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Performance Analysis of Different Polymer Core for Badminton String Application

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Abstract: The string of a badminton racket is one of the main components that affect the performance of a player because the performance of the string could affect the accuracy and power of a stroke during a match. Nowadays there are many strings that are made from variety type of material in the market. As technology evolves, polymers are used manufacturing synthetics strings. Polymers are used because they have a wide range of properties and many type of the polymer are extremely tough or stiff. Polymer can be relatively cheap to process and it is lightweight. This study will help to highlight and compare which polymer material that will give the best performance if it is made into a badminton string. The polymers that are being compared in this study is polyester, nylon, polyethylene and polyphtalamide. The finite element model is created and simulated by using a software called ABAQUS. Two finite element simulation were carried out in this study, which is drop test simulation and tensile test simulation. The first test is done to determine the value of coefficient of restitution (COR) of each material and the dwell time of the string during an impact between the ball and the string-bed. The second test is to determine the stress vs strain graph of each string of different polymer. From the results of these simulation, the badminton string performance of different material can be compared in terms of COR value, dwell time and stress vs strain graph and the best material for a badminton string core will be determined.

Keywords: Coefficient of Restitution, Dwell Time, Badminton String, Polymer

1. Introduction

The string of a badminton racket is one of the main components that affect the performance of a player. A brand new high-end racket such as Yonex, Li Ning, and Victor doesn't come with a pre-installed string. This gives the user the freedom to choose any badminton string and string tension that

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suit their style. It is crucial to pick the best badminton string since each string has its own limit in term of performance. A correct selection of string should give you good resilience, good feeling, less shock during smashing and more control on your play. The string should also be durable so that you don't have to restring it frequently. The badminton string will begin to lose its tension when contact occurred between shuttlecock and the string during gameplay. Thus, every badminton player wishes to avoid this kind of incident since lack of string tension will affect the control and accuracy during gameplay.

This study aims to investigate the performance of different badminton string made with different polymer material. There are many types of polymer material available in the market, but this study will only focus on a certain type of polymers that are low in density and suitable to be used as badminton string core material that is polyester, nylon, polyethylene and polyphtalamide. As technology evolves, polymers are used manufacturing synthetics strings. Polymers are used because they have a wide range of properties and many type of the polymer are extremely tough or stiff. Polymer can be relatively cheap to process and it is lightweight.

A good quality of badminton string provides more excellent gameplay performance to the player where it has the ability to maintain its tension since the string tension can influence the rebound speed and accuracy of the shuttlecock after a stroke [1]. Besides that, it also needs to have a good elastic limit because ideally the strings ought to experience deformation when impacted with a shuttlecock. In the event that the strings experience plastic deformation upon impact, not all of the energy will be restored to the ball when it rebounds and furthermore, they will experience a loss in tension over time as the string elongates [2]. In comparison with a tennis string, an article from Tennis Warehouse University [3] stated that generally, tennis string would reach its life limit after 2-20 hours of play. The string will begin to lose power, feels mushy, and caused the ball to spray all over the place.

Due to the various type of polymers available in the market which might be suitable to be used as badminton string core material, this study will highlight the performance for each badminton string material in terms of energy absorption, string elongation, the coefficient of restitution and stiffness of the string. Subsequently, this study will aid manufacturers to consider different type of polymers that can be used for badminton strings.

2. Materials and Methods

The test simulation that is conducted in this study is a drop test simulation which is based on previous study [4]–[6] and a tensile test simulation. The drop test was conducted to determine the value of coefficient of restitution and dwell time, meanwhile the tensile test is to determine the stress vs strain graph of each material.

2.1 Finite Element Modelling

The assembly of the drop test simulation consists of a frame, string bed and a ball to represent the shuttlecock. The racket frame was created using an oval shape with a dimension of 253mm × 200 mm. To ensure the frame does not move, all six degrees of freedom on the rigid body of frame have been constrained. The string was modelled using truss elements and were constrained to the frame. The ball was modelled as a sphere with hyperelastic option as a Mooney-Rivlin material with a constant C_{10} = 0.69Mpa, C_{01} = 0.173Mpa and D_1 = 0.0145Mpa^{-1}. Meanwhile the density of the ball is set to a value of 1068kg/m^3 [4] a diameter of 26.4mm which is equally the same as the diameter of the cork on the tip of a shuttlecock. The ball is placed 50mm from the origin point. Figure 1 shows the assembly of the model simulation. Surface-to-surface (STS) contact was used to define the interaction contact between the ball and the string bed. The coefficient of friction value between the ball and the strings was set to a default value of 0.1.

