The Effect of Baseball Construction on the Game of Baseball

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TOPICS: baseballs

Abstract: Many leagues have introduced or tightened performance regulations of baseball bats over the past decade as the technology to quantify their performance has improved. However, little to no emphasis has been spent on understanding the range of baseballs that are used across the different levels of play, and as a result, baseball regulations are typically limited to size, weight and coefficient of restitution at 26.8 m/s (60 mph). This paper will explore many of the different baseballs that are used and highlight the similarities and the differences with respect to the construction, overall size and weight, and performance among these baseballs. Coefficient of restitution, both the standard using a flat wood block and cylindrical using a solid-steel half cylinder, and compression tests are used to evaluate the performance in a controlled lab environment.

Key words: Baseball, Coefficient of Restitution, COR, CCOR, Compression

1- Introduction

Generally, baseballs are recognized by a specific size, weight and seam pattern. Other than these properties, the general public may have little idea of what is inside the ball. Most official game baseballs have wool-winding layers that surround a cork-and-rubber center, called the pill, and a finished exterior of cowhide or synthetic leather. Some leagues at the early youth levels have introduced relatively soft baseballs in an effort to reduce injuries from being hit by a baseball and to make youth players comfortable with playing the game by reducing the fear of injury from a batted or thrown ball.

The University of Massachusetts Lowell Baseball Research Center (UMLBRC) has the equipment and expertise to investigate many different aspects of the baseball. Since 2000, the UMLBRC has directed most of its efforts in baseball testing to compliance testing for Major League Baseball, which has very tight specifications for each component of the baseball. The objectives of these compliance tests has been to establish a database of year-by-year performance of the major league baseball and to ensure there are no changes in the construction and performance of the baseballs. This experience of testing baseballs for each specific component's properties for compliance and consistency and seeing essentially no difference from test to test led to the interest to explore the differences in construction and performance among baseballs for other levels of play. The typical Major League game uses around ten dozen baseballs per game. In contrast, the operating costs for amateur baseball teams may be limited to using three to ten baseballs per game. Thus, the construction of amateur baseballs may need to account for a durability factor that is not critical to a major league ball. This paper will present a comparison of a variety of different baseballs from different manufacturers and for different leagues in an effort to quantify the performance, hardness and construction of the different baseballs.

2- Methodology

The test procedure for this study included two traditional metrics and a new metric for evaluating performance. The traditional measures were COR (Coefficient of Restitution) and static compression. The new metric was CCOR (Cylindrical Coefficient of Restitution), which was recently developed as part of measuring dynamic stiffness. The dynamic-stiffness measure is not presented as part of this study, because there are several aspects of the test that are still being developed at this time. The CCOR tests were performed at 26.8 m/s (60 mph) and 40.2 m/s (90 mph) to replicate a range of impact conditions that these baseballs experience in the field.

This study does not include all of the different constructions or manufacturers of baseballs. Rather the goal of this study was to survey some of the popular contemporary baseballs used by the various leagues. Therefore, the initial task was to obtain many different baseballs. A sample of two baseballs for each of 20 different constructions was evaluated for performance through the standard COR test and cut in half to reveal the construction. From these 20 types of baseballs, nine baseball models were chosen to investigate the ranges of COR values and variety of constructions. The final selection included models from different manufacturers.

With the diverse assortment of baseball models, the work began to evaluate the respective performances with the tools available. The UMLBRC has the capabilities to perform tests on baseballs ranging from the standard static compression using a universal material testing load frame to CCOR and COR performance testing using a high-speed air cannon and two-wheel pitching machine, respectively. Sections 2.1 through 2.4 will discuss each of the procedures used for the testing of the baseballs.

2.1- Size and Weight

The size of a baseball is defined by its circumference. A steel rule PI tape was used to make these measurements. This type of measurement allows the circumference to be measured to within 0.254 mm (0.01 inches). The circumference was measured in two directions, across two seams and across four seams. The average of these two circumference measurements is reported as the circumference of the ball. The weight of each baseball was measured using a digital scale with an accuracy of 0.14 g (0.005 ounces).

