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Permeability ofCompetition Swimsuits – Unstrectched Testing

• Integrity • Swimming • Permeability • Textile

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The permeability of competition suits greatly affects the performance of swimmers. To keep a fair and level playing field, FINA has set standards on the permeability that all competition suits must comply with. The current standard is that the fabric must have a minimum air permeability of 80 $L/m^2/s$ when stretched 25% biaxial at a flow pressure of 20 Pa[1]. However, stretching the fabric during testing has many disadvantages because it causes permanent deformation to the material. Therefore, this project focuses on equivalating stretched to unstretched testing by utilizing the relationship between flow pressure and permeability. Two experiments were conducted, one using single layers of fabric and one using double layers, that involved testing permeability at various pressures.

For both single-layers and double-layers, the unstretched results showed nearly perfect linearity between flow pressure and permeability. It was determined that this relationship can be used to equivalate unstretched to stretched testing. In addition, a model was found to accurately estimate the total permeability of a double layer system.

Fig. 1: Image of air permeability testing machine.

PROJECT OVERVIEW

The permeability of a swimsuit refers to how easily water can flow through the fabric, and is an important factor in performance because it affects the swimmer's buoyancy. Therefore, to keep a level playing field, the International Swimming Federation (FINA) set specific standards on permeability, where the fabric must have a minimum air permeability of 80 L/m^2/s when tested at 25% biaxial stretch and 20 Pa of pressure[1]. However, this testing method has a few disadvantages. First, stretching the material permanently deforms the material, causing all the tested material to go unused. This deformation after stretching is shown in Fig. 2. Second, testing cannot be performed on finished suits due to this deformation and not having a homologous area large enough on the suit to test stretched. Therefore, this project focuses on determining a new method to test the fabric unstretched. To do this, the relationship between permeability and testing pressure is examined. The goal is to equivalate stretched permeability testing to unstretched testing and recommend an update to the FINA standard.

PROJECT METHOD AND RESULTS

The main experiment involved ten different swimsuit fabrics that were tested stretched and unstretched at six flow pressures. Each fabric was assigned a name based on its color. In addition, an experiment testing with double layers of fabric was conducted to mimic the combination of a shell and liner in a suit.

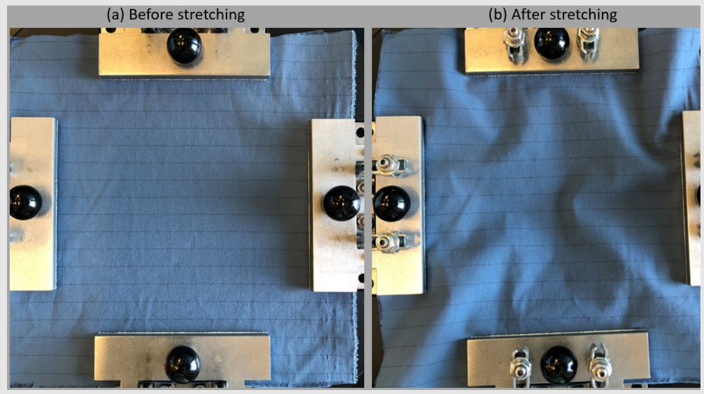

Fig. 2: Comparing swimsuit fabric (a) before stretching and (b) after stretching.

Three measurements were taken at each flow pressure and then an average and standard error was calculated. All the tests were done on a TEXTEST FX 3340 MinAir permeability machine, which is shown in Figure 1.

All ten single-layer fabrics were above the minimum 80 L/m^2/s when tested using the current stretched standard, therefore, to be equivalent, the unstretched test should result in all fabrics passing. To do this, the relationship between flow pressure and permeability was examined. The unstretched results for all ten fabrics are shown in Fig. 3, with a reference line at 80 L/m^2/s. All fabrics showed a linear relationship between pressure and permeability, with an R^2 of 0.99 or higher. However, each fabric had a different rate of change, which causes them to pass the minimum standard of 80 L/m^2/s at different flow pressures.

