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Identification of basketball parameters for a simulation model

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Abstract

We estimate values of the coefficients of air drag, friction, stiffness and damping for a dynamic model of basketball shots by analyzing ball position and orientation using video data for basketball-rim and basketball-backboard bounce tests. The dynamic model can calculate any configuration change of a basketball during shots. The simulation model is compared to actual bounce tests and the parameters are determined from these experiments. The dynamic model with the identified parameters calculates a ball trajectory similar to the actual measured results. Stiffness and damping coefficients are determined from basketball-backboard bounce tests.

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Keywords: Basketball; dynamic model; coefficient of friction; basketball stiffness and damping

1. Introduction

A complete, detailed and accurate dynamic model with real parameters for basketball shots can be used in numerical simulations to replace actual dynamic experiments. In order to improve the model it will be necessary to compare it to actual physical experiments.

Some previous studies have measured basketball parameters. Okubo and Hubbard [1] did MTS tests to obtain the ball stiffness and damping coefficients. Okubo and Hubbard [2] also measured the coefficient of friction between the ball and rim, and between the ball and a polycarbonate backboard. Always et al. [3] introduced a new friction test apparatus to determine coefficients of friction for round balls including basketballs. Two dynamic models have been used to analyze basketball shots. Okubo and Hubbard [4][5] investigated and compared release conditions for capture in direct and bank shots using their dynamic model, which has six distinct sub-models. Silverberg et al. [6] analyzed direct and bank shots using a comparable dynamic model.

To our knowledge, no one has compared their dynamic model to actual basketball shots. We compare our dynamic model to actual data and improve it. Data on basketball shots are obtained in some simple bounce tests

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from the rim and backboard. By comparing ball trajectories and angular velocities, reasonable estimates are determined for the air drag coefficient, basketball stiffness and damping coefficients, and coefficients of friction between the ball and rim, and ball and backboard.

2. Methods

We assume that the basketball with radial compliance and damping maintains contact with the rim/backboard. The configuration has six degrees of freedom. Three determine ball position and the others describe ball orientation. A Coulomb friction force is assumed to act in the tangential plane either between the basketball and rim or between the ball and backboard.

An official NBA basketball was used in the experiment with a mass of 0.591 kg and a radius of 0.12 m. The official basketball rim had major inside diameter of 0.45 m and minor diameter of 0.019 m, and the official backboard was made from safety tempered glass. Ball inflation pressure was 8 psi. Gravity was estimated to be 9.7975 at a latitude of 35.68 degrees.

Data on basketball trajectories were obtained by filming free fall and bounce tests on the rim and backboard using a video camera. Ball position and angle were analyzed from the video data in order to identify ball parameters. Comparing trajectories between actual data and our dynamic simulation, we identify ball stiffness, damping, air drag coefficient, and coefficient of friction between the ball and rim and the ball and board.

3. Results

3.1 Air drag

A basketball was dropped from the height of the bottom of backboard as shown in Fig. 1. We calculated the trajectory of the ball using the DLT method. The camera was operated at 500 Hz. When the ball is assumed to be acted on by air resistance with constant air drag, the equation of motion is

$$-mg + \frac{1}{2} \rho A C_D v^2 = m\dot{v} \quad (1)$$

where m is basketball mass, g is gravity, ρ is air density, A is ball cross sectional area, C_D is the coefficient of drag and v is the vertical velocity. The vertical displacement h of the basketball from the floor can be expressed as

$$h = h_0 - \frac{a^2}{g} \ln \cosh\left(-\frac{g}{a} t\right) \quad (2)$$

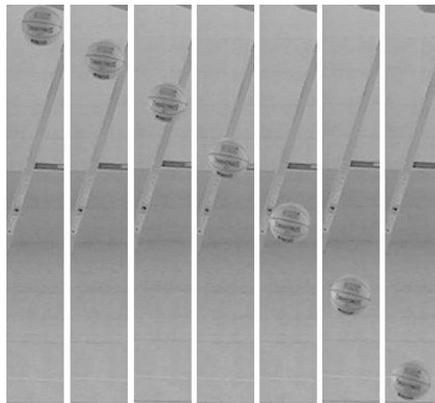


Fig.1: Film data of a basketball free fall.

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