Conférence Sciences2024: saison 2021
https://sciences2024.polytechnique.fr
May 28, 2021

IMPACT PREDICTION OF THE TABLE TENNIS BALL/BAT

Author: Sheedev Antony[1] *sheedev.antony@insa-lyon.fr*
Co-author: Renaud G. Rinaldi[2], Lionel Manin[1]
[1] Univ Lyon, INSA Lyon, CNRS, LaMCoS, UMR5259, 69621 Villeurbanne, France
[2] Univ Lyon, INSA Lyon, CNRS, MATEIS, UMR5510, 69621 Villeurbanne, France

Keywords: Table tennis Ball/Bat, Impact, Rubber, Finite Element Analysis

1 Introduction

Table tennis is a common worldwide sport in which a bat and a ball are used as the key equipment. Table tennis bats are made up of three layers: a wood or composite paddle base, a foam and rubber covering adhered to the base with adhesives. The table tennis ball is mainly made of polymeric material. The main strategy in the game is to hit the ball at the right speed, spin, and angle. Researchers conducted several studies to better understand the impact behaviour of the table tennis ball and bat in the past. Zhang et al [1] investigated the dynamic test of a table tennis ball by hitting it with a 10-50 m/s velocity on a PMMA plate. The maximum contact diameter, impact time, and contact diameter at buckling were measured using images taken with a high-speed camera. It was discovered that the ball's dynamic energy absorption is greater under dynamic loading than under quasi-static loading. Recently, Miyazawa et al [2] studied the effect of pimple height of table tennis rubber on ball rebounding behaviour. It was concluded that there was no noticeable effect on the order of the pimple height on the rebound angle and spin rate. But the horizontal component impulse varies with the change in the pimple height. The aim of this work is to investigate the effect of the impacted surface type on the ball rebound: rigid, foam, rubber+foam, pimple in/out, rubber geometry.

2 Method

The impact tests were first carried out to examine the table tennis ball's impact on rigid, foam, and rubber+foam targets. A homemade testing machine that can monitor the incident velocity, incident angular velocity and incident angle of the ball was used (Figure (1)) in the french company Cornilleau©. The experimental test setup included camera with long exposure time settings and stroboscopic lights to monitor the ball impact locations. A single image was taken during the test, and was post-processed to calculate the reflected velocity, reflected angular velocity, and reflected angle. Numerical models of ball, rigid, foam, rubber with pimples in/out were created using ABAQUS© CAE. Density and Poisson's ratio were assigned for each components. Large strain hyperelastic and viscoelastic properties for foam and rubber were described using the Ogden form and Prony series respectively [3, 4]. The ball is meshed using shell elements and foam, rubber with pimples are

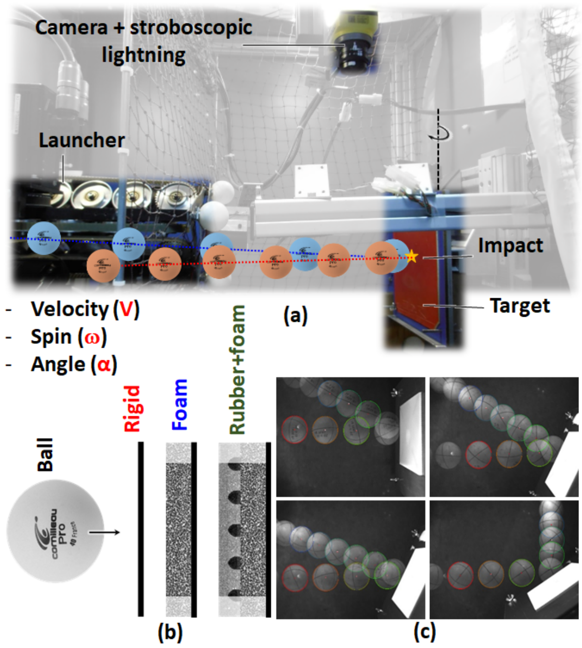

Figure 1: (a) Experimental setup, (b) targets, (c) ball-prints obtained with stroboscopic lightning for 4 varying incident conditions.

