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ScienceDirect

Procedia Engineering 72 (2014) 557 – 562

Procedia Engineering

www.elsevier.com/locate/procedia

The 2014 conference of the International Sports Engineering Association

Measurement of main strings movement and its effect on tennis ball spin

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Abstract

Ball spin plays an important role in the modern game of tennis. Previous work has shown that reducing the number of cross strings in a tennis racket can increase rebound ball spin. The aim of this study was to further our understanding of the effect of the number of cross strings on ball spin generation. Two rackets were tested, one with 16 main and 19 cross strings and the other with 16 main and 12 cross strings. The racket frame was fully-constrained and a ball was fired onto the strings at inbound angles of 24 and 38º. Inbound velocity was set at 30 m/s and inbound spin was varied from 0 to 500 rad/s. Ball velocity and spin, and lateral main string deflections during impact, were measured from high-speed video footage. Lateral string deflections were consistently larger for the racket with fewer cross strings. The racket with fewer cross strings produced slightly higher rebound spin and lower horizontal rebound velocity, which was attributed to the main strings returning during the restitution phase of the impact.

Selection and peer-review under responsibility of the Centre for Sports Engineering Research, Sheffield Hallam University

Keywords: tennis; impact; high-speed video; spin; angle; string bed

1. Introduction

The introduction of composite materials in the 1970s led to considerable changes in tennis racket design, including increased stiffness and head size, alongside reduced mass (Haake et al., 2007). The faster swing speeds and larger head sizes, associated with the new racket designs, are believed to have enabled players to hit balls faster

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Selection and peer-review under responsibility of the Centre for Sports Engineering Research, Sheffield Hallam University
doi:10.1016/j.proeng.2014.06.097

and with more spin. Topspin generates a downwards force on a ball in flight called Magnus force, which enables players to hit their shots faster and still land within the court boundary. Both the International Tennis Federation (ITF) and equipment manufacturers are concerned with the mechanics of spin generation from a racket. The ITF aims to protect the nature of tennis, while manufacturers continually strive to make improvements to their products. Recent work has focussed on the effect of string bed properties on ball spin generation (Allen et al., 2010; Haake et al., 2012; Nicolaides et al., 2013).

Allen et al. (2010) used a computational model to show that reducing ball/string friction can increase rebound spin, although no experimental data was presented to validate the predictions. Haake et al. (2012) presented experimental data which showed rebound spin to be dependent on inter-string friction. Nicolaides et al. (2013) investigated the effect of string bed pattern on ball spin generation. They fired balls at a velocity of 24 m/s, an angle of 26º (relative to normal) and spin rate of 218 rad/s, onto 9 fully-constrained rackets with different string bed patterns. They found rebound angle to decrease with the number of cross strings, while rebound spin increased. Nicolaides and colleagues presented images, captured at high-speed, which indicated the lateral deflection of the main strings increased as the number of cross strings decreased, however, no measurements were taken.

The aim of this research was to further our understanding of the effect of the number of cross strings on spin generation, by measuring both ball rebound and lateral deflections of the main strings.

2. Method

Two prototype rackets with the same head size - 0.35 x 0.25 m inside dimensions - but a different number of cross strings were used in this research. Both rackets had 16 main strings, one had 19 cross strings (16 x 19) and the other had only 12 (16 x 12). These rackets were strung with Polyester string (Prince Beast XP 17, Prince) at a tension of 245 N 24 hr prior to testing. ITF approved tennis balls (HEAD Radical, HEAD) were opened 24 hrs prior to the testing to stabilise the pressure and were marked to enable measurement of spin.

The experimental setup followed closely Nicolaides et al. (2013). A ball pitching machine (BOLA, UK) with a bespoke barrel fired the ball onto the face of the racket (Figure 1b). The frame of the racket was fully-constrained to allow any lateral movements of the main strings to be observed in a mirror set at 45º beneath the string bed. The ball was fired at two inbound angles, 24º (S.D. 1.6º) and 38º (S.D. 1.3º). For each angle, the inbound velocity of the ball was set at 30 m/s (S.D. 1.5 m/s) and the inbound spin was varied from 0 to 500 rad/s. Inbound spin was defined as positive at backspin, while the outbound spin was positive at topspin (Figure 1b). The ball was targeted at the geometric centre of the string bed, which is typically where elite players aim to strike (Choppin, 2011). Each racket was impacted 24 times per inbound angle and the maximum number of impacts per ball was 15.

A monochrome high-speed camera (Phantom v4.3, Vision Research) – operating at 1,265 Hz at a resolution of 320 x 240 with exposure time of 30 µs – was placed perpendicular to the plane of motion to record the trajectory of the ball. The footage was automatically digitised with in-house software (SpinTrack3D), to obtain the spin and velocity of the ball. Manual digitization in Phantom Cine Viewer v2.0 was used to measure inbound spin for balls with minimal inbound spin, as SpinTrack3D is inaccurate at low spin rates (Kelley, 2011).