Effects of booster on bounce properties of rubber
(Data for proposal of banning post-treatment of rubbers)

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Abstract: Measurements were made to see the effects of commercially available boosters on bounce properties of rubbers. The purpose of this work is to provide data for the proposal of banning post-treatment of rubbers. In this experiment a small steel ball (9mm diameter and 3g mass) was released on the rubber from the position of 513mm high and the rebound height of the ball was measured. The results clearly show the effect of the booster on the rebound height, that is, the rebound height is larger in the case of rubbers treated by booster. It is found that a simple measurement using a small steel ball proves to be an efficient method to check rubbers with abnormal elasticity.

Keywords: Rubber, rule violation, booster, elasticity, rebound height, steel ball.

1. INTRODUCTION

The following law and regulation are described in the Handbook of ITTF [1].

2.04.07: The racket covering shall be used without any physical, chemical or other treatment.

3.04.02.02: The racket covering shall be used as it has been authorized by the ITTF without any physical, chemical or other treatment, changing or modifying playing properties, friction, outlook, color, structure, surface, etc.; in particular, no additives shall be used.

In spite of these law and regulation, manufacturers, players and coaches ignore the rule of rubber openly. Manufacturers immerse rubbers in mineral oil to increase elasticity and tension. This immersing process is made against rubbers which are regarded as a completed industrial product. As a result, rubbers contain a large amount of mineral oil in this treatment. It is post-treatment undoubtedly. Many rubbers made through such a process are approved by ITTF and distributed in the world. Booster, the content of which is mineral oil, is abundant on the market in the world, though it is banned to use in regular games. Many law-breaking players use such booster to enhance rubber performance. Law-abiding players using no booster are faced with a big handicap in the play. Such unfairness occurs in regular games.

Speed and rotation of a ball hit by pimples-in rubber increase excessively. Some people might say that play of table tennis becomes powerful owing to boosting materials, but it should be recognized that negative influences are becoming apparent. Table tennis is a sport played by human. Winning should be gained by high playing skill, not by equipment. This principle is common to every sport. Post-treatment of rubber spoils modern table tennis. As the result of speed increase over the tolerable level, the playing style of table tennis tends to converge on the attack style. Especially in case of men's play, choppers are hard to win against attack style players. Variety of playing style and techniques (drive, slice, short etc.) make table tennis an attractive sport. The use of excessively high tension and elasticity rubber reduces such variety of playing style.

The attractive point of racket sports lies in rally, not service and not smash. Play ending by a few rallies or play continuing 2 hours are boring. Players are satisfied by thrilling and exciting rallies continuing a suitable number of times. Spectators are also fascinated by such rallies. It was attempted to reduce ball speed by changing in ball size from 38 to 40 mm. However, it was not long before the development of high performance rubbers increased ball speed and spin, and cancelled the effect of size increase. The purpose of this work is to provide data for the proposal of banning post-treatment of rubbers.

2. EXPERIMENT

2.1 Equipment

We tried to show difference in elastic properties between rubbers with and without booster experimentally. Also we aimed to prove that the present method can be used to detect rubber violating the rule.

A few methods are applicable to check rubbers.

(1) Additives contained in the rubber are detected by a gas chromatography.
(2) Mineral oil is extracted from the rubber by using chemicals such as acetone. The weight or volume of the oil is measured.
(3) Bouncing properties of rubbers are measured in a test where a test ball is released on the rubber from the position of suitable height and rebound height of the ball is measured.