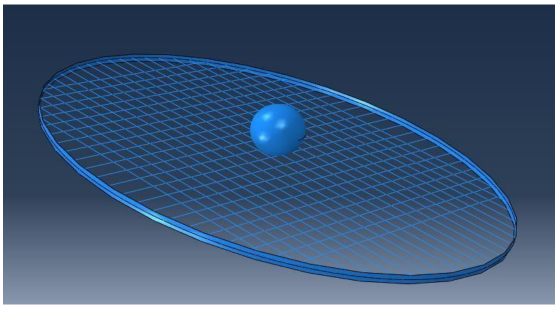

Figure 1: Assembly of String-bed and Ball

Meanwhile for the tensile test a single strand of badminton string was modelled with a length of 260 mm and a diameter of 0.66 mm (Figure 2) which follows the sample length that have been stated in The International Standard ISO 2062 'Textiles: Yarn from packages - Method to determine the breaking strength and elongation of a single strand [7].

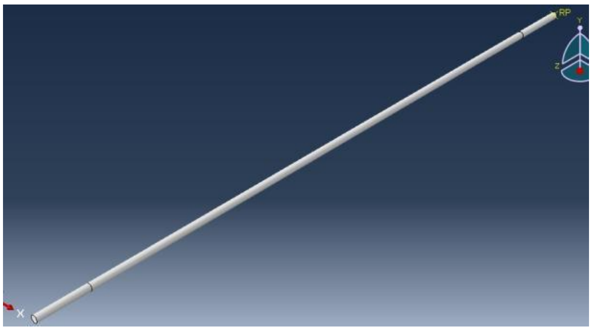

Figure 2: Single Strand String Model

2.2 Simulation

The drop test simulation is conducted by subjecting the ball to an initial velocity, v_1 of 10 m/s by using the predefined field option and the whole cycle time was set to 0.5 seconds. The initial velocity of the ball was set to 10 m/s because based on previous studies, 10m/s is enough to compute the value of COR and dwell time [5]. In tensile test, both ends of the string were set to a distance of 5 mm to show distance that the end of the string that will be clamped. To ensure the bottom end of the string does not move, all six degrees of freedom have been constrained. Meanwhile, force will be applied at the other end of the string. The material properties of the string will be changed after completing each test and the material properties value of each string is shown in Table 1 where the material properties was obtained from Grata Design sample material and Omnexus [8] [9].

Table 1: Material Properties

Material	Young's Modulus (Pa)	Poisson's Ratio	Density (kg/m^3)
Polyester	2.9E+9	0.389	1340
Polyethylene	1.08E+9	0.418	958
Nylon	1.48E+9	0.41	1140
Polyphtalamide	3.7E+9	0.3	1155

2.3 Equations

The value of coefficient of restitution is calculated using using an equation which was derived by Haron and Ismai [10].

3. Results and Discussion

The results and discussion part will be divided in to two parts of which the first part is the results obtained through simulation using ABAQUS explicit dynamics while the second part will be the discussion of the results obtained.

