Computerised Technique to Determine and Analyse the Coefficient of Restitution

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Personal Details

I began my study of Applied Science in September 1998. During the first two years of my degree I studied a blend of core science subjects, Physics, Chemistry and Mathematics combined with Management Studies and German. In third and fourth year my chosen option subject, Physics Technology, substituted Chemistry. Combining a study of practical physics technologies with theory based physics has been both a beneficial and a thoroughly enjoyable experience.

I have a diverse range of scientific interests including Medical and Biophysics, Optical Communications and Nuclear Physics. Another associated interest is the application of computers in science and education generally. My hobbies include Photography, Music and work with the Society of St. Vincent de Paul.

Project Summary

The aim of the project was to develop a PC based method to record the sound produced by a ball bouncing on a rigid surface and then to analyse these recordings to determine the coefficient of restitution.

Defined by Newton (c.1680), the coefficient of restitution has been the subject of numerous research papers over the years. In particular, mechanical systems to determine the coefficient have been in a constant flux of development since the early seventies. Indeed the scientific journal *American Journal of Physics* has had on an intermittent basis papers devoted to research on this topic.

The word 'restitution' in the Oxford English dictionary is defined as "*a return to or restoration of a previous state or position*". This describes the physics involved in the coefficient of restitution. The coefficient of restitution may be related to the ratio between decreasing heights. Figure 1 below illustrates the decreasing height of a bouncing ball.

Recalling childhood experiences of playing with bouncing balls it is easy to correlate experience with the behaviour shown in Figure 1. Essentially the coefficient of restitution, denoted by the letter epsilon ε, for this situation may be described by Equation (1) below:

$$\varepsilon = \sqrt{\frac{h_1}{h_0}}$$

(where h_0 represents the initial height and h_1 represents the 1st rebound height).

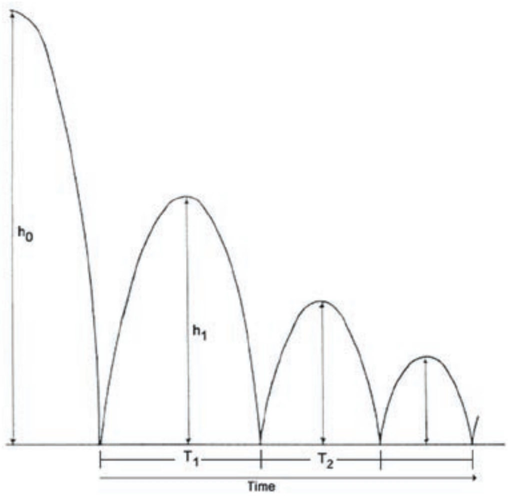

Figure 1. Schematic representation of the bounces of a ball spread out over time.

Using simple mathematical relationships it is possible to describe the coefficient of restitution both in terms of velocity before and after an interaction and the time between bounces. Equation (2) below illustrates the more useful form of these expressions, the time relationship:

$$\varepsilon = \frac{T_2}{T_1}$$

(where T_1 represents the time taken for the first bounce, T_2 represents the time taken for the second bounce).

It is clear that the coefficient of restitution is basically an expression of how well the ball will bounce. Essentially describing the elasticity of a ball, the coefficient has a value between 0 and 1 where a ball possessing a high coefficient of restitution is termed a happy ball.

The sound pattern produced by a bouncing ball is illustrated in Figure 2 below. In this picture one may see the peaks created by the impact of the ball with the surface.

Using *MatLab* I wrote a program to analyse sound patterns similar to Figure 2. Affectionately called CORA – *Coefficient of Restitution Analysis*, this program determined the time gaps between successive peaks and hence calculated the coefficient of restitution associated with each bounce.

The experimental procedure consisted of allowing a ball to fall from a fixed height (and thus a fixed impact velocity) onto a large slab of polished granite. This procedure was undertaken for ball specimens of various materials and for various impact velocities. Particular emphasis was placed on steel ball bearings, mainly due to their availability. An interesting observation, verified by my experimental work, was made by much of the past research. All pointed to a decrease in the coefficient of restitution with increased impact velocity. Essentially this means that more energy will be lost by a ball travelling at a high velocity when it hits off a surface than a ball travelling at low speed. Figure 3 illustrates this velocity dependence and was obtained for a steel ball bearing.

The coefficient of restitution is relevant in many areas of modern living from the obvious applications in sporting equipment such as *sliotars* (hurling balls) and running shoes to more abstract uses in the design of high performance tyres for all types of vehicles.

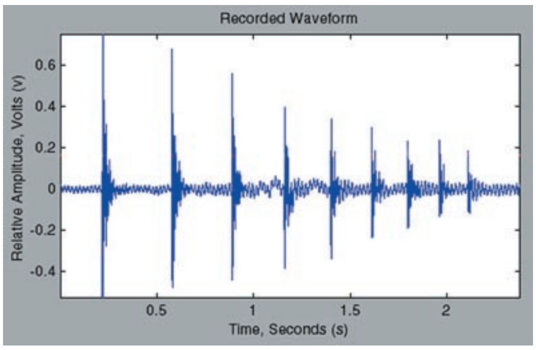

Figure 2. Illustration of sound pattern produced by a bouncing ball.

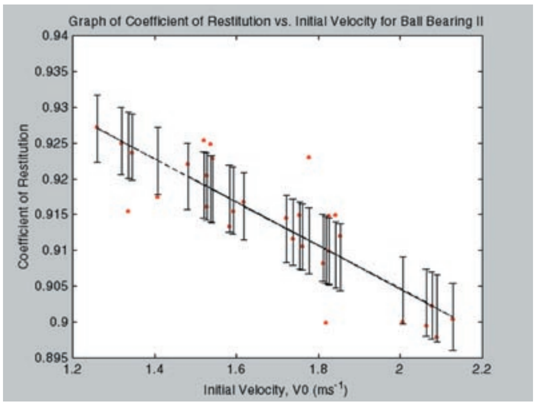

Figure 3. Coefficient of restitution dependence on impact velocity.