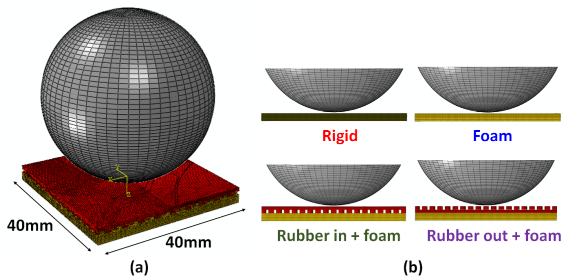

Figure 2: Finite element models: (a) isometric view, (b) Z-X views of the configurations

meshed using solid elements (Figure (2)). Tie constraint interaction was used to attach the constituents. The friction model in ABAQUS© is used to assign surface to surface interaction properties between the ball and the target surfaces. A graphical user interface (GUI) is developed by combining Python©, ABAQUS©, and MATLAB© to make parametric computations easier. Numerical simulations were performed in ABAQUS© Explicit Finite Element software. Effect of different rubber pimples geometry such as diameter ($d_p = 0.720$ mm, 1.08 mm, 1.44 mm), height ($h_p = 0$ mm, 0.48 mm, 0.96 mm) and volume ($D_{p_{int}} = 0.00$mm, 0.72mm, 1.08mm) were analysed (Figure (3)).

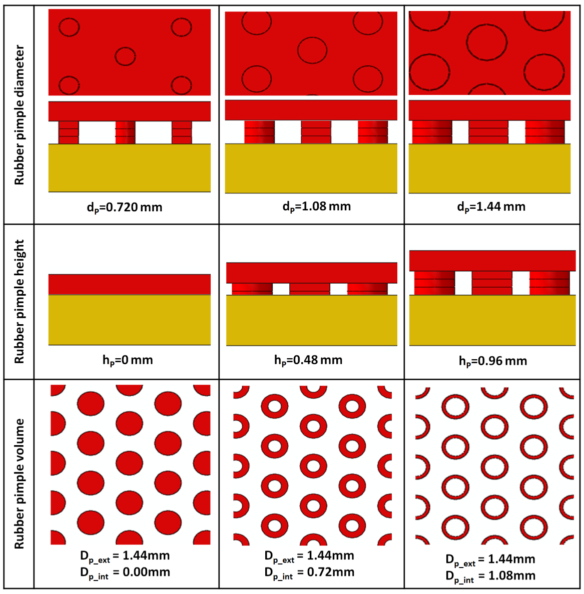

Figure 3: Different geometry of rubber pimples

3 Results

According to experiments, the coefficient of restitution (CR_L) and spin ratio (SR) decrease linearly as the incident velocity increases in the case of two polymer targets. The coefficient of restitution and spin ratio for rigid targets shows inconsistent behavior with respect to incident velocity. On all targets, the deviation angle (θ) increases as the incident velocity increases [3]. The results of simulations were compared to the experimental results for linear coefficient of restitution, spin ratio, and deviation angle (Figure (4)). In the case of rigid surface, the target is non-deformable and the only factor that affect the interaction will be friction. In the case of deformable target such as foam and rubber + foam, the material behaviour of the target also influence the contact. The polymer coating will snap the ball from its surface after the buckling of ball crosses some limit. The material properties of the rubber and foam have been updated according to the experimental results. Then the established model permits estimating with confidence the bat/ball impact for any rubber pimple geometry. The effects of the pimple geometry on the coefficient of restitution, spin ratio and deviation angle obtained for different rubber pimples are also presented in Figure (5). It was observed that the values are always lower for pimple out than in. This is consistent with the fact that pimple out rubber are being used by defensive players.