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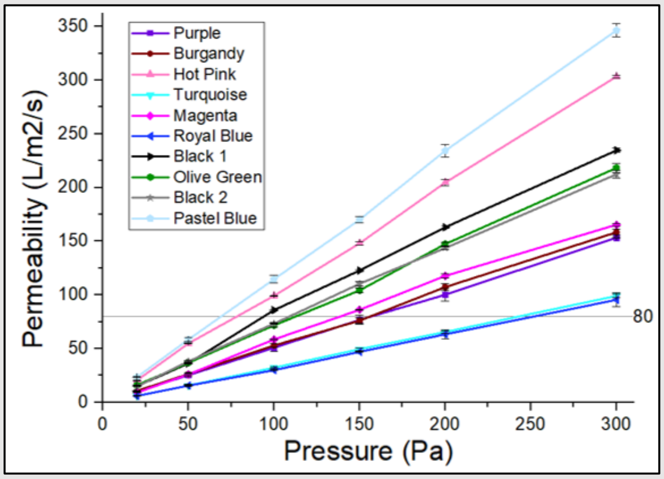

Fig. 3: Unstretched permeability vs. pressure data for 10 single-layer fabrics with standard error bars.

During testing, it was observed that high pressures caused the fabric to bow, which then caused deformation, so pressures over 200 Pa need to be avoided. To account for this, the permeability standard needs to be adjusted down with the pressure. For example, instead of testing unstretched at 260 Pa to ensure all suits in Fig. 3 pass 80 L/m^2/s, the standard can be shifted down to be 45 L/m^2/s so that the fabric can be tested at 150 Pa. Overall, the linearity of the relationship between pressure and permeability can be used to switch from stretched to unstretched testing.

The double-layer experiment involved six different fabric combinations tested unstretched at seven different flow pressures. The results are shown in Fig. 4 below.

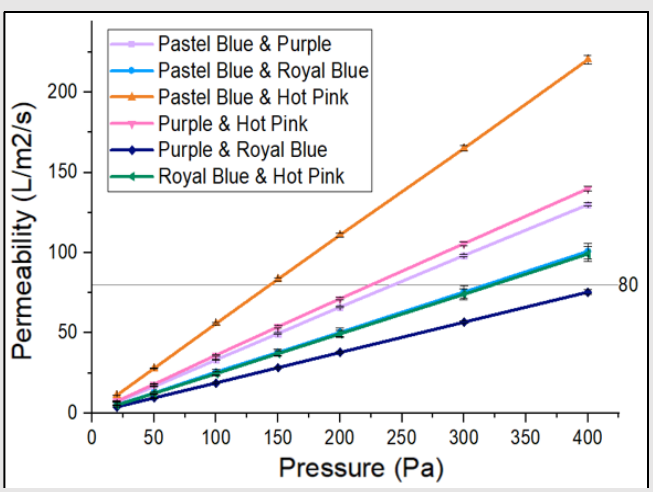

Fig. 4: Unstretched permeability vs. pressure data for 6 double layer combinations with standard error bars.

The results from the double-layer experiment showed the same results as the single layers, except the flow pressure needed to reach 80 L/m^2/s is about doubled. Therefore, the pressure vs. permeability linearity can also be utilized for double layers as well. A material-in-series model can predict the total permeability of a double-layer system.

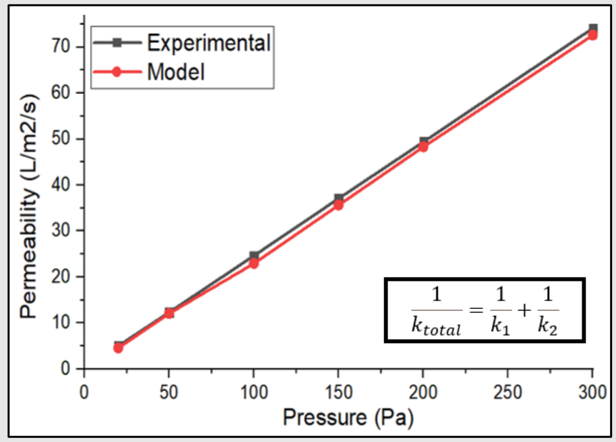

Fig. 5: Comparison of experimental data and model values for the royal blue and hot pink fabric system. Where k_{total} is the total permeability of the system and k_1 and k_2 are the single-layer permeabilities

The k_{total} was calculated for all six double-layer combinations and compared to the experimental results. In general, the model matched the experimental data well for all combinations. Fig. 5 shows how the model followed the data for the royal blue and hot pink combination.

