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Batted-Ball Performance of a Composite Softball Bat as a Function of Ball Type

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Abstract

A composite softball bat and two different softball constructions were investigated using experimental and finite element (FE) methods. Softball characterizations were completed using COR (coefficient of restitution against a flat wall), CCOR (cylindrical coefficient of restitution), compression, and dynamic stiffness. The composite bat characterization included barrel compression and modal analysis. FE analyses were completed in LS-DYNA to explore the capabilities for the experimentally determined material parameters for the softballs to be used in predicting bat performance as quantified by BBS (batted-ball speed). Softballs were modeled using the viscoelastic material models, and the composite softball bat model was constructed per the ply stack-up and ply properties as provided by the manufacturer. The model showed mixed results for its ability to predict the relative batted-ball speed as a function of ball type for the two softballs considered in the study.

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1. Introduction

In the early 2000s, advancements in composite softball bat design led to increasing batted-ball speeds (BBS) and concerns that the balance between offense and defense of the game was being compromised. In a response to

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restore balance, the Amateur Softball Association (ASA), and other softball governing bodies implemented strict regulations to limit bat performance as quantified by BBS, which is in part a consequence of the combination of the respective constructions of the bat and the ball. The BBS is calculated using

$$BBS = v_p(BESR - 0.5) + v_s(BESR + 0.5) \quad (1)$$

where v_p is the ball pitch speed (25 mph / 40.5 kph), v_s is the bat swing speed at point of contact (mph / kph), and BESR (Ball Exit Speed Ratio) is given by

$$BESR = \frac{BBCOR_N - \frac{m_s}{M_e}}{1 + \frac{m_s}{M_e}} + 0.5 \quad (2)$$

where m_s is the weight of the standard ball and M_e is effective bat mass and is given by

$$M_e = \frac{I + I_{pivot}}{Q^2} \quad (3)$$

where

I - moment of inertia about the pivot location, 6 in. (15.24 cm) away from knob (oz-in^2 or N-cm^2)
I_{pivot} - moment of inertia of pivot stage (oz-in^2 or N-cm^2)
Q - distance between pivot location and impact location (in. or cm)

and

$$BBCOR_N = \sqrt{\frac{r_s CCOR_S^2 + 1}{1 + r_s}} \quad (4)$$

$$r_s = \frac{DS}{DS_S} \frac{1 - BBCOR^2}{BBCOR^2 - CCOR^2}$$

where:

$BBCOR_N$ - normalized BBCOR
r_s - ratio of bat stiffness to the stiffness of the standard ball
DS - dynamic stiffness of the test ball, Test Method ASTM F2845 (lb/in or N/cm)
DS_s - dynamic stiffness of the standard test ball provided by the test sponsor (lb/in or N/cm)
$CCOR$ - cylindrical coefficient of restitution of the test ball
$CCOR_s$ - cylindrical coefficient of restitution of the standard ball, provided by the test sponsor

Currently, all softball bats undergo certification testing according to ASA (2004). As a result, most bats are designed to perform at the BBS limit in the test, thereby making all bats essentially equal with respect to the conditions of the certification test. To ensure consistency in the test conditions from bat to bat for the bat certification process, the process specifies the brand, compression and COR of the ball to be used in test. However, not all softballs used on the field are equal to the properties of the ball used in the certification test. The compression and COR can vary among brands and vary among models within a brand. Thus, while the certification test is a valuable tool in measuring the relative liveliness of one bat to another, it is not necessarily a true reflection of the relative liveliness among bats in the field when using balls that differ from that used in the certification test. Thus, as a consequence of the ball used in the game, there is potential for the situation where a bat can meet the speed limit associated with the certification test conditions but can hit a ball significantly faster or slower in the field than what is projected from the certification test. Well calibrated models of softballs and credible methods for the modeling of bats would be valuable to assist in customizing the design of a bat to satisfy the performance limits of the certification test while tuning BBS for a particular ball construction.

This paper presents a complimentary experimental and finite element study that was completed to explore a