Considering that the equipment will be used in the playing arena, the equipment satisfies the following conditions:

- Simple and clear measuring principle understood by anybody
- No need for calibration

- Portable
- Manipulated by non-expert
- Inexpensive

We adopted the method (3) in this work. Fig.1 shows the experimental equipment. When the method (3) is adopted, a question arises whether it is sufficient to watch only the rebound height to see the effect of booster. The meaning to note the rebound height is discussed in Appendix 1

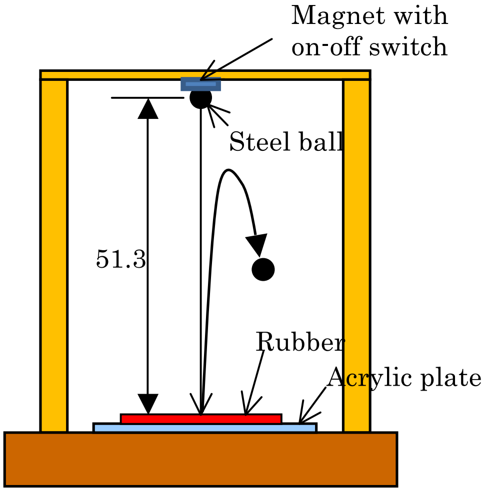

Fig.1 Experimental equipment

Experiment was made in JISS on 24th ,January 2013. People attending the experiment were researchers in table tennis rubber, engineers of a gum manufacturer, sports science experts and staff of JTTA. The ball was a steel ball used for bearing. The diameter and mass are 9 mm and 3 g. Tested rubbers were pimples-in ones. The rubber was glued on the acrylic plate. In general, surface of rubber is sticky more or less. In order to remove the effect of sticky nature of the rubber on the bouncing motion, the surface was made frictionless by a treatment using powder (talc). A magnet with on-off switch was set to fix the steel ball. The height of the initial ball center measured from the rubber surface was 513 mm. Motion of the ball was taken by a high speed video camera.

Players who are accustomed to use booster know well from their experience the technique of treatment of booster, at what timing they start putting on booster and how many times they put on booster. However in our experiment we put booster only once: 72 hours before the test. In fact the treatment of booster on some rubbers was incomplete, particularly for the rubber which has already very high elasticity owing to post-treatment by manufacturers. In this paper, results of such cases are also shown.

2.2 Rubber tested

We selected 6 kinds of popular rubbers for the test. They are named Rubber 1, 2, 3, 4, 5 and 6. Four cases of each of 1 to 5 were tested according to the following conditions; black or red, and with or without booster. For Rubber 6, only the red rubber was tested in 2 cases with and without booster. Thus, the total number of the rubbers 1 to 6 was 22. Rubber 2 and 6 have not had the post-treatment by manufacturers. Other rubbers contain a large amount of mineral oil in the post-treatment by manufacturers in the factory.

2.3 Measurement procedure

The steel ball is small. Thus, there is a possibility that the results of the rebound height are affected by the location of the contact point between the ball and rubber surface relative to pimples. Thus, we changed the position of rubber by changing the direction of rubber as shown in Fig. 2. In the case of Rubber 1, measurements were repeated 4 times under the same condition to check the reproducibility of measured data.

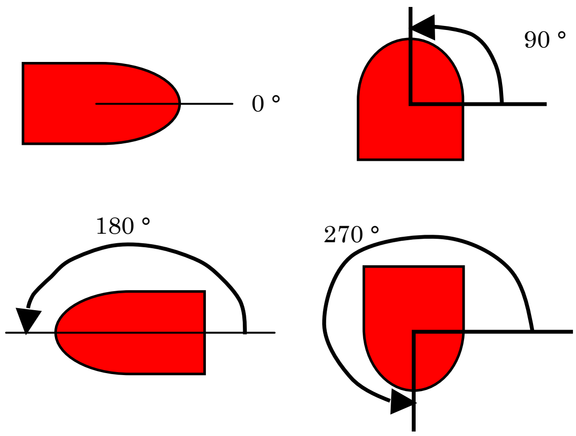

Fig.2 Rotation of rubbers

3. RESULTS

Results are shown in Fig. 3. Numerical data are shown in Table 1. The coefficient of restitution (COR) was calculated from the following equation.

$$e = \sqrt{\frac{h}{h_0}} \qquad (1)$$

The above equation is derived by neglecting fluid drag. All the data except for the case of Rubber 3 show that the rebound height increases owing to the use of booster. As described before, rubbers except Rubber 2 and 6 have post-treatment by manufacturers. It is found that the commercial booster used in this experiment is effective even for such a rubber.