3.1 Results

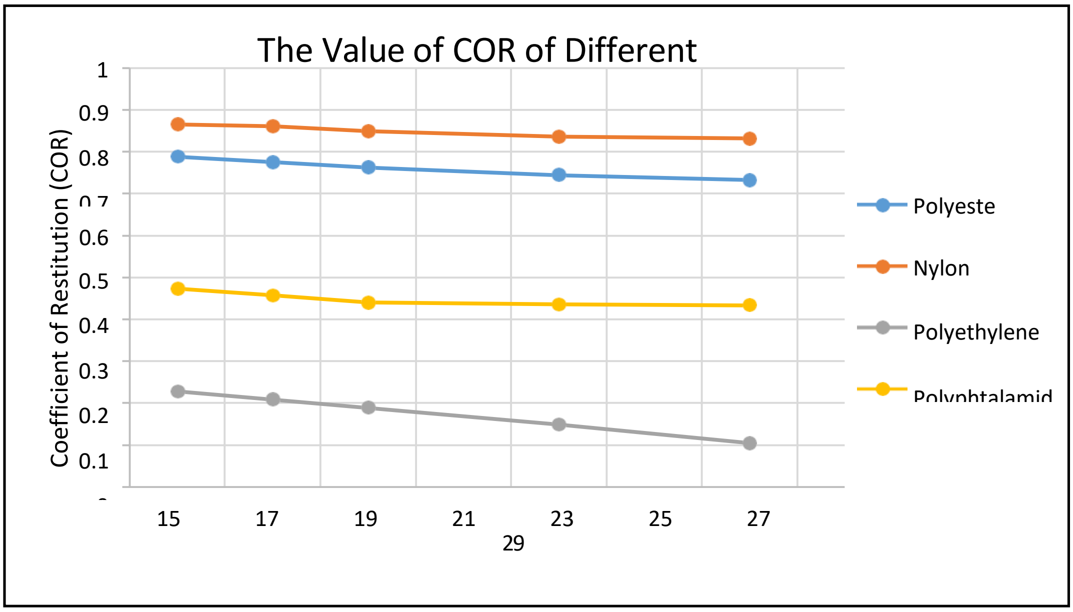

Figure 3: The Value of COR of Different Polymer

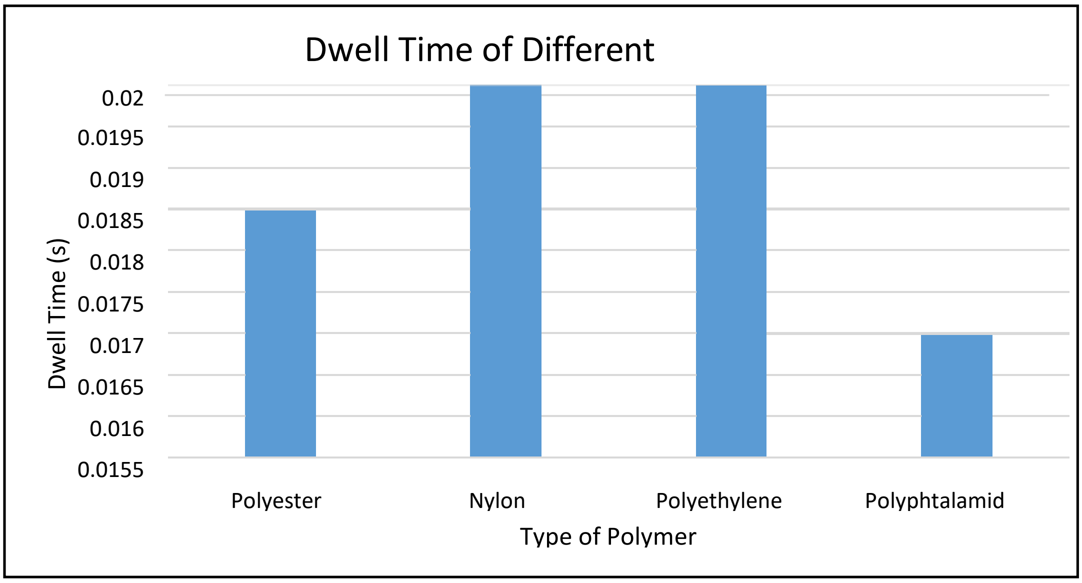

Figure 4: Dwell Time of Different Polymer

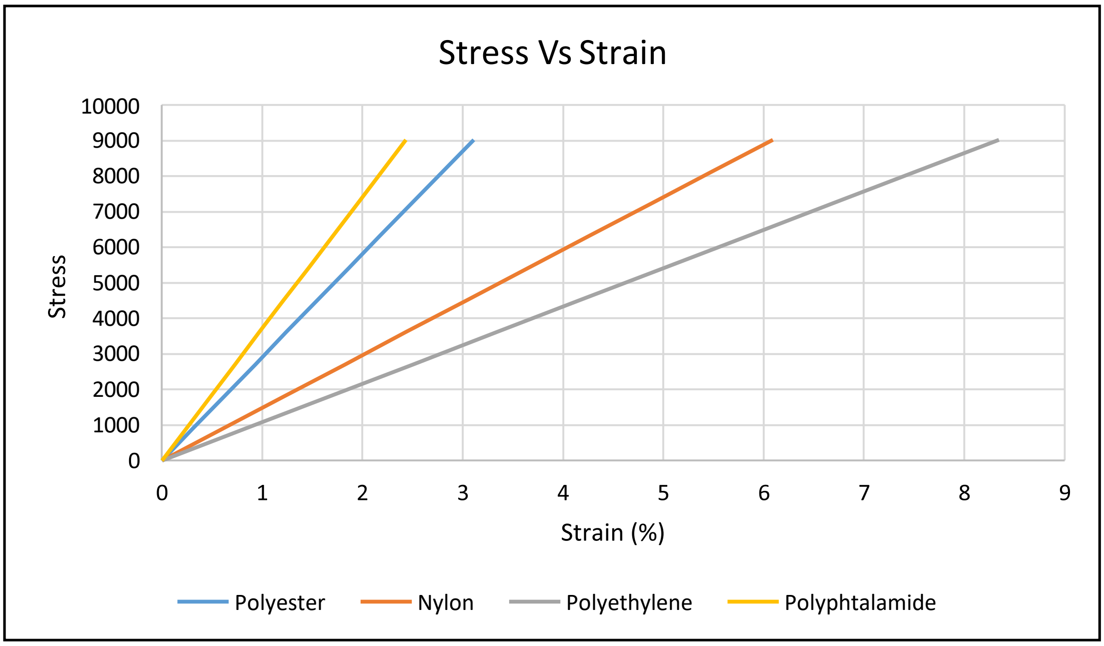

Figure 5: Stress vs Strain Graph of Different Polymer

3.2 Discussions

Figure 3 shows that the highest COR value was obtained by nylon while polyethylene produced the lowest COR value. The value of COR shows how much energy the string of different polymer is able to release onto the ball after the string have absorb a huge amount of energy after the ball impacted with the string-bed. The higher the value of the COR the greater the kinetic energy that the string will be able to release. This shows that the string that is made from nylon will be able to release more energy after an impact of the ball and the string-bed, then followed with the string that is made from polyester, polyphtalamide and polyethylene respectively. The value of COR differs for each material due to the material elastic potential energy. The elastic potential energy shows how the string with different material is able to return to its original shape after it deforms when collided with the ball and how much kinetic energy is lost during a collision [5], [11].

The results shown in Figure 3.2 is the dwell time of the string-bed when impacted with the ball at an initial velocity, v_1 of 10m/s and the string-bed tension was set to a value of 28lbs. From the results shown, nylon and polyethylene have the highest dwell time followed by polyester and polyphtalamide respectively. The results for the dwell time of the string-bed during an impact with the ball is to show the stiffness and control the string can provide. Furthermore, the dwell time of the string depends on the stiffness of the materials. This is because a softer material will have higher dwell time compared to stiffer material. The stiffness of a material can reflect the value of Young's modulus where a material with higher value of Young's modulus will have higher stiffness [12]. This shows that the string made from nylon and polyethylene is softer compared to the string made from polyphtalamide and polyester but it will not be able to provide good control compared to the string made from polyphtalamide and polyester during a play because the longer the dwell time the longer the ball will stay on the string during a stroke [13], [14]. Even though stiffer string will provide more control during a play, if a player does not poses great technique the player will be exposed to a risk of elbow and shoulder injury [15].

