Abstract

We develop several models based on the work-energy theorem to simulate the horizontal and vertical effects of a stack of cardboard boxes on the velocity of a motorcycle and stunt rider with the intent of determining the most cost effective and safest configuration of boxes. All of our models depend on box strength of crushing. Two methods were used to determine box strength:

- An empirical approx in which sheets of cardboard of varying height and width were subjected to increasing mass until the buckled.
- A model using industry standard data. This method used data for the edge crush test.

To determine the optimum configuration of boxes we develop the following models:

- Boxes are treated in layers. Only the vertical velocities and forces are considered. The force exerted by a layer is the force of crushing of one box times the number of boxes that the rider will hit per layer.
- The same as model 1 with the addition of linearly increasing layer strength per layer.
- A model that takes into account gravitational potential energy, kinetic energy, and box crush force in the vertical direction and kinetic energy and friction between boxes in the horizontal direction.

Data were collected with each model for a variety of combined masses, initial velocities and box sizes and strengths.

Model 1 with a mass of 200, 260, 320, 360 kg resulted in the rider traveling through between 11 and 18, 17 and 32, 20 and 65, and 20 and 130 box layers respectively varying with layer strength. The time to stop was 0.3 to 2.5, 0.5 to 4.5, 0.7 to 8.5, and 0.8 to 15 seconds respectively.

Model 2 with an initial box strength equivalent to that of a layer of 1m boxes predicted that the rider would travel through 7 to 9 layers of boxes. The time predicted was between 0.5 and 0.7 seconds.

The opitimial launch angle was found to be 60 degrees, the following data was collect with an angle of 60 degrees and an inital velocity of 8.9 m/s. Model 3 with varying box size and constant mass (from 0.4 to 1.6 meters in 0.20 m increments) and a launch angle of 60 degrees resulted in a time of 0.1 to 0.5 seconds in the horizontal direction and to 0.05 to 0.4 seconds in the vertical direction. For varying mass and constant box size (200 to 360 kg in 20 kg increments) time ranged from 0.2 to 0.4 seconds in the horizontal direction and 0.07 to 0.17 in the vertical direction.

Our suggested modifications to the boxes are the use of double wall corrugated box. We have found that this would significantly reduce the number of layers without significant increase in danger to the stunt rider.