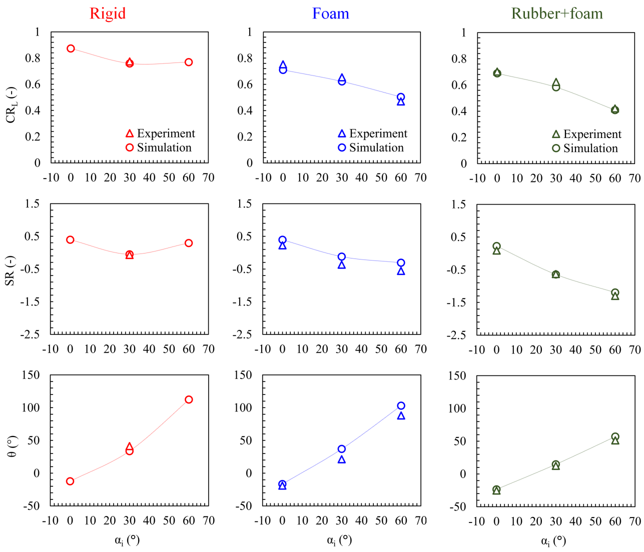

Figure 4: Comparison and validation of experimental and numerical results

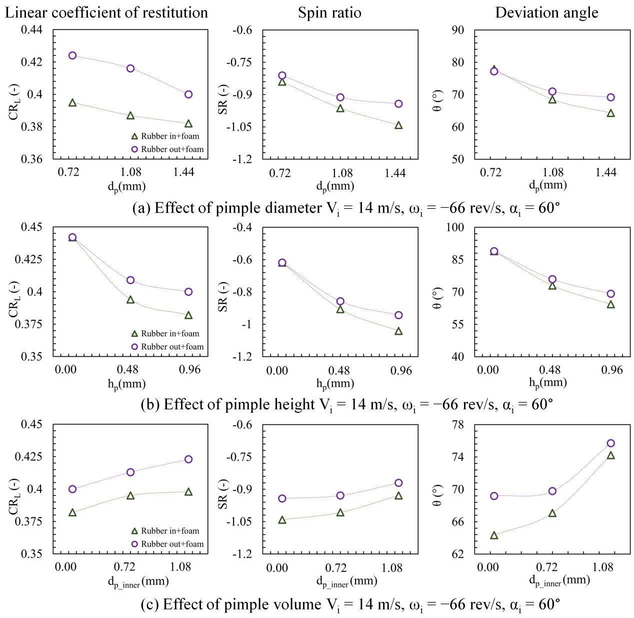

Figure 5: Effect of different geometry of rubber pimples

4 Conclusion and perspectives

The mains strategy of the table tennis game is to control the speed, spin and velocity of the ball. Selection of appropriate bat is a key priority of the players and each constituents of the bat contribute to the performance. In this study, the impact of table tennis ball/bat are investigated. Initially, experimental analysis was performed and the results were compared with simulation results. Different geometry of rubber pimples have been investigated. In the further work, several other parameters such as incident velocity, incident angular velocity, incident angle, friction coefficient, ball Young's modulus, ball radius, foam thickness will be studied.

5 Acknowledgements

The authors would like to acknowledge the valuable financial support of Ingénierie@Lyon carnot institute, CNRS and Sciences 2024 throughout this research. The authors are grateful to the Cornilleau company (N. Havard and S. Moineau) for providing the test apparatus and also for fruitful discussions.

References

[1] Xian-Wan Zhang and TX Yu. Experimental and numerical study on the dynamic buckling of ping-pong balls under impact loading. *International Journal of Nonlinear Sciences and Numerical Simulation*, 13(1):81–92, 2012.

[2] Yoshiya Miyazawa, Akihiro Hadano, and Katsumasa Tanaka. Effects of pimple height of a table tennis rubber on ball rebound behavior. In *Multidisciplinary Digital Publishing Institute Proceedings*, volume 49, page 55, 2020.

[3] Renaud G Rinaldi, Lionel Manin, Clément Bonnard, Adeline Drillon, Hugo Lourenco, and Nicolas Havard. Non linearity of the ball/rubber impact in table tennis: experiments and modeling. *Procedia engineering*, 147:348–353, 2016.

[4] Renaud G Rinaldi, Lionel Manin, Sébastien Moineau, and Nicolas Havard. Table tennis ball impacting racket polymeric coatings: Experiments and modeling of key performance metrics. *Applied Sciences*, 9(1):158, 2019.