INSTRUMENTATION AND PADDLE RACKETS

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INTRODUCTION: Tennis rackets have long been studied, Brody (1979), (1981), (1987), (1989), but only recently has attention been focused on paddle rackets, since tennis with paddle rackets may be considered a recent, emerging sport. Knowledge of racket characteristics and properties will contribute to their improvement, better athletic performance and, most importantly, injury prevention. Tennis players are known to develop "tennis elbow," which has been associated with the transmission of impact forces and vibrations to the arm joints, Hennig et al. (1992), (1993). The same is expected to happen to paddle tennis practitioners. The choice of a good racket is not necessarily made by an expert, who should be aware of the mechanical characteristics or properties of the sport equipment. More often the racket is just held, and this is not necessarily undesirable, since other biomechanical parameters are, as in any sport, involved in tennis practice. Knowledge of some racket mechanical characteristics such as center of mass and center of percussion is far more widespread than that of restitution and vibration. Since it is desirable to obtain higher rebound ball speeds, compromise between a high coefficient of restitution and vibration absorption should be achieved, Hatze (1993). Paddle rackets are suitable to accept surface-bonded sensors, thus making electronic instrumentation an efficient way to investigate mechanical problems such as impacts, vibrations, and so on. The aim of this paper is the description of an instrumentation setup designed to investigate the coefficient of restitution and vibration on paddle rackets.

METHODS AND PROCEDURES: The coefficient of restitution is an attribute of a system of impacting bodies. It depends on the way energy is transformed within the system, and its precise determination is not an easy task. During an impact, it can be partly analyzed by constraining one of the bodies and taking the ratio of post-impact to pre-impact velocities of the free moving body. Although not strictly correct, this could provide information about the racket itself, however, for high ball speeds, image discrimination may not be enough for a reasonable analysis by a video system, thus electronic instrumentation was used to measure ball speeds. The setup consisted of a window with a pair of parallel screw adjustable mirrors attached to the frame. A 4 mW, 670 nm laser beam provided by a pointing device inserted into the frame was adjusted to a zigzag trajectory by multiple reflections spaced at about 1/6 of the ball diameter, which was considered enough for a 97% precision for trajectories which are orthogonal to the window plane. At the end of the zigzag light beam, a photo diode detected beam interruptions while the ball was passing through, Fig. 1, allowing the measurement of the time interval between the light beam interruption and its recovery, so speeds could be easily calculated from the ball diameter. An adjustable pneumatic cannon, as seen in Fig. 2, was used to shoot the tennis ball at speeds within the range usually seen in competition. As an additional feature, a LED - photo diode pair was installed at the cannon extremity so the ball could be monitored precisely when leaving.

Fig. 1
Partial view of the setup: racket and laser window

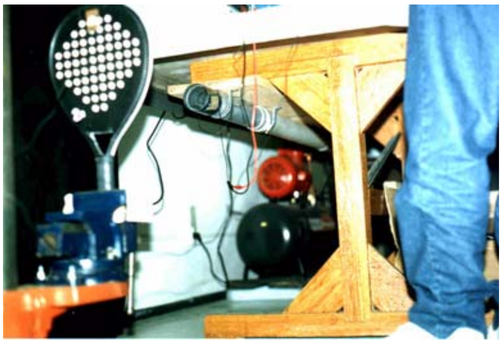
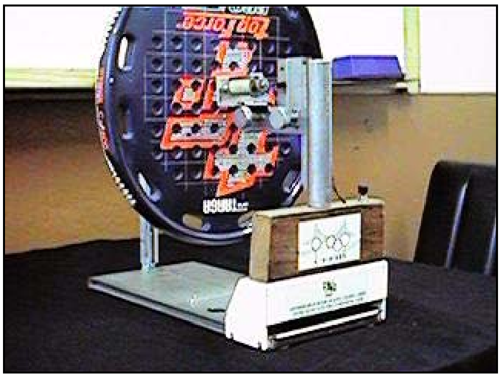


Fig. 2
Partial view of the setup: racket and pneumatic cannon

Vibration is an important racket mechanical response to be taken into consideration. For a homogeneous beam of uniform cross section, vibration nodes should be two in number, each one at 1/5 of the beam length, measured from the ends. Since rackets are non-homogeneous bodies of complex geometry, the best way to obtain this information is experimental. Piezoelectric transducers were bonded to the racket surfaces in order to investigate vibrations. Held by a wire in a stationary vertical position, they were hit on the middle line at different heights by an adjustable magnetically driven hammer Fig. 3, allowing us to analyze vibrations and locate sites where their amplitudes were minimal; those sites are vibration nodes.