Rubbers 2 and 6 are different from other rubbers. These rubbers did not have the post-treatment by manufacturers. As expected, their rebound height without booster is quite small compared with Rubber 1, 3, 4 and 5. It should be noted that the effect of booster is remarkable in Rubber 2 and 6.

In the present work, we experienced that the technique of putting on booster is very important. To make the booster effective, we must make the boosting material sink into the rubber uniformly. However, we failed to make such a rubber in case of Rubber 3. This is the reason why the effect of booster on the bouncing height is not clear or sometimes opposite. Rubber 3 without booster shows extremely high rebound height. The results of Rubber 3 indicate that additional treatment of booster does not work for such a rubber.

We made experiments using table tennis ball as an attempt. The rubber was Rubber 6. The initial height of the ball was 496 mm. We did not use the magnet in this experiment. We held the ball by hand and released it. Results are shown in Table 2. The effect of booster is obvious as in the case of steel ball.

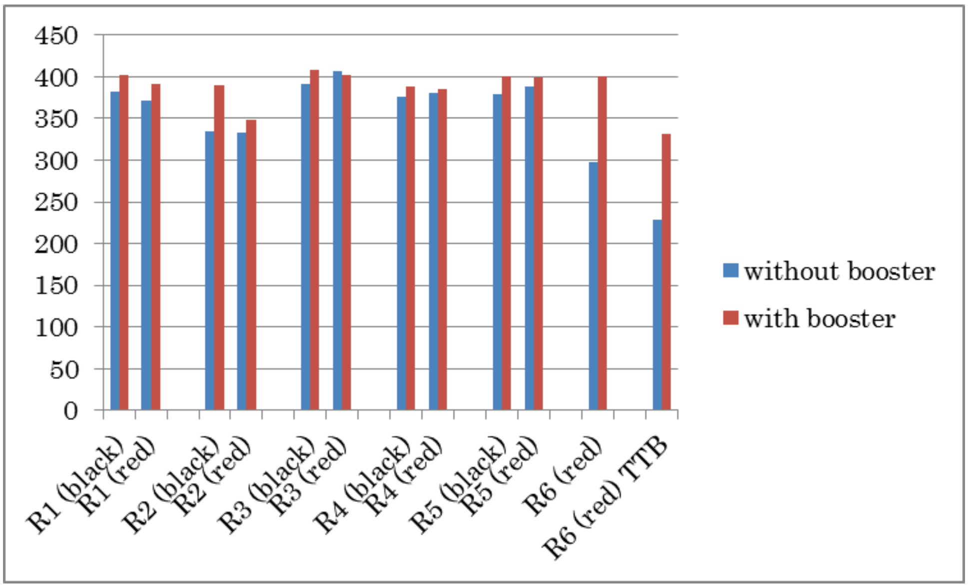

Fig.3 Rebound height
Initial height : 513 mm (steel ball), 496 mm (TTB: table tennis ball)

4. UPPER LIMIT OF REBOUND HEIGHT

The most valuable findings in the present experiment is that a simple measurement using a small steel ball proves to be an efficient method to detect rubbers treated by boosting materials. The meaning of using a small steel ball is discussed in Appendix 2. The next stage is to determine the upper limit of rebound height. To proceed to such a stage, it is necessary that ITTF approves the measuring equipment officially. The present method is one of candidates. However, the present method has a problem. The rebound height was measured from pictures taken by a video camera. It is not practical to depend on the video camera in an actual play arena. One solution of this problem is to use an optical sensor. However, the data processing system dealing with optical signals will be expensive. Therefore, there is a possibility that the present method will be improved though the condition of using a small steel ball is the same. Also, measurements for many more rubbers are needed. We should improve the technique using booster to the level of experienced players.

Finally, we will make a proposal concerning the upper limit of the rebound height. The upper limit should be determined based on the data of rebound height of rubbers without booster. The rebound height without booster is clearly different whether rubbers have already post-treatment by manufacturers or not. The range of the rebound height on Rubber 1, 4 and 5 without booster is between 372 and 388 mm while the range of Rubber 2 and 6 without booster is from 298 to 333 mm. (The case of Rubber 3 is here omitted because its rebound height without booster is abnormally high.) Concerning determination of the upper limit, two ways are considered.

