EXPERIMENTAL ANALYSIS OF MECHANICAL PROPERTIES OF SELECTED TAKRAW BALLS IN MALAYSIA

Nor Mariah Adam
Department of Mechanical and Manufacturing Engineering,
Faculty of Engineering, Universiti Putra Malaysia

ABSTRACT

Sepak Takraw is a popular sport among the Southeast Asian countries and various brands of takraw balls are available in the local market to suit the needs of players. In this study, four different takraw balls commonly used by the Malaysian takraw players were selected for testing of mechanical properties by using compression and fatigue analysis. It was found that the GE takraw balls were more suitable to be used by Malaysian takraw players due to higher fatigue life and tensile strength. This finding is particularly useful for the local sport academy in deciding which ball is to be used in the future takraw competitions.

Keywords: Takraw ball, mechanical properties, fatigue analysis, tensile strength

INTRODUCTION

The modern Sepak Takraw is a famous sport among the Southeast Asians, and it is a national sport for countries like Malaysia and Thailand. This sport combines the elements of some of the sports like soccer, volleyball, baseball, badminton and the ancient sport of Sepak Raga. The current International Games of Sepak Takraw, such as the SEA Games and Asian Games prefer the use of synthetic ball over rattan ball. The advantage of using a synthetic ball is the reduction in impact force towards the players, as noted in several studies. However, the introduction of rubber-coated ball during the SEA games had sparked an issue where a participating team decided to pull out of the competition, by claiming that the bouncing of the ball was inconsistent and not safe for the players [1].

Many studies have been directed towards different sport balls to examine the aerodynamic features and mechanical properties of these balls. The aerodynamic drag of sport balls is crucial in understanding the flight of a ball [2] and this is usually measured in a laboratory setting. Asai et al [3] used wind tunnel to study the aerodynamic characteristics of conventional and new volleyballs, and concluded that the surface roughness of the balls was significant towards reduced aerodynamic instability. Besides, a study conducted by Alam et al [4] which analyzed the aerodynamic properties of two different soccer balls have proposed that the ball made from thermally bonded synthetic curved panels had higher aerodynamic drag in high speeds. Subsequent works were carried out by the same author that studies the aerodynamic features for several new soccer balls [5] ,baseball and softball [6]. However, despite the heavily studied aerodynamic features, the fatigue life and other physical characteristics of sport balls are essential and required further analysis as well. Ismail and Stronge [7] has developed a model to study the energy dissipation in sport balls during collision, and noted the difference in energy dissipation due to plastic deformation and viscous dissipation. The effect of duration of linear impulse on energy dissipation during collision was also studied [8], and increased rate of energy dissipation was found with longer impact duration.

In this study, a few of the most commonly used takraw balls were selected for experimental analysis to determine physical characteristics as well as the fatigue life of these balls. Compression test was used to determine the behavior of materials under a certain load. Besides, the usefulness of fatigue test in determining the behavior of a certain specimen under fluctuating load was also noted [9]. The tests were repeated with other specimens (takraw balls) and the results obtained were compared to analyze the fatigue life and safety.

METHODOLOGY

Prior to this study, a pilot survey was conducted by a group of researchers from the Faculty of Engineering, UPM to determine the most commonly used takraw balls in Malaysia. After the survey was carried out, 4 regularly used takraw balls - GE 511, GE 411, MT 301 and MT 201 were obtained from the sport centre to undergo a series of tests to find out the specific mechanical properties of these balls. The GE 511 and MT 301 were designed for training purposes, while the GE411 and MT201 were used for actual field tournaments. Both of the GE balls were manufactured in Malaysia by using special waterproof synthetic polymeric fibres, while the MTs were made from synthetic polymeric fibres with rubber coating.

The tests were conducted in this study by using a precision materials testing machine, which was capable of performing both compression test (tensile test) and fatigue test. The machine was run for 100 cycles prior to the loading of specimens for warming up purpose. Once the specimen was inserted on the base plate of the machine, the dimension and cross-head speed of the specimen was entered by using the control panel, which is an integral component of the testing machine.