CONCLUSIONS AND FUTURE WORK

- Permeability and pressure are linearly related, and each fabric has a different rate of change.
- Need to account for bowing at high pressures.
- For both single-layers and double-layers, the linearity can be utilized to adjust the flow pressure and permeability standard to equivalate unstretched to stretched testing.
- The permeability of a double-layer system can be estimated using the model.
- Furtherer exploration on the cause of variations in the rate of change
- Create an actionable implementation plan for FINA

REFERENCES

1. Federation Internationale de Natation. (2017, January 1). *FINA requirements for swimwear approval (FRSA).* FINA.

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ABOUT RESEC

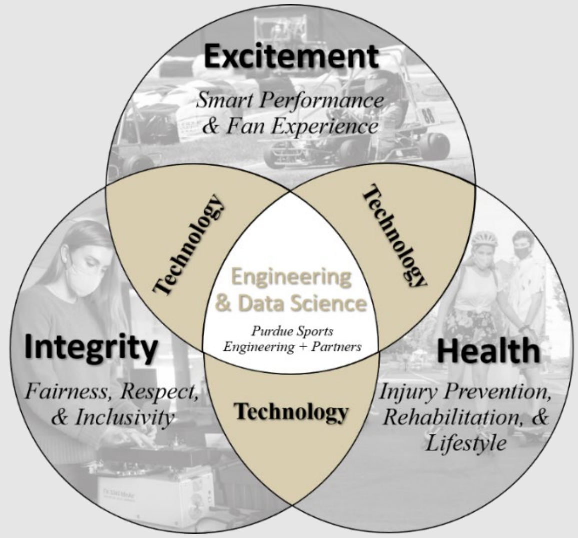
The Ray Ewry Sports Engineering Center (RESEC) was launched as a joint collaboration between Purdue College of Engineering and Purdue Intercollegiate Athletics, highlighting Purdue's reputation as the Cradle of Quarterbacks and Astronauts.

Sports have the power to unite, to teach, to challenge, and to initiate change, and those are our goals for RESEC. We are driven by our passion for sport and a deep understanding of the influence it has in shaping society. As technology continues to advance, there is enormous room for opportunity to rethink how athletes train, coaches coach, fans engage, and event organizers plan events. We collaborate closely with partners in athletics, industry, academia, and more to create the solutions that will help bring sports into the future, specifically in the three key research areas highlighted below.

Smart Performance & Fan Experience

Injury Reduction & Rehabilitation

Sports Integrity, Fairness, & Societal Integration



WHAT IS SPORTS ENGINEERING?

Sports engineering is a global, fast-paced, and multidisciplinary industry that brings people from different backgrounds, cultures, and experiences together. It is an industry that is heavily influenced by advances in other sectors as well as societal pressures and shifts, making working as a sports engineer very exciting. However, it also means being keenly aware of how these innovations and discoveries can be integrated and applied, especially as digitalization expands and what people – the athletes, fans, coaches, governing bodies – expect from sport evolves.

Engineering and data science are at the center of excitement, health and safety, and the integrity of sport, and by bringing a data-driven, human-centered approach to this industry, we can address the growing need and desire to increase participation and engagement of athletes and fans.

WHO IS RAY EWRY?

A Boilermaker track and field athlete, Ewry (1873-1937) won eight gold medals in three Olympic Games from 1900 to 1908. But his story is relatively unknown: at the age of five he became an orphan, and at seven he contracted polio and was confined to a wheelchair. Doctors had little hope he would be able to walk. Later nicknamed "The Human Frog," Ewry won gold in the standing long and high jumps and standing triple jump. By the end of the 1908 Games, Ewry had set a medal count record that lasted more than 100 years.

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