(1) The upper limit is determined from the rebound height of rubbers without post-treatment by manufacturers like Rubber 2 and 6.
(2) The upper limit is determined from the rebound height of rubbers with post-treatment by manufacturers like Rubber 1, 4 and 5.

If all post-treatments by manufacturers and players are banned, the way (1) should be adopted. However, if this way is adopted, the influences on table tennis circles would be very large, because such rubbers with post-treatment by manufacturers are widely distributed in the world. Besides, those rubbers are formerly approved by ITTF. The way (1) is idealistic but considering social impact, it is not realistic to adopt this way at short notice. We will propose that two steps should be taken toward the final goal. The first step is to adopt the way (2) at the start point of regulation. A few years later, the way (1) will be adopted after confirming that confusion caused by regulations can be avoided.

5. CONCLUDING REMARKS

It is found that a simple measurement using a small steel ball proves to be an efficient method to detect rubbers treated by boosting materials. The effect of booster on rubber performance was made clear in the present experiment. A steel ball of 9 mm diameter was released from the position of 513 mm high, and rebound height was measured using a high speed video camera. Rubbers tested are classified into two groups: the one is the group which has the post-treatment by manufacturers in the factory; the other is the group without such post-treatment. The commercially available booster was put on the rubber. Cases with and without the booster were compared. Rubbers with post-treatment by manufacturers showed large rebound height even in the case without booster. The booster is found to be effective on such rubbers. The effect of booster is much remarkable in rubber without post-treatment by manufacturers.

Acknowledgement:

The present experiment was conducted with the cooperation of JTTA (Japan Table Tennis Association), JISS (Japan Institute of Sports Sciences), researchers, engineers and other people concerned. We are pleased to acknowledge the considerable assistance of people cooperating with us

Appendix 1: Use of a small steel ball

The purpose of the present work was to investigate the bouncing properties of the rubber, not the bouncing properties of ball. The rebound height reflects the properties of both rubber and ball. In order to use a ball as the standard test ball approved officially, its bouncing properties should be stable. Specification of steel balls used for bearings is strict. The bouncing properties of different balls are the same if the specification is the same.

On the other hand, the bouncing properties of table tennis ball are not so stable because allowance error of table tennis ball is quite large. Further, surface of table tennis ball changes if a same ball is used a number of times. Such change does not happen in steel balls. Also, table tennis balls are easily affected by atmospheric conditions such temperature, pressure, humidity, etc.

In general, when two objects collide, both objects deform more or less. A part of the kinetic energy is lost due to the deformation. As the result of this energy loss, the coefficient of restitution becomes less than unity. Deformation of ball and rubber is directly related to bouncing properties. When the steel ball collides against the rubber, deformation of the steel ball is small compared with that of the rubber. To extract only the effects of rubber on bouncing motion, it is sensible to use a hard sphere like the steel ball, because most of the energy loss is due to the rubber.

The speed of the steel ball at the moment of collision is smaller than the speed of table tennis ball in real play. This means that the force which the steel ball acts on the rubber is smaller than the force acted by the table tennis ball. However, the contact area between the steel ball and rubber is so small that the force per contact area (pressure) acting on the rubber is not very small. Concerning the size 9 mm, there is no rigorous reason. We have reached this size by trial and error. Using the ball of 9 mm diameter, we succeeded in getting the results which show clear differences between cases with and without booster.

Appendix 2: Meaning to note rebound height

Players use booster not only to increase ball speed but also to increase rotation. Rotation is generated by friction. Thus, it is natural to have a question whether the results of the present work have something to do with friction.

It is true that the rebound height of the ball represents the normal component of bouncing properties, not the tangential component. However, the present results can be relevant to friction to some extent. The reason is described in this Appendix.