*Compression Test*The specimen was compressed and deformation at various loads was recorded. The ASTM Standard C496-96 [10] was used in this compression test on the takraw balls. The compression force was exerted by constant displacement at a rate of 1mm in every 10 minutes. The purpose of this compression test was to determine the tensile strength of the takraw balls and the research team was interested to determine which takraw ball is more suitable and safer to be used by the players. Fig 1 presents the testing machine used for compression test. The dimension of each of the takraw ball was first inserted into the system, and the gripper was tightened soon after the takraw ball was placed firmly into the machine. The compression test was run by pressing the “start” button on the machine and the results obtained were subsequently recorded.

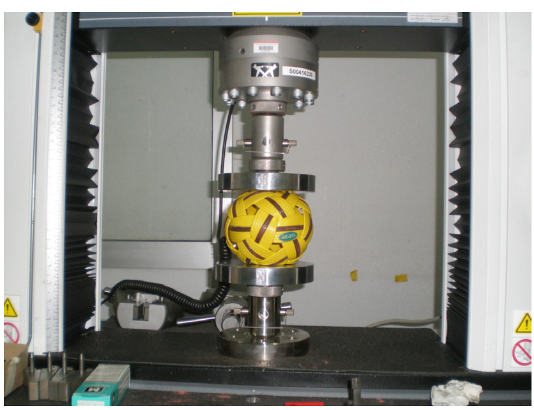


Fig 1: Testing machine for compression test

Fatigue test is the method for determining the behavior of materials under fluctuating loads, and the fatigue life of a material is commonly known as the number of stress cycles of a specified character that a specimen sustains before failure of a specified nature occurs (Fatemi and Mars, 2002). In this study, a computer-aided materials testing machine was used to conduct the fatigue test on the takraw balls. Some parameters were set up before the test, such as the amplitude, frequency and number of cycles, as shown in Table 1. The tests were repeated by changing the displacement values. The ASTM E2714 [11], which is a standard that specifies the test methods to determine the properties of materials such as deformation and damage condition analysis, was referred to in this study. The electromechanical equipment used for fatigue test is shown in Fig 2.

Table 1: Parameters for fatigue test

Types of takraw ball	Control Value	
	Fixed Value	Adjustable Value
GE 411	Frequency. F = 1.5 Hz and a total of 10,000 cycles	Displacement values (mm) – 20, 15, 10, 8, 5, 3, 2 and 1
GE 511		
MT 201		
MT 301		

It should be noted that if the displacement between the load and the specimen is larger, a smaller number of cycles is obtained. After completion of the tests, the S-N curve was plotted in this study to compare the fatigue strength and toughness of the takraw balls that are commonly used in Malaysia.

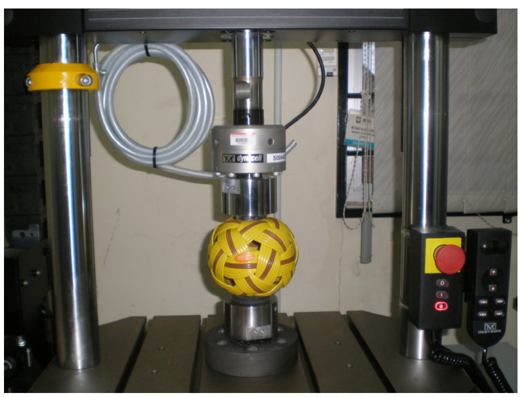


Fig 2: Testing machine for fatigue test

Results and Discussion

The compression and fatigue tests were carried out on the four selected takraw balls. The purpose of the compression test was to determine the tensile strength of the balls. None of the synthetic balls were fractured during the test. Therefore, an assumption was made in this study that the synthetic takraw ball was deemed as completely deformed when the load drop exceeded 15% of its initial value. The fatigue test was conducted by repeated compression on the specimen and the load drop was measured at 15% of deformation rate. The number of cycles and fatigue life of the takraw balls were obtained by using this test.