The results of the stress vs strain graph of the string made from different polymer shown in Figure 3.3 shows that the string will elongates when subjected to stress. From the results obtained, the string that is made from polyphtalamide will produce a lower strain rate followed by polyester, nylon and polyethylene respectively. During a match the string will be exposed t stress numerous time because the shuttlecock will be hit repeatedly, so it is a better for a string not elongates quickly because when the string it will reduce the tension of the string and it will increases the dwell time and lowers the COR value thus reducing the accuracy and power during a stroke [16].

3.2 Performance Scoring

A weighted scoring method is used to highlight the performance of each material and determine is the best material that could be used as a core material for a badminton string. The scoring method is shown in Table 2 where the scale is from the best (4) to the worst (1) respectively.

Table 2: Material Properties

		Material			
Criteria	Weight	Polyester	Nylon	Polyethylene	Polphtalamide
COR (Power)	0.3	3	4	1	2
Dwell Time (Stiffness)	0.3	3	2	2	4
Tensile Test (Elongation)	0.4	3	2	1	4
Total Score	1	3	2.6	1.3	3.4

4. Conclusion and Recommendations

Through this study a drop test and tensile test simulation have been created by using a finite element method. From the finite element method, the result for the value of coefficient of restitution, dwell time and stress vs strain graph have been obtained. From the performance scoring and results that have been obtained, it have been concluded that the string that is made from polyphtalamide is considered as the best polymer string that have the highest performance rating followed with polyester, nylon and polyethylene respectively. This is because polyphtalamide does not easily loses it tension and accuracy easily because it does not easily elongates when exposed to stress during a stroke. Besides that, polyphtalamide is stiffer compared to other material thus showing that it will have the best accuracy and control during a match if compared to other material. Finally even though it does not have the highest COR value compared to nylon and polyester, players can compensate the lack of power produced by the string by improving their arm strength thus increasing the power of their stroke.

The work presented in this thesis has provided a better understanding on the effect of the string performance from different polymers. However, further investigation can be conducted to deepen the understanding of this study. Some recommendations were as follows:

1. Fatigue test should be performed in the future to determine the life of each material.
2. Use a different meshing shapes for the finite element model.
3. Increase the number of material to be compared.
4. Perform experimental study to validate the finite element analysis that have been performed

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