Friction is classified into two kinds: static friction and dynamic friction. Two objects contacting with each other do not slide necessarily even though the tangential force acts on the objects. The contact surface of each object keeps sticking and moves laterally together. When the tangential force exceeds the critical value, the two objects begin to slide. The tangential force before the objects slide is called static friction. The tangential force acting between two sliding objects is called dynamic friction. The maximum value of the static friction is larger than the dynamic friction. The static friction of rubber producing high rotation is quite large. Thus, a ball does not slide on such a rubber.

Let us look at this phenomenon from the microscopic view point. In general, when the ball collides against the rubber with or without rotation, the rubber deforms as shown in Fig. 4. The more the deformation, the larger the force acting on the ball. This relation between deformation and force holds for the friction force as long as the ball sticks to the rubber. Thus, the mechanism generating the friction force is qualitatively the same as the normal force of repulsion. The rebound height represents the normal force of repulsion. Thus it is expected that a large value of rebound height corresponds to large friction. This concept does not hold for the dynamic friction.

REFERENCE

[1] The Laws of Table Tennis, The International Table Tennis Federation Handbook, 2012/2013.

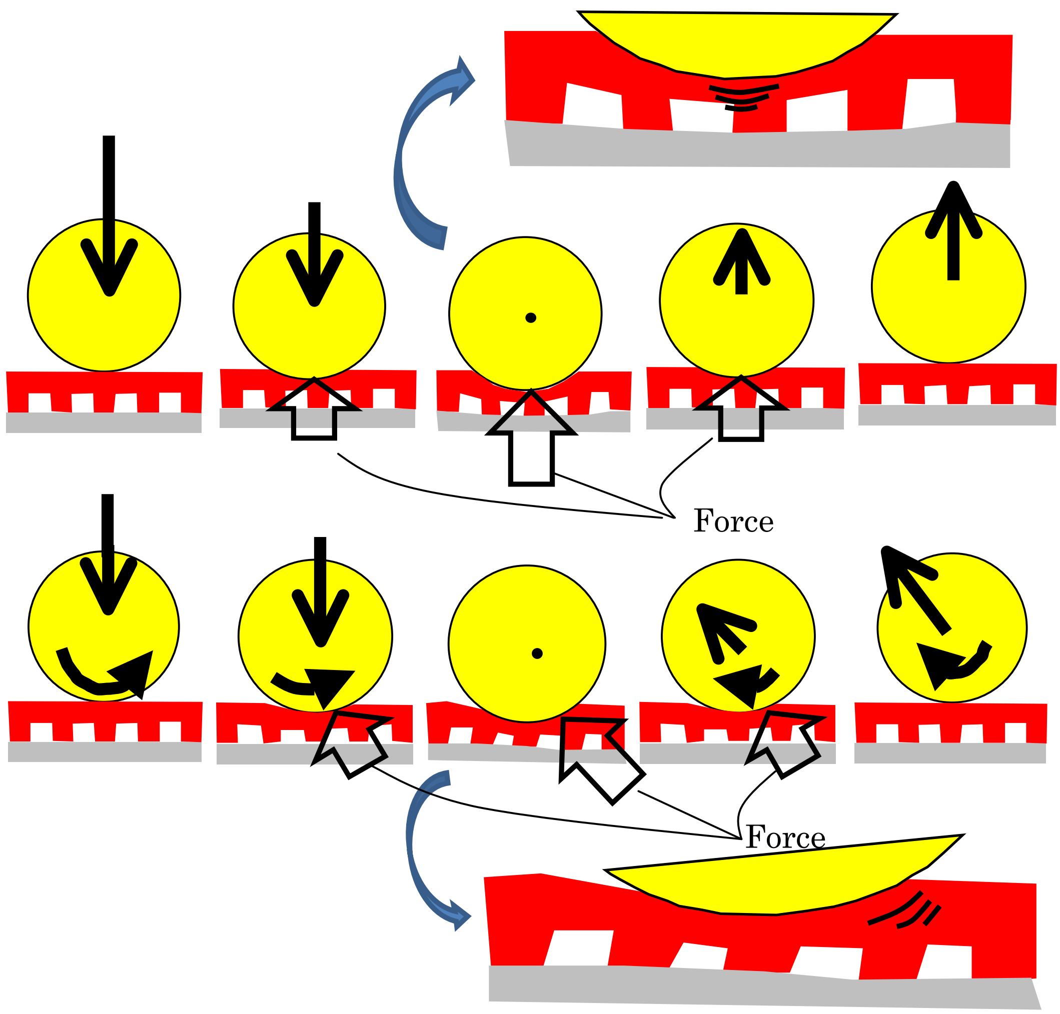

Fig.4 Deformation of rubber and force acting on rubber

Table 1 Rebound height (R. height) of steel ball (h_0 =513mm) and coefficient of restitution (COR)

Rubber 1 (Black)	Angle Θ	R. height h (mm)	Mean height	COR e
Without booster	0	383	383	0.864
	0	386		
	0	388		
	0	298		
	90	384		
	90	390		
	90	391		
	90	391		
	180	384		
	180	389		
	180	390		
	180	390		
	270	387		
	270	390		
	270	393		
	270	392		

Rubber 1 (Black)	Angle Θ	R. height h (mm)	Mean height	COR e
With booster	0	409	403	0.886
	0	409		
	0	410		
	0	333		
