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Analytical and experimental determination of the energy dissipation of the bounced basketball in the natural drop test

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Abstract: *Analytical and experimental investigation of dissipation of rebound energy of basketball in natural drop.*The work presents a short history of the creation of the game called basketball and the method of determining the selected parameters of the dynamic rebound of the basketball. These parameters are necessary in the construction of a numerical model of basketball and analysis of the behavior of sports flooring structures based on wood and wood-based materials.The steps of the basketball bounce process from the stiff floor are explained and explain the causes of energy loss at the moment of impact.When a basketball bounces off of a surface, some of its energy is absorbed by that surface. Some surfaces absorb more energy than others do. A hard surface, such as concrete, absorbs less energy compared with a soft surface. The more energy absorbed by the surface, the less that remains in the ball for it to bounce.The value of the material damping coefficient was estimated at the optimal internal pressure of the ball being considered.The tests showed a change in the rebound height depending on the ball's internal pressure. Measured parameters of ball bounce are necessary for the construction of a numerical model of sports floor construction made, among others of wood and wood-based materials.The test results are presented in the form of diagrams.

*Keywords:*normal drop test, basketball, energy dissipated, bounce, sport floor.

INTRODUCTION

Many players and audiences nowadays are involved with sports , sach as handball, volleyball, and bascetball. The most important equipment of these games is ball. Basketball is one of few sports with a known date of birth. On December 1, 1891, in Springfield, Massachusetts, James Naismith hung two half-bushel peach baskets at the opposite ends of a gymnasium and out-lined 13 rules based on five principles to his students at the International Training School of the Young Men's Christian Association which later became Springfield College. The peach baskets he hung as goals gave the sport the name of basketball. Basketball is a sportplayed by two teams of five players on a rectangular court. Each ball has its own characteristics and has to be made according to the rules of its federation. For the basketball ball these characteristics is determined by the NBA and FIBA federation. As the ball is intended to be operated by a single hand, the official size of the ball varies depending on age and gender of the participating teams. The regular dimension of a basketball in the NBA is 24.1–25.0 cm in diameter. The ball must be inflated to a pressure sufficient to make it rebound to a height (measured to the top of the ball) of 1.2-1.4 m, when it is dropped on a solid wooden floor from a starting height of 1.80 m, measured from the bottom of the ball.

The impact proces a ball and hard surface involves a change, albeit temporary, in the shape of the ball. The collision of a ball always involves some dissipated of energy [1]. For example, the energy may be dissipated in the ball during the collision as a result of internal friction, or energy may be lost as a result of a permanent deformation of the ball or the surface and other form example sound, vibrations [3,4]. The relationship between the mechanical energy dissipated by a basketball bouncing off a right surface and the impact was investigatedexperimentally and shown pictorially. In other words, energy may be stored in the ball as a result of its compression and subsequently dissipated after the rebound either in internal modes of oscillation or by a slow recovery of the ball to its original shape.

MATERIALS AND METHODS

The impact proces a ball and hard surface involves a change, albeit temporary, in the shape of the ball. When the ball hits rigid surface its bounce actually loses momentum by transferring some of its energy into different form. This is closely related to the so-called coefficient restitution (COR) or bounce coefficientand can be expressed as [4]:

$$C_R = \sqrt{\frac{h_2}{h_1}} \text{ or } C_R = \frac{V_A}{V} = \frac{\sqrt{2gh_2}}{\sqrt{2gh_1}} \quad (1.0)$$

$$C_R = \sqrt{\frac{1060}{1400}} = 0{,}87$$

where:

