ON THE COEFFICIENT OF RESTITUTION OF TENNIS RACQUETS

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INTRODUCTION

In order to validate a mathematical model for the impact phase recently developed by our group (Casolo and Ruggieri, 1992) and to evaluate tennis equipment, some experimental tests has been carried out in our laboratory. The apparatus developed for this purpose also allows us to analyse some parameters currently adopted for comparing racquets; the most popular among them is probably the coefficient of restitution (COR) or the coefficient of rebound of the racquet. It is usually defined as the ratio of the rebound speed of the ball versus relative speed of the ball with respect to the racquet before their impact. According to this definition it is clear that COR in general does not represent the mechanical efficiency of the impact of the ball against the racquet because it does not take into account the speed of the racquet after the impact and the elastic energy stored in the racquet frame. However, since both racquet producers and tennis journals often refer to this parameter for evaluating the equipment, a better understanding of influence of testing conditions on COR can be useful.

METHODOLOGY

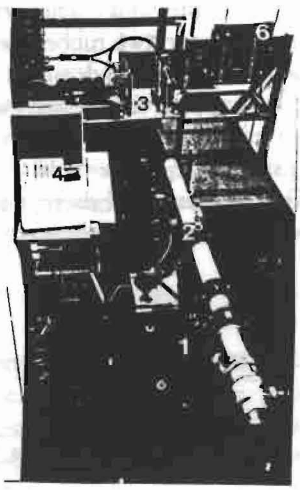


Figure 1. Ball and racquet testing set-up:1) air gun; 2) laser pointer; 3) speed measuring device; 4) velocity display;5) rigid frame; 6) racquethead holder; 7) frame for whole racquet test.

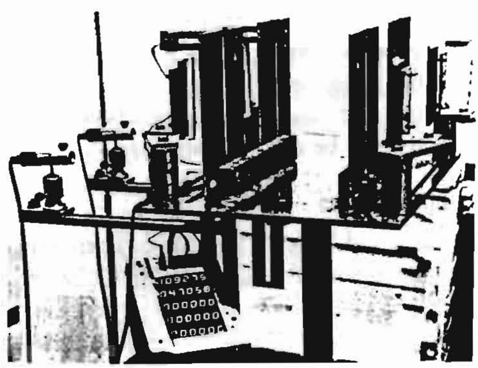


Figure 2 - Speed gauge.

The testing apparatus used consisted of: a) a precision air gun capable of ball speed from 5 to 80 m/s and equipped with a laser pointer (Figure 1); b) a speed gauge for the ball velocity before and after the impact; it consisted of a double laser barrier connected with a logic circuit and a 10Mhz clock (Figure 2): c) two kinds of targets: a very rigid frame to test the balls against a rigid wall and to support the racquet head rigidly; and a special frame (Figure 3) that can free the racquet just before the impact by means of two electromagnets driven by the ball. On this frame a racquet with the equivalent mass (Casolo, 1991) can also be mounted (Figure 4).

Some kinds of COR tests have been carried out: a) for balls against a rigid wall, in order to test different kind of balls and different ball wearing conditions; b) for a rigidly constrained racquet head, in order to test the influence of strings tension and of the location of the impact point (Figure 5); and c) for racquets free for a global evaluation of the equipment.

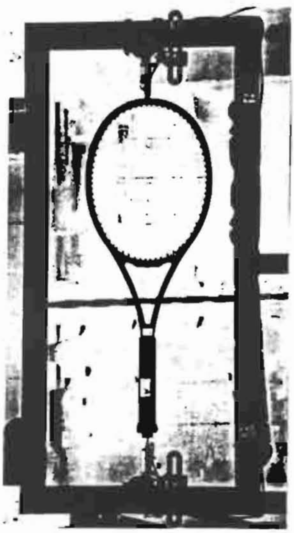


Figure 3. Frame with the racquet release system.

Figure 4. Racquet with the body equivalent mass on the grip.

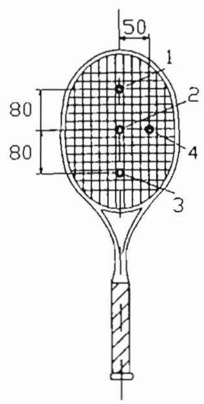


Figure 5. Impact points.

RESULTS AND DISCUSSION

All graphs of COR highlight that the main affecting parameter is the impact velocity. At higher velocities a greater portion of energy is lost during the impact. This is evident looking at the graphs (Figures 6 and 7) obtained using balls against the rigid wall. In this particular case COR is proportional to the square root of the ratio of the ball energy before and after the impact. The same graphs show that different kinds of homologated balls can have quite different efficiency. In particular, the non-pressurized tested balls were less efficient; also that ball wearing strongly affects the COR.

Figure 7 shows the influence of the strings. The increase of their tension corresponds to a COR decrease; if we consider that balls dissipate much more energy than strings and that a higher deformation of strings will allow a lesser deformation of the ball. The preliminary results also suggest that over a certain impact velocity the effect of strings on COR decreases.

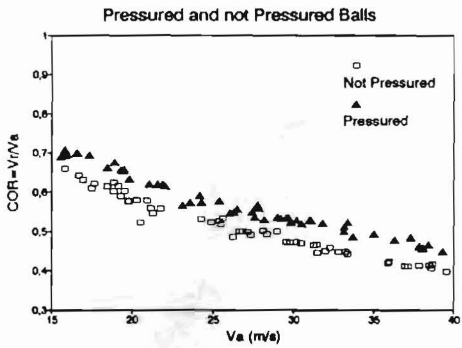


Figure 6. Pressurized vs. non-pressurized balls.