2.2- Standard Static Compression

The static compression of each baseball was measured similarly to the process described in ASTM standard F1888 (2002). This test compresses the baseball between two flat steel plates at a rate of 0.42 mm/s (1 in./min). The test is stopped at a displacement of 6.35 mm (0.25 inches) and is repeated on two additional orthogonal axes of the baseball. The compression value of the baseball is reported as the average of these three measurements.

2.3- COR (Coefficient of Restitution)

The dynamic performance of a baseball is typically measured using a setup to measure the coefficient of restitution (COR) of the ball. This setup at the UMLBRC utilizes a combination (two-wheel) pitching machine, a ballistic speed gate capable of measuring speed in both directions and a rigid wall with a wood hitting surface. This test is performed in accordance with the ASTM standard F1887 (2002). The pitching machine was set to fire the ball with little to no spin at a speed of 26.8 m/s (60 mph, 88±1 ft/s). The ballistic speed gates are set 30.48 cm (12 in.) apart with a gate located 30.48 cm (12 in.) from the solid ash hitting surface. The ball speeds $V_{Inbound}$ and $V_{Rebound}$ were measured, and the COR was calculated as,

$$COR = \frac{V_{Rebound}}{V_{Inbound}} \tag{1}$$

Each baseball was tested to obtain six valid COR measurements, and the reported COR is the average of these six values.

2.4- CCOR (Cylindrical Coefficient of Restitution)

The cylindrical coefficient of restitution (CCOR) is a measure of the dynamic performance of the baseball similar to the COR. However, the CCOR test uses a cylinder for the target rather than the flat-plate target used in the COR test. The use of the cylinder, which has a diameter similar to the barrel on a bat, is a better simulation of how the ball is used in the game than the flat plate. At the UMLBRC, the CCOR test setup utilizes a high-speed air cannon capable of firing a baseball with no spin at speeds from 26.8 m/s (60 mph) to over 51.4 m/s (115 mph). The CCOR tests used in this study were performed at the speeds of 26.8 and 40.2 m/s (60 and 90 mph). The CCOR was calculated as,

$$CCOR = \frac{V_{Rebound}}{V_{Inbound}} \tag{2}$$

Each baseball was tested to obtain six valid CCOR measurements, and the reported CCOR is the average of these six values.

3- Results

Nine different baseball models were investigated in the study. This section presents cross-section views of each baseball construction and summarizes the results of each model's coefficients of restitution (COR and CCOR) using different speeds and impact surfaces and compression testing. To make the data blind with respect to the manufacturer and model, each baseball is designated throughout the paper with a letter A through I. The letters were designated after the tests had been concluded and were ordered with A having the lowest COR value and I having the highest COR value. This labeling and ordering is intended to assist in the comparison of the results among the different figures and tables.

3.1- Construction

The baseballs selected for the study ranged in construction and included many different materials and designs. This study purposely included non-competition grade baseballs in order to explore the large range of ball constructions and performances that are currently available. Figure 1 shows the cross-section views of each of the nine ball models examined in this study. Table 1 briefly describes the construction and the level of play is denoted as [recreational], [youth], [high school] or [collegiate].

