leads to a higher permeability [2]. The percentage that the material is stretched also effects the permeability. As the stretch level increases, the pores get larger, and results in an increase in permeability [2]. In addition, as the orientation angle of the warp and weft increases to 45 degrees, the permeability decreases because the pores start to close at high angles [2]. Swimsuits are composed of two layers, a shell and liner, for decency purposes. The combination of these layers results in a lower permeability compared to the layers separately because pores get covered by the other layer.

In order to keep the playing field level between swimmers, the International Swimming Federation (FINA) set standards for the permeability. The current standard is that the suit must have a minimum permeability of 80 $L/m^2/s$ at 25% biaxial stretch [3]. The current method of testing is to take a 160x160 mm square of new, dry, unstretched fabric and biaxially stretch it to 25%, and then place it into an air permeability machine [3]. The shell and liner layers are tested separately and together. The machine will suck air through a 25 mm diameter area of the stretched fabric to measure the permeability. The current machine being used by FINA for permeability is a TEXTEST FX 3340 MinAir with testing parameters set to a test head area of 5 cm^2 and an applied pressure of 20 Pa.

A model was identified to calculate the theoretical permeability of the combined shell and liner layers of a swimsuit. It is a series model, which is shown below in Equation 1, where *k* is the permeability [2].

$$\frac{1}{k_{total}} = \frac{1}{k_{shell}} + \frac{1}{k_{liner}} \qquad (1)$$

Table 1: Permeability and porosity results at different orientations for a shell and liner with a 95% confidence interval.

Sample	Average Permeability [L/m²/s]	Porosity [%]	Model Permeability [L/m²/s]
Shell at 0°	53.65 ± 4.9	6.59 ± 0.27	-
Liner at 0°	401.25 ± 30	91.89 ± 1.5	-
Shell at 45°	31.68 ± 1.4	4.36 ± 0.18	-
Liner at 45°	338.25 ± 24	83.66 ± 2.5	-
Shell + Liner at 0°	53.28 ± 1.8	-	47.32 ± 3.4
Shell + Liner at 45°	33.98 ± 6.2	-	28.96 ± 1.2

Table 1 shows permeability and porosity data at 0° and 45° for a shell and a liner. Four repeated tests were done for each sample type and then averaged. The shell permeability values are much lower than for the liner, which is common because the shells are on the outside of the suit interacting with the water. The permeability and porosity significantly decreased from 0° to 45° orientation for both the shell and liner. For example, the shell decreased by a factor of 1.7 when the angle increased. This decrease in permeability is caused by the closure of pores at high angles, which was observed in optical micrographs during this experiment. Therefore, we can conclude that orientation angle, porosity, and permeability are dependently related. The model in Equation 1 was used to get theoretical permeability values of 47.32 L/m^2/s and 28.96 L/m^2/s for the combination of the shell and liner at 0° and 45° respectively. The standard deviation between the theoretical and experimental values are 2.98 for 0° and 2.51 for 45°. Previous research by Giesler shows that the model can accurately predict the permeability values for multiple layers.

More testing that investigates a larger range of orientation angles will be worked on to acquire more data on the relationship between the angles, porosity, and permeability. In addition, more calculations using the model will be conducted to verify its accuracy in predicting permeability values of combined layers. The performance of a competition suit, and by extension the swimmer wearing it, is greatly affected by the permeability and porosity. Therefore, it is important to regulate and understand these two quantities of swimsuit material. Future work on this topic includes redesigning a permeability testing method that accurately captures how the material stretches on the human body since the current method assumes that the material is stretched at 25% everywhere on the body.

1. Yanai, T. and Wilson, B.D. (2008), How does buoyancy influence front-crawl performance? Exploring the assumptions. Sports Technol., 1: 89-99. https://doi.org/10.1002/jst.23
2. Giesler, A. (2019). *Device Design and Measurement of Permeability on Competition Swimsuits under FINA Rules* [PowerPoint slides].
3. Fédération Internationale de Natation. (2017, January 1). *FINA requirements for swimwear approval (FRSA)*. FINA.

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