C_R- is the coefficient of restitution,

V_A -is the velocity of the object after the collision,

V - is the velocity before the collision,

h_2 – is the height of the natural drop,

h_1 – is the height of first rebound

The bounce coefficient

$$k = \frac{h_2}{h_1} \quad (1.1)$$

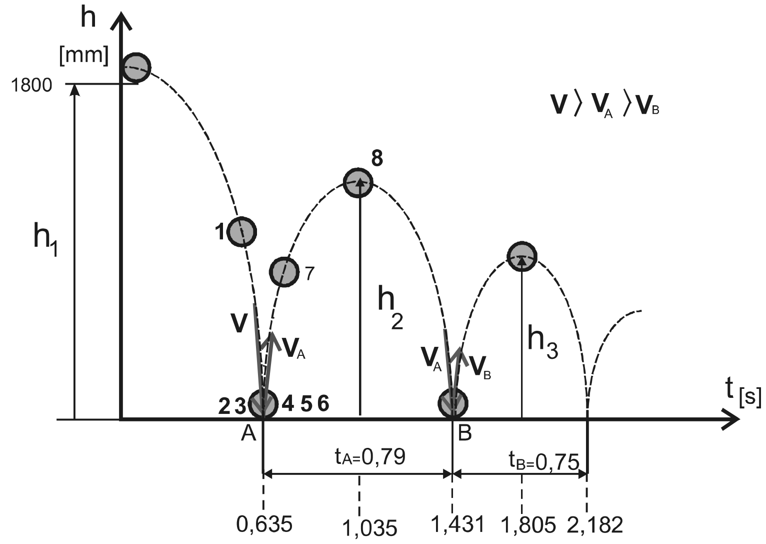


Figure 1. Stages of the ball's rebound process

The coefficient of restitution has been measured for many objects and surfaces, but very little information is available on the energy loss process itself or on the force acting on a colliding ball [2,3,4]. The collision of a ball always involves some loss of energy. When a basketball bounces off of a surface, some of its energy is absorbed by that surface. Some surfaces absorb more energy than others do [1]. A hard surface, such as concrete, absorbs less energy compared with a soft surface, such as a carpeted floor [5,7]. The more energy absorbed by the surface, the less that remains in the ball for it to bounce. This is why you should have seen that when you bounced the basketball on a relatively hard surface it bounced higher (it lost less energy) compared with when it was bounced on a softer surface (where it lost more energy) [8]. For example, if a ball of mass *m* is dropped from a height h_1 onto a surface and it rebounds to a height h_2 then

the loss of energy is:

$$\Delta E = mg(h_2 - h_1) \quad (1.2)$$

Estimation of the characteristic parameters of system damping (pressure is *p=0,06N/mm²*) [6]. The logarithmic decrement of damping is:

$$\partial = ln\frac{h_1}{h_2} = ln\frac{1400}{1060} \quad (1.3)$$

$$\partial = 0{,}278$$

where:

h_1 - the greater amplitude of rebound is 1400mm

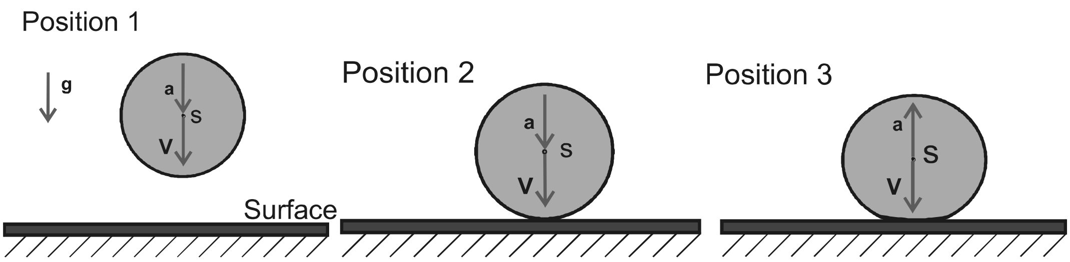
h_2 -the lower amplitude of reflection is 1060mm

Coefficient of absorption:

$$\varphi = 2\partial \quad (1.4)$$

$$\varphi = 0{,}556 \approx 0{,}6$$

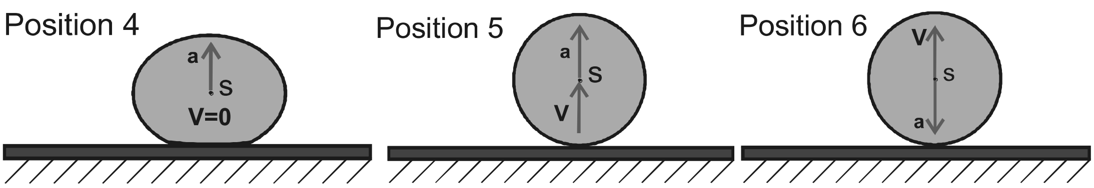
The analytical process of bouncing the ball will be presented in several stages. The analysis was carried out with the following assumptions: that the bounce surface is hard (rigid), and that air resistance is negligible, the geometric center of the ball as point S, the velocity of point S as V and the acceleration of point S as a, the ball has uniform density, which means that point S of the ball coincides with its center of mass. The individual stages (1-8) of the ball bounce process are presented in the Figure 1 and figures below. For simplicity, assume the ball motion is planar (two-dimensional).



Position 1. At this position, the ball falls vertically down under the influence of gravity (***g***). The velocity***V*** is directed downwards. Acceleration ***a*** is also directed downwards. The size of *a* is equal to ***g*** in the absence of air resistance. (It should be noted that the acceleration due to gravity is ***g*** = 9.8 m/s^2, on earth).