Calculation

The cycle of fatigue test for every specimen was calculated manually, since the Instron Machine was not able to calculate the exact cycle where the 15% load drop occurred. By using the interpolation formula, the exact cycle was calculated as below:

$N_{exact} = N_{initial} + (F_{exact} – F_{initial}) / (F_{final} – F_{initial})$

Where:

N_{exact} = exact cycles
$N_{initial}$ = initial cycles before exact cycles
F_{exact} = load at the exact cycles
F_{final} = load at the final cycles
$F_{initial}$ = load at the initial cycles

An example calculation for GE 411 1mm is shown below:
The load of the 1st cycle = 0.01121 kN
For the load drop of 15%,
-0.398346186 x 85% = 0.00953 kN
The interpolation data is presented in Table 2.

Table 2: Interpolation data for GE 411 at displacement of 1mm

Total Cycles (N)	Position (mm)	Load (kN)
7000	17.313	0.00689
N_{exact}	x	0.00953
8000	16.714	0.01614

The value of 15% load drop falls between 7000 cycles and 8000 cycles, so interpolation is used to find the exact cycle.

N_{exact} = 7000 + (8000 – 7000) (F_{exact}-F_{7000}) / (F_{8000}-F_{7000})
= 7000 + (1000) x (0.00953 – 0.00689)/(0.01614 – 0.00689)
= 7285.41 cycles

This was rounded off to 7285 cycles. The calculation was repeated with the displacement values of 2mm, 3mm, 5mm, 8mm, 10mm, 15mm and 20mm.

The exact cycles for each of the takraw ball are shown in Table 3 to Table 6.

Table 3: Exact cycles and load (kN) for GE 411

Displacement value (mm)	Load at 1st Cycle (kN)	Cycles	Load (kN)
20	0.17779	95	0.15112
15	0.14711	243	0.12504
10	0.09537	504	0.08107
8	0.07375	844	0.06268
5	0.05483	4138	0.04660
3	0.03565	5097	0.03030

2	0.02259	6121	0.01920
1	0.01121	7285	0.00953

Table 4: Exact cycles and load (kN) for GE 511

Displacement value (mm)	Load at 1st Cycle (kN)	Cycles	Load (kN)
20	0.16389	93	0.13698
15	0.10833	309	0.09208
10	0.10226	636	0.08692
8	0.07866	809	0.06686
5	0.04799	4649	0.04079
3	0.03425	5125	0.02911
2	0.02246	6882	0.01909
1	0.01184	7264	0.01007

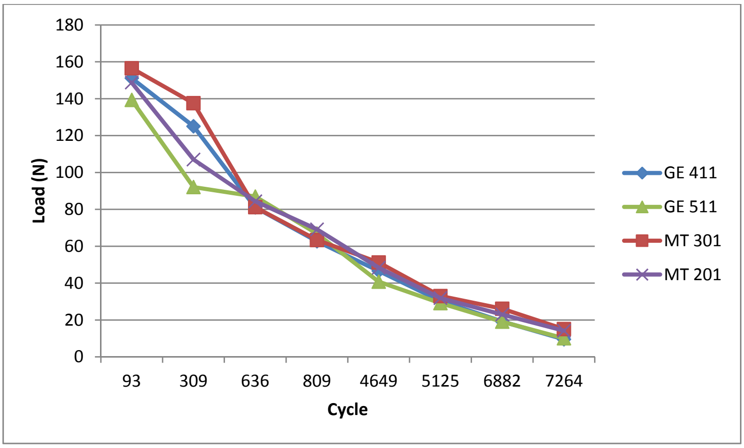
Table5: Exact cycles and load (kN) for MT 301

Displacement value (mm)	Load at 1st Cycle (kN)	Cycles	Load (kN)
20	0.18414	173	0.15652
15	0.16182	368	0.13755
10	0.09549	654	0.08117
8	0.07515	989	0.06388
5	0.06024	2432	0.05120
3	0.03881	6166	0.03299
2	0.03072	7500	0.02611
1	0.01772	8624	0.01506

Table 6: Exact cycles and load (kN) for MT 201

Displacement value (mm)	Load at 1st Cycle (kN)	Cycles	Load (kN)
20	0.17501	95	0.14771
15	0.12591	286	0.10702
10	0.09926	679	0.08437
8	0.08135	971	0.06915
5	0.05686	2038	0.04833
3	0.03749	3652	0.03187
2	0.02702	6313	0.02297
1	0.01667	7242	0.01417

