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SUPER HIGH SPEED VIDEO ANALYSIS OF TENNIS TOP SPIN AND ITS PERFORMANCE IMPROVEMENT BY STRING LUBRICATION

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Players often say that some strings provide a better grip and more spin than others, but ball spin did not depend on string type, gauge or tension in the past laboratory experiment. There was no research work on the spin to uncover what is really happening during actual tennis impact owing to difficult experiment. This study made clear for the first time the mechanism of actual top spin and its improvement by lubrication of string intersections using 10,000 frames/sec high-speed video analysis, which is contrary to the hypothetical conventional spin theory. As the main strings stretch and slide side ways more and they spring back by lubrication of strings intersections, the ball is given more spin when the ball is released from the strings. More spin produce longer contact time between ball and strings, resulting in the reduction of shock vibrations of the wrist joint during impact. The design concept of strings spin performance should be taken a turn of 180 degrees in future.

1. Introduction

Since the sport should be learned from the experience, it is the subjective thing. Accordingly, it is quite difficult to see how the physical property of equipment has an effect on the performance of a player. The terms used in describing the performance of a tennis racket are still based on the feel or perception of an

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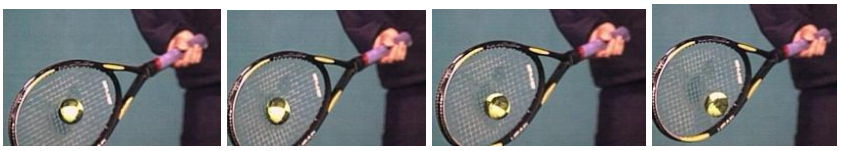
experienced tester or a player even today. However, the optimum racket depends on the physical and technical levels of each user. Accordingly, there are a number of unknowns regarding the relationship between the performance estimated by a player and the physical properties of a tennis racket. Players often say that some strings provide a better grip and more spin than others, but ball spin did not depend on string type, gauge or tension in the past laboratory experiment. There was no research work on the spin to uncover what is really happening during actual tennis impact owing to difficult experiment.

This study will make clear the fact of impact and the mechanism of actual tennis top spin as well as its performance improvement by lubrication of string intersections using high-speed video analysis of 10,000 frames/sec [1].

2. Super High-speed Video Analysis of Tennis Top Spin and Its Performance Improvement by String Lubrication

Figure 1 shows a topspin hitting frames from pre-impact to post-impact by a professional tester in the experiment. Figure 2 shows an example of frame using ultra high-speed video operating 10,000 frames/sec for topspin impact analysis, where (a) view from side for velocity analysis of spin angular motion and rectilinear motion of a ball and (b) view from behind for analysis of contact time and spin behaviors. Figure 3 shows the frames from behind the racket to see



(a) before impact (T2-f30L) **(b) start of contact** (T2-f50L) **(c) end of contact** (T2-f70L) **(d) after impact** (T2-f90L)

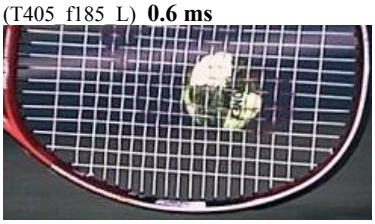
Figure 1 Topspin impact of a tester in this experiment.

(a) From side direction **(b) View from behind the racket**

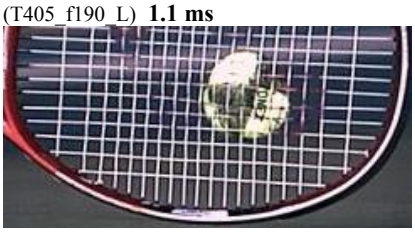
Figure 2 Ultra high-speed video for impact topspin analysis.

(T405_f179_L) **Start of contact 0.0 ms**

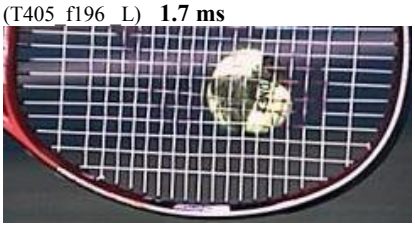
(T405_f185_L) **0.6 ms**



(T405_f190_L) **1.1 ms**



(T405_f196_L) **1.7 ms**



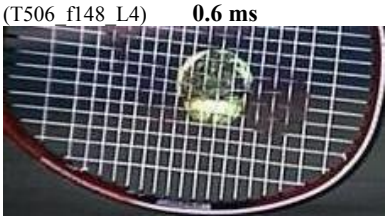
(T405_f200_L) **2.1 ms**

(a-1) Ordinary topspin (without string lubrication (Trial 405)