Position 2. In this position the ball begins to touch the surface. It still falls vertically down under the influence of gravity. The velocity ***V*** and the acceleration ***a*** = ***g*** are directed downwards.

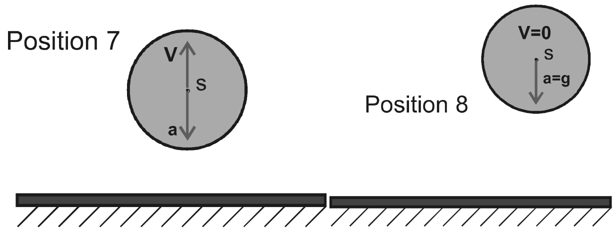
Position 3. The ball slowed in this position. The velocity ***V*** is still pointing downward. However, the ball has deformed sufficiently such that the acceleration ***a*** is now pointing upward. This means that the ball has deformed enough such that it's pushing against the surface with a force greater than its own weight,as a result the acceleration ***a*** is directed upwards.



Position 4. In this position the ball achieves maximum deformation. As a result, the acceleration **a** is pointing upward and the velocity **V**is zero. This means that point **S** is at its the lowest point.

Position 5. In this position, the ball velocity **V** is increasing and pointing upward since the ball is now in the rebounding phase. As a result, the ball is less deformed than at the previous position, but it is still deformed enough such that it's pushing against the surface with a force greater than its own weight. This means that the acceleration **a** is still pointing upward.

Position 6. In this position, the ball is barely touching the surface. The velocity ***V*** is still pointing upward since the ball is still in the rebounding stage. However, since the ball is no longer deformed it has essentially zero pressure and contact force with the surface. This means that the only force acting on the ball is gravity. As a result, the acceleration ***a*** is now directed downwards, and the upward velocity ***V*** is now decreasing.



Position 7. In this position, the ball has fully rebounded and has lifted off from the surface. The velocity ***V*** is still pointing upward, and the acceleration ***a*** is still pointing downward since the only force acting on the ball in this stage is gravity.

Position 8. The ball achieves the maximum height of the first bounce. The speed in this position is equal to 0. 0. The only force acting on the ball is the force of gravity.

Experimental tests of ball bounce were performed using the standard basketball ball "KIPSTA" size 7.The recommended ball pressure value is 0.6 bar. The tests were carried out with the following data: diameter of the ball 240mm, weight 597g. The ball was dropped from a constant height h_1 = 1800mm on a rigid hard floor with variable internal pressure. The results of experimental research are presented in the diagram drawing.