Fig 3: The Overall S-N curve for all the takraw balls



The basis for the creation of an S-N curve is constant amplitude testing of smooth specimens. The overall S-N curve for the takraw balls are presented in Fig 3. This S-N curve was particularly useful in determining the fatigue strength and toughness of the takraw balls. It should be noted that if the ball recorded high value of load (N) in the S-N curve, it shows that it has higher fatigue strength but lower fatigue life due to absorption of impact [12]. It can be observed that the MT balls recorded higher load values than the GE ones. In other words, the GE takraw balls which had lower fatigue strength, was able to absorb higher impact of momentum force between the ball and the players. Therefore, it was identified that the GE 411 and GE 511 takraw balls are safer to be used by the takraw players.

CONCLUSION

Not many studies were carried out to determine the fatigue life of balls used for sport games. In this study, the compression test was used to determine the ultimate tensile strength of the takraw ball. It was assumed that for a load drop of 15%, the synthetic takraw ball was deemed as completely deformed and cannot be reused again. From the experimental tests, it was found that the GE 411 could sustain the highest load, which was -0.339 kN when 20 mm of displacement was set, followed by GE 511 which recorded -0.331 kN. Subsequently, the MT 301 was identified to have the load of -0.324 kN and MT 201 had the lowest load of -0.295 kN.

Also, it was identified that the GE 411 and GE 511 achieved 5997 cycles for 15% of load drop. This proved that the fatigue life of these two balls was longer than the MT 201 and MT 301. The MT 201 achieved 5647 cycles and for MT 301, only 3993 cycles was recorded. With higher number of cycles, the higher the ductility of the takraw ball. Hence, the GE 411 and GE 511 were found to be less harmful to the sepak takraw players. However, it should be noted that only four takraw balls were used in this study. The authors proposed that more experimental analysis should be carried out to identify the fatigue life of other takraw balls in future studies so as to select the more suitable ones for tournament use.

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Higher Education, Malaysia for the financial support provided in this project. Besides, the help provided by the technical staff in UPM is much appreciated.

REFERENCES

[1] Asai, T, Ito, S., Seo, K. and Hitotsubashi, A. (2010). Aerodynamics of a New Volleyball. Procedia Engineering, 2, 2493–2498.

[2] Alam, F., Chowdhury, H., Moria, H., Fuss, F.K., Khan, I., Aldawi, F. and Subic, A. (2011). Aerodynamics of contemporary FIFA soccer balls. Procedia Engineering, 13, 188–193.

[3] Kensruda, J.R. and Smitha, L.V. (2010). In situ drag measurements of sports balls. Procedia Engineering, 2, 2437–2442.

[4] Alam, F., Chowdhury, H., Moria, H. and Fuss, F.K. (2010). A Comparative Study of Football Aerodynamics. Procedia Engineering, 2, 2443–2448.

[5] Alam, F., Ho, H., Chowdhury, H. and Subic, A. (2011). Aerodynamics of baseball. Procedia Engineering, 13, 207–212.

[6] Harbour, R.J., Fatemi, A. and Mars, W. (2008). Fatigue life analysis and prediction for NR and SBR under variable amplitude and multi-axial loading conditions. International Journal of Fatigue, 1231-1247.

[7] Van Vlack, L.H. and Osborn, C.J. (1992). Study Aids for Introductory Materials Courses. Modes of Deformation in Compression Testing, Addison, 56-88.

[8] Klesnil, M. and Lukas P. (1992). Fatigue Of Metallic Materials. Elsevier Science Publishing Company, Inc., Second revised edition, 19-22 & 27-30.

[9] Ismail, K.A.and Stronge, W.J. (2012). Viscoplastic analysis for direct impact of sports balls. International Journal of Non-Linear Mechanics**,** 47 (4), 16-21.

[10] ASTM C496-96. Standard test method for splitting tensile strength of cylindrical concrete specimens. ASTM International.

[11] ASTM E2714-13. Standard test method for creep-fatigue testing. ASTM International.

[12] Njock-Libii, J. (2012). Applying Dynamics to the bouncing of game balls: Experimental investigation of the relationship between the duration of a linear impulse during an impact and the energy dissipated. 119th ASEE Annual Conference and Exposition, San Antonio.