	90	401		
	90	409		
	90	410		
	90	410		
	180	402		
	180	410		
	180	410		
	180	409		
	270	401		
	270	405		
	270	407		
	270	410		

Rubber 1 (Red)	Angle Θ	R. height h (mm)	Mean height	COR e
Without booster	0	382	372	0.852
	90	364		
	180	372		
	270	369		
With booster	0	393	391	0.873
	90	389		
	180	392		
	270	391		

Rubber 2	Angle Θ	R. height h (mm)	Mean height	COR e
Black Without booster	0	337	334	0.807
	90	331		
	180	328		
	270	337		
Black With booster	0	395	390	0.871
	90	390		
	180	387		
	270	390		
Red Without booster	0	333	333	0.805
	90	333		
	180	335		
	270	332		
Red With booster	0	337	349	0.824
	90	358		
	180	363		
	270	340		

Rubber 3	Angle Θ	R. height h (mm)	Mean height	COR e
Black Without booster	0	387	391	0.873
	90	389		
	180	394		
	270	394		
Black With booster	0	407	408	0.891
	90	410		
	180	404		
	270	411		
Red Without booster	0	404	407	0.891
	90	409		
	180	403		
	270	409		
Red With booster	0	411	403	0.886
	90	384		
	180	410		
	270	406		

Rubber 4	Angle Θ	R. height h (mm)	Mean height	COR e
Black Without booster	0	372	376	0.856
	90	378		
	180	378		
	270	379		
Black With booster	0	387	389	0.871
	90	386		
	180	387		
	270	394		
Red Without booster	0	379	380	0.826
	90	379		
	180	381		
	270	380		
Red With booster	0	379	385	0.866
	90	387		
	180	386		
	270	387		

Rubber 5	Angle Θ	R. height h (mm)	Mean height	COR e
Black Without booster	0	390	379	0.860
	90	384		
	180	384		
	270	360		
Black With booster	0	398	401	0.884
	90	410		
	180	398		
	270	399		
Red Without booster	0	390	388	0.870
	90	389		
	180	389		
	270	384		
Red With booster	0	398	399	0.882
	90	398		
	180	397		
	270	401		

Rubber 6 (Red)	Angle Θ	R. height h (mm)	Mean height	COR e
Without booster	0	293	298	0.762
	90	299		
	180	301		
	270	301		
With booster	0	395	401	0.884
	90	403		
	180	404		
	270	404		

Table 2 Rebound height of table tennis ball (initial height h_0 =496mm) and COR (e)

Rubber 6 (Red)	Angle Θ	R. height h (mm)	Mean height	COR e
Without booster	0	252	228	0.674
	90	250		
	180	253		
	270	155		
With booster	0	338	332	0.818
	90	336		
	180	327		
	270	329		