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Increasing Collision Time through the use of Cushioning

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Abstract

The utilization of cushioning to increase collision time and reduce impact force was explored using a metal ball and varying thicknesses of polyester sponge. A linear relation was found between collision time and the thickness of polyester sponge cushioning up to a limit. After the limit, the collision time was independent of the thickness.

Introduction

The gait cycle is the cycle in which a runner moves his or her feet from the front of the body to the back of the body. During the gait cycle, the foot makes contact with the ground in order to propel the runner forward and into the next cycle. During the time that a foot and the ground are in contact, an impulse is exerted by the ground on the runner to stop the fall of the foot and propel the runner forward. This force of the ground on the runner's feet can be dangerous to the ankles as well as the knees, thus a reduction in impact force is advantageous. The reduction in force provided by the running shoe is usually achieved through the use of cushioning.

This investigation will explore the reduction of impact force through the use of cushioning with a small lead ball and a large pad, thus there are limits in the similarity to a foot compressing the entire cushioning pad.

The reduction of impact force can be deduced from the definition of impulse[1] in which

$$\int F \, \mathrm{d}t = m \cdot \Delta v \qquad \text{(Equation 1)}$$

where F is the impact force, m is mass, v is velocity, and t is time. From equation 1, it can be seen that an increase in the time of collision between the ground and the runner's foot will result in a reduction of average impact force, even though the total impulse needed to reduce the velocity of the foot to zero remains the same. The reduction of impact force on the foot with cushioning in a running shoe is simulated in this investigation with the use of a lead ball and polyester sponge.

Figure 1 The set up of the experiment.

Methods

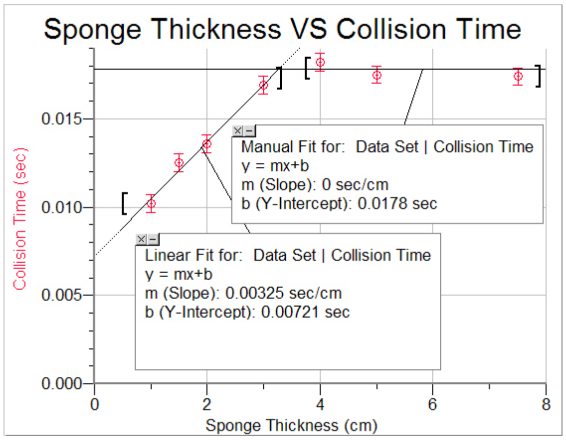
Six blocks of polyester sponge approximately 20 cm on a side and varying in thickness from 1.0 to 7.5 (± 0.1) cm were prepared.

Each block of polyester sponge was placed on a Vernier Force Plate, as shown in figure 1. The force plate was set to collect data at 15,000 readings per second.

A 67.10 g steel ball was released from a height of 0.850 ±0.005 m above the upper surface of each block so that it landed in the center of the block. The force plate recorded the force as a function of time during each collision.

Results and Discussion

Figure 2 demonstrates that for polyester sponge thicknesses of 1.0 cm to 3.0 cm an increase in sponge thickness linearly increases the collision time. The limit of the linear relationship is approximately 3.3 cm since that is where the two linear fits intersect in figure 2.



A clear change occurs between sponge thicknesses of 3.0 cm and 4.0 cm. The collision time becomes independent of the sponge thickness for thicknesses above 4.0 cm. Observing the ball as it bounced, it was noted that the penetration of the ball into the sponge, *k* in figure 3, was approximately the same for thicknesses above 4.0 cm. It is speculated that for thicknesses above 4.0 cm, the bottom part of the polyester sponge did not experience any compression and did not play a role in increasing the collision time. Further research using high-speed video of the collision is needed to confirm this to be a factor in the relationship between sponge thickness and collision time.

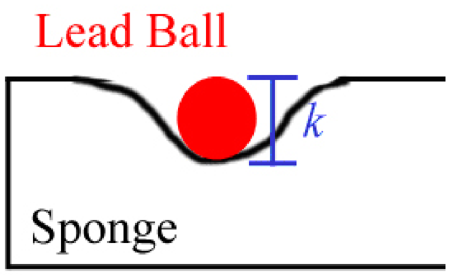


Figure 3 Diagram showing ball compression into the polyester sponge.

An equation for the relationship between polyester sponge thickness and collision time was derived from figure 2. The following equation is applicable for polyester sponge heights between 1.0 cm to 3.0 cm,

$$T = (0.0032 \pm 0.0005)\, x + (0.0072 \pm 0.0009) \qquad \text{(Equation 2)}$$

where T is the collision time in seconds and x is the polyester sponge thickness in centimeters. It was found that for thicknesses of 4.0 cm to 7.5 cm, collision time is independent of polyester sponge thickness.

Increasing the mass of the ball or the drop height is predicted to decrease the slope of the graph in figure 2 since the initial kinetic energy is greater. Increasing the stiffness of the cushioning is predicted to increase the coefficient of x in equation 2. Further research could be conducted with variable heights, ball mass and rigidity of cushioning.

In reference to the running shoe, this investigation suggests that using cushioning will increase collision time and therefore reduce impact force up to a thickness limit. After the limit is reached, any more cushioning will not further reduce impact force on the feet. Since a foot compresses the whole cushioning pad while running, a mass with the same size and surface shape as the cushioning could be used in future research to better simulate the situation of running.

Conclusion

The relationship between polyester sponge thickness and collision time was found for a 67 g steel ball dropped from height of 0.85 m. A linear relation between polyester sponge thickness and collision time was deduced for thin polyester sponge up to a limit of 3.0 cm. Utilizing polyester sponge thicknesses greater than the limit showed no increase in collision time.

References

1 Nave, R. (2006). Impulse of Force. In Hyper Physics. Retrieved May 24, 2009, from Georgia State University Web site: http://hyperphysics.phy-astr.gsu.edu/hbase/impulse.html#c4