(to be continued)

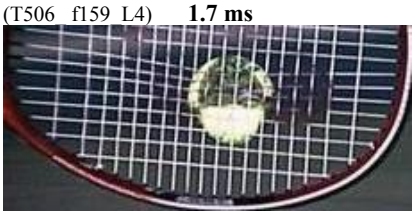
(T506_f142_L4) **Start of contact 0.0 ms**

(T506_f148_L4) **0.6 ms**



('T506_ f153_L4) **1.1 ms**

(T506_f159_L4) **1.7 ms**

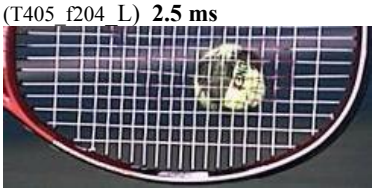


(T506_f163_L4) **2.1 ms**

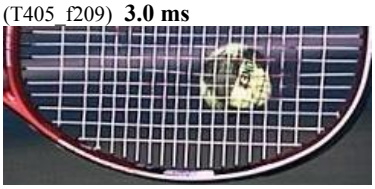
(b-1) Topspin with string lubrication (Trial 506) **(to be continued)**

Figure 3 (Part 1) Effect of strings lubrication on the ball spin behaviors: Impact views from back side direction.

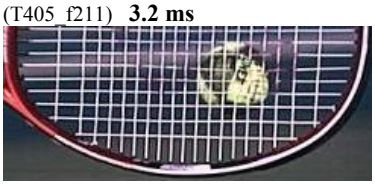
(T405_f204_L) **2.5 ms**



(T405_f209) **3.0 ms**

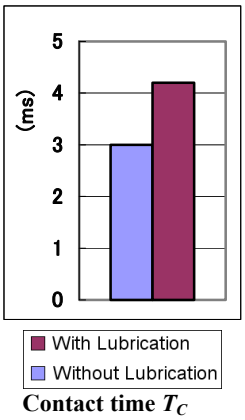


(T405_f211) **3.2 ms**



(T405_f213_L) **End of contact 3.4 ms**

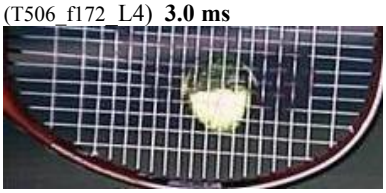
(a-2) Without strings lubrication



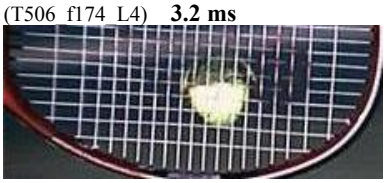
Contact time T_C

(T506_f167_L4) **2.5 ms**

(T506_f172_L4) **3.0 ms**



(T506_f174_L4) **3.2 ms**



(T506_f176_L4) **3.4 ms**

(T506_f180_L4) **3.8 ms**

(T506_f183_L4) **End of contact: 4.1 ms**

(b-2) With strings lubrication

Figure 3 (Part 2) Effect of strings lubrication on the ball spin behaviors: Impact views from behind the racket.