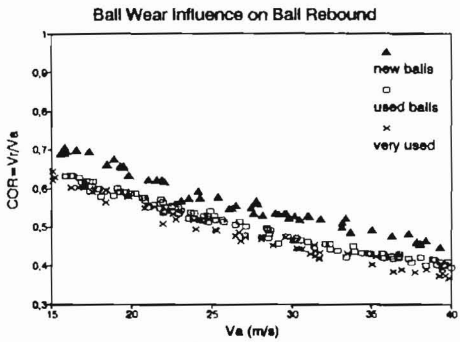


Figure 7. Influence of ball wear on ball rebound.

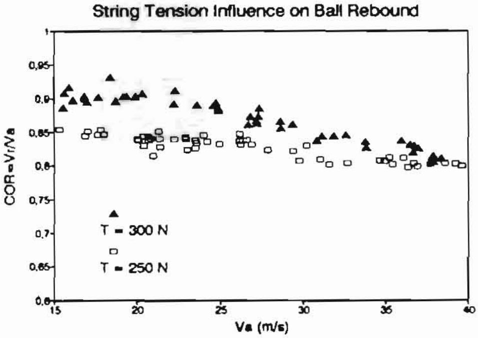


Figure 8. String tension influence on ball rebound.

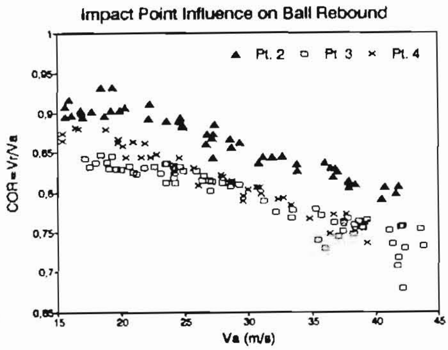
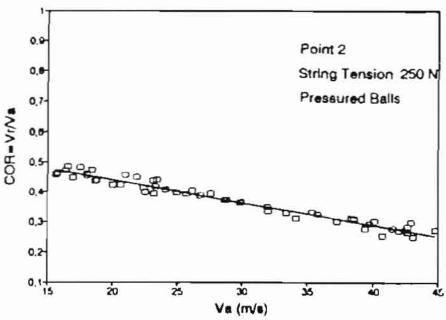


Figure 9. Impact point influence on ball rebound.

Analogously, the graph in Figure 8, also obtained with the racquet head constrained, shows that hitting the racquet out of the center of the strings plane decreases the COR. In fact, shorter strings deflect less.



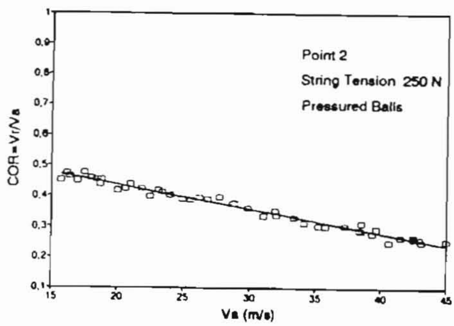


Figure 10. Racquet handled. Figure 11. Racquet with mass on grip.

Figures 10 and 11 show that the COR obtained by hitting a handled racquet is substantially equal to the one obtained hitting a racquet free in the space with an equivalent mass on the handle (Casolo, 1991). Therefore, to increase the repeatability of the tests, it is convenient to substitute the player with the equivalent mass, positioning the racquet by means of our release system. In these last two tests and in the following one, the value of COR was obviously lower than the ones obtained in the previous tests because, as we pointed out, this value does not take into account the racquet velocity after the impact.

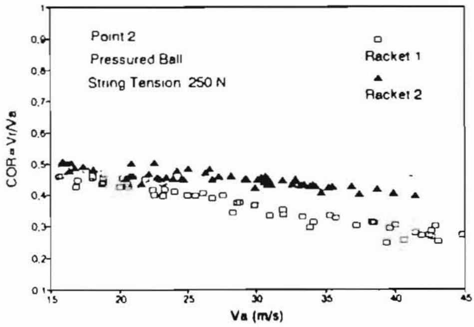


Figure 12. Influence of impact velocity on racquet test.

Figure12 shows the COR of racquets having two different profiles, measured in the same conditions. They behave equally at low impact speed while they have a very different COR at higher speed.

CONCLUSIONS

The COR of the racquet cannot be directly related to the efficiency of its frame and involves ball, strings, racquet frame and grip restraint together. In order to be classified by means of COR, racquets must be tested with the same kind of balls and the same kind of strings at equivalent string tension (i.e. the tension that gives the same stiffness to the string plane). With regards to the relative velocity before the impact, only one test is insufficient. Figure 12 shows that racquet 1 and racquet 2 have similar COR for Va=20 m/s and a very different one for higher speed. For weak players, the two tested racquets are probably equivalent, while a stronger player can certainly feel a very big difference between them.

Therefore, if one wants to use COR for comparing racquets, we suggest to measure it at four different velocities from 15 to 45m/s. Unfortunately, due to the big lack of information on the testing parameters, most of papers reporting racquets' COR values are useless for racquet classification.

ACKNOWLEDGMENT

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