RESULTS AND DISCUSSION: The laser net was extremely sensitive to ball passage, so the system needed an LM 339 high precision comparator in order to provide a sharp pulse which could be correctly read on the oscilloscope screen. Pulse widths were within a couple of ms. Fig. 4. Channel 1 (blue) curve is a negative pulse output whose width is the time interval of the ball passing by. t1 is the time when the ball interrupts the cannon light beam. Interval t3 - t2 and t6 represent the laser beam interruption which occurred when the ball passed by. t4 is the time taken by the ball in moving from the window to the racket surface. In all cases the ball speed can be determined. Channel 2 (red) curve is a signal provided by the piezoelectric transducer bonded to the racket.

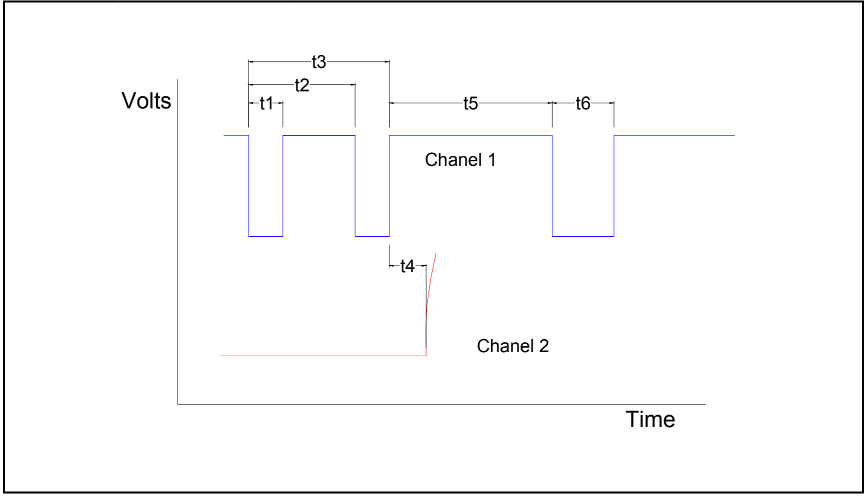


Fig. 4 Oscilloscope sketch of pulse output

Interesting results such as a non-homogeneous coefficient of restitution could be observed, and this deserves further studies. Vibration nodes were typically situated at about 110 mm from the free racket end, while the other node is located in the grip. A minimum of vibration will be generated when the ball impacts near those sites. Together with the appropriate theory, our results are contributing to paddle racket improvements. New rackets have been designed taking our results into consideration. A hollow racket is an example; laboratory tests have shown that the coefficient of restitution is higher and vibrations lower than those of solid rackets; as a consequence, better performance and a reduction in injuries are expected.

REFERENCES:

Brody, H. (1979). Physics of the Tennis Racket. *Am. J. Phys*. **6**, 382-487.

Brody, H. (1981). Physics of the Tennis Racket II. *Am. J. Phys.* **49**, 816-819.

Brody, H. (1987). Models of Tennis Racket Impacts. *Int. J. Sports Biomech.* **3**, 293-296.

Brody, H. (1989). Vibration Damping of Tennis Rackets. *Int. J. Sports Biomech*. **5**, 451-456.

Hatze, H. (1993). The Relationship between the Coefficient of Restitution and Energy Losses in Tennis Rackets. *J. Appl. Biomech*. **9**, 124-142.

Hennig, E. M, Rosenbaum, D., Milani, T. L. (1992). The Transfer of Tennis Racket Vibrations on the Human Forearm. *Med. Sci. Sports Exerc*. **24**, 1134-1140.

Hennig, E. M., Milani, T. L. (1993). The Influence of Tennis Racket Characteristics and Grip Strength on the Magnitude of Arm Vibration. In *Proc. Int. Soc. Biomech. XIV Congress*.