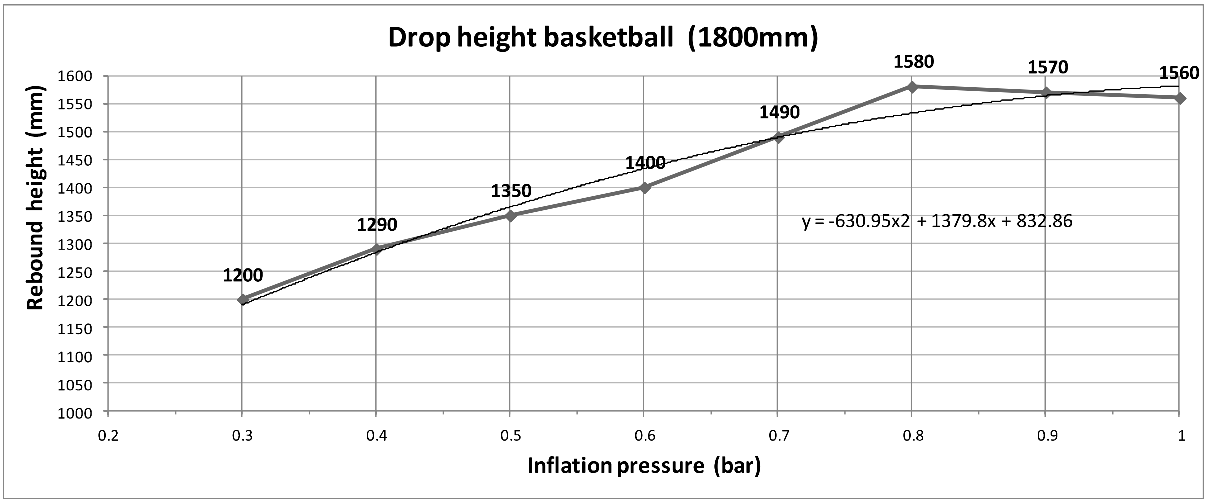


Figure 2. Height ratios vs. inflation pressures

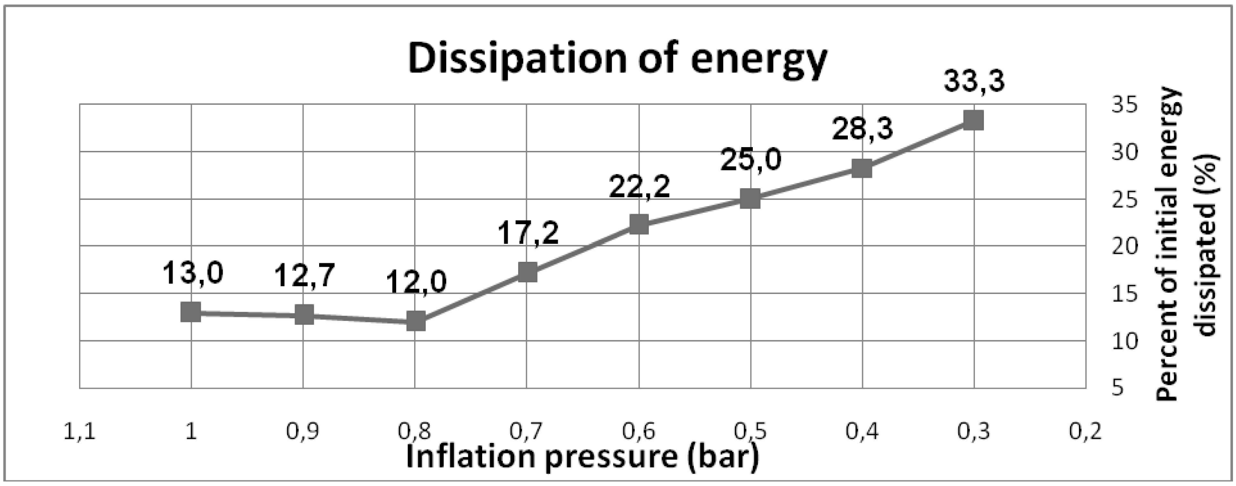


Figure 3. Percent of energy dissipated vs inflation pressures

RESULTS

Before each test, the ball was inflated to a different level of internal pressure. It was found that increasing the inflation pressure of a basketball reduced the duration of its impact with the floor, reduced the energy dissipated during the impact, and increased the height to which the ball rebounded, Figure2 end 3. Internal pressures between 0.6 and 0.8 bar yielded excellent results in that the durations of impacts were low and the rebound heights very large.

CONCLUSION

It has been established experimentally that, for a given drop height, the rebound height depends upon the nature of the ball; and that, for a given ball, the rebound height depends upon both the drop height and the inflation pressure. Therefore, it is possible to achieve the same rebound height with a given ball by using various combinations of the internal pressure and the drop height. Accordingly, specifying the height from which a basketball is dropped during a ball-drop test and its internal pressure during the subsequent fall is essential in order to interpret the quality of the bounces of different basketballs accurately and without ambiguity.

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Streszczenie: *Analityczne i eksperymentalne badania rozpraszania energii odbicia piłki koszykówki w teście swobodnego spadku.*W pracy przedstawiono krótką historię powstania gry zwanej koszykówką oraz sposób wyznaczenia wybranych parametrów dynamicznego odbicia piłki koszykowej. Parametry te są niezbędne przy budowie numerycznego modelu piłki koszykowej i analizę zachowania się konstrukcji podłóg sportowych opartych na drewnie i materiałach drewnopochodnych. Wyjaśniono etapy odbijania koszykówki od sztywnej podłogi i wyjaśniono przyczyny strat energii w momencie uderzenia. Kiedy piłka koszykówka odbija się od powierzchni, część jej energii jest pochłaniana przez tę powierzchnię. Niektóre powierzchnie pochłaniają więcej energii niż inne. Twarda powierzchnia, taka jak beton, pochłania mniej energii w porównaniu z miękką powierzchnią. Im więcej energii pochłania powierzchnia, tym mniej pozostaje w kuli, aby mogła się odbić. Wartość współczynnika tłumienia materiału została oszacowana przy optymalnym wewnętrznym ciśnieniu rozważanej piłki koszykowej. Przeprowadzone badania wykazały zmianę wysokości odbicia w zależności od wewnętrznego ciśnienia piłki. Zmierzone parametry odbicia piłki są niezbędne do budowy modelu numerycznego konstrukcji podłóg sportowych, wykonanych m.in. z drewna i materiałów drewnopochodnych. Wyniki testu przedstawiono w postaci wykresów i rysunków.

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