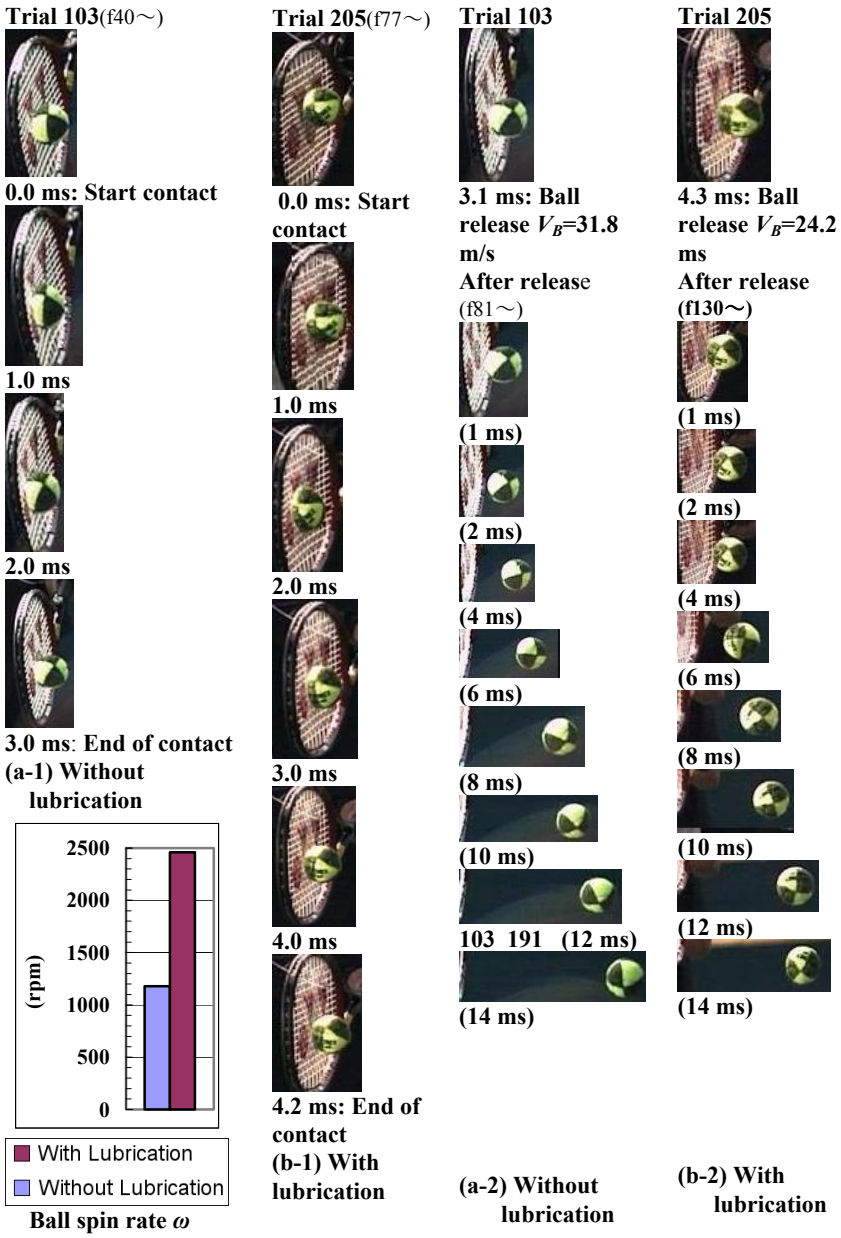


Fig.4 Effect of string lubrication on the ball spin (Impact views from side direction)

and analyze the effect of string lubrication on the ball spin during topspin forehand stroke, using high-speed video operating at 10,000 frames per/sec. Figure 3(a) shows the ordinary strings and Figure 3(b) shows the strings with oil lubrication. The mains stretch and slide side ways more and they spring back by lubrication of string intersections in Figure 3(b) compared to the ordinary strings in Figure 3(a), which does not move much and does not recover to their original position. The contact time (dwell time) with lubrication in Figure 3(b) is longer (4.1 ms) than that of ordinary strings (3.4 ms) in Figure 3(a).

Figure 4 shows the frames from side views, where Figure 4(a) shows the ordinary strings and Figure 4(b) shows the strings with oil lubrication. As the main strings stretch and slide side ways more and they spring back by lubrication of strings intersections in Figure 4(b), the ball is given more spin (2460 rpm) when the ball is released from the strings compared to the ordinary strings (1180 rpm).

3. The more lubricant, the more spin

The ball is given more extra spin when the main strings can slide freely over the cross strings, bite into the ball (the ball sinks into the strings) and spring back to their original position by reducing friction with oil lubrication of the string intersections, where the elastic force in a direction parallel to the string surface make a ball spin. More spin produces longer contact time between ball and strings, resulting in the reduction of shock vibrations of the wrist joint and a feel of softer impact [2].

4. Conclusions

This study made clear for the first time the mechanism of actual tennis top spin and its improvement by lubrication of string intersections using 10,000 frames/sec high speed video analysis, which is completely contrary to the hypothetical conventional spin theory. Opposite to the hypothetical conventional friction theory, the more lubricant the string is, the more spin is produced when a player actually hits topspin groundstroke. Thus, the design concept of strings spin performance should be taken a turn of 180 degrees in future.

References

1. Y. Kawazoe, K. Okimoto and K. Okimoto, *JSME Dynamics and design Conference 2004*, CD-ROM Proceedings, No.04-5, 1 (2004). (in Japanese)
2. Y. Kawazoe, K. Okimoto and K. Okimoto, *Proc. Sympo. on Sports Engineering, JSME*, No.04-265, 60 (2004). (in Japanese)