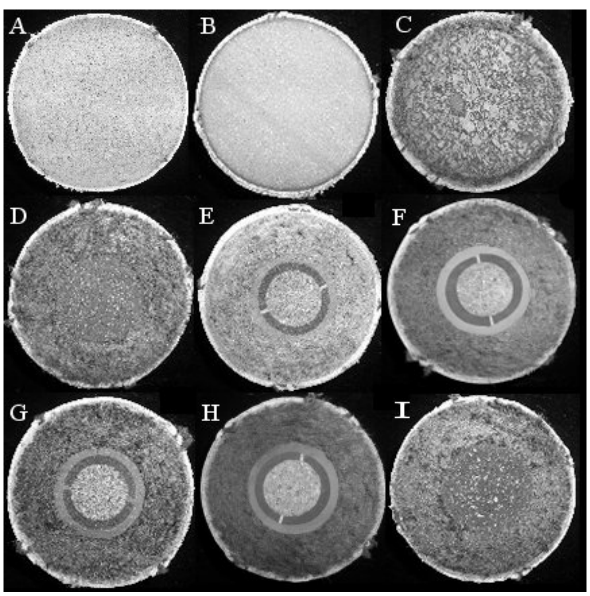

Figure 1: Cross-sectional views of the baseballs investigated

Model	Comments
A	Sponge core, synthetic cover (would rip at stitching after a few 40.2 m/s (90 mph) CCOR tests) [recreational]
B	Polymer core [youth]
C	Large cushioned cork core, thin wool winding layer [youth]
D	Small cushioned cork core, thick wool winding layer [youth]
E	Small cork center within two rubber layers as core, thick wool winding layer [collegiate]
F	Small cork center within two rubber layers as core, thick wool winding layer [youth]
G	Small cork center within two rubber layers as core, thick wool winding layer [youth]
H	Small cork center within two rubber layers as core, thick wool winding layer [high school]
I	Small cushioned cork core, thick wool winding layer [youth]

Table 1: Ball Constructions

The baseball constructions varied significantly, but the overall appearance and feel of most of the balls were the same. With the exception of Model A, which has a "spongy" feel, all of the balls feel relatively hard. The average weights and circumferences are listed in Table 2. Baseballs are generally identified as being 141.7 to 148.8 g (5.00 to 5.25 oz.) in weight and having a circumference of 22.9 to 24.1 cm (9.0 to 9.5 in.). Again, with the exception of Model A which was slightly lighter than the rest of the baseballs, all of the baseballs were essentially the same weight and circumference.

Ball Model	A	B	C	D	E	F	G	H	I
Weight, g (oz)	133.1 (4.69)	143.9 (5.07)	141.6 (4.99)	146.1 (5.15)	144.6 (5.10)	145.4 (5.13)	143.5 (5.06)	146.0 (5.15)	144.3 (5.09)
Circumference, cm (in.)	22.7 (8.94)	23.0 (9.04)	22.9 (9.00)	22.9 (9.02)	23.0 (9.07)	22.8 (8.99)	23.0 (9.05)	22.8 (8.99)	23.0 (9.05)

Table 2: Summary of Average Ball Weights and Circumferences

3.2- Performance and Hardness

The measures of dynamic performance are COR and CCOR. Hardness was measured using the compression test. Figure 2 identifies the average values for all of the dynamic performance and hardness tests for each model of baseball. With the exception of Model A, which has already been described to be very different than the other baseball models, the measured COR at 26.8 m/s (60 mph) was higher than the CCOR at the same speed. The CCOR at 40.2 m/s (90 mph) was lower than the both tests at 26.8 m/s (60 mph). There are several additional trends among the COR and CCOR data. Baseball models B, D, G, and H had only a slight difference between the two dynamic tests at 26.8 m/s (60 mph). Baseball models C, E, F, and I had CCOR values at 26.8 m/s (60 mph) that were almost halfway between the COR test at 26.8 m/s (60 mph) and the CCOR test at 40.2 m/s (90 mph). The baseball models with similar constructions did not have similar performance criteria and therefore the metrics of performance could not be predicted by any observation of the cross section of a baseball. Models of the bat/ball collision that use ball COR to predict batted-ball speeds should consider using ball CCOR at the appropriate collision speed instead of COR because the COR value and CCOR are different. The static compression values are also identified on the plot in Figure 2 to show the relative hardness of each baseball model. There does not appear to be any trend among the COR and CCOR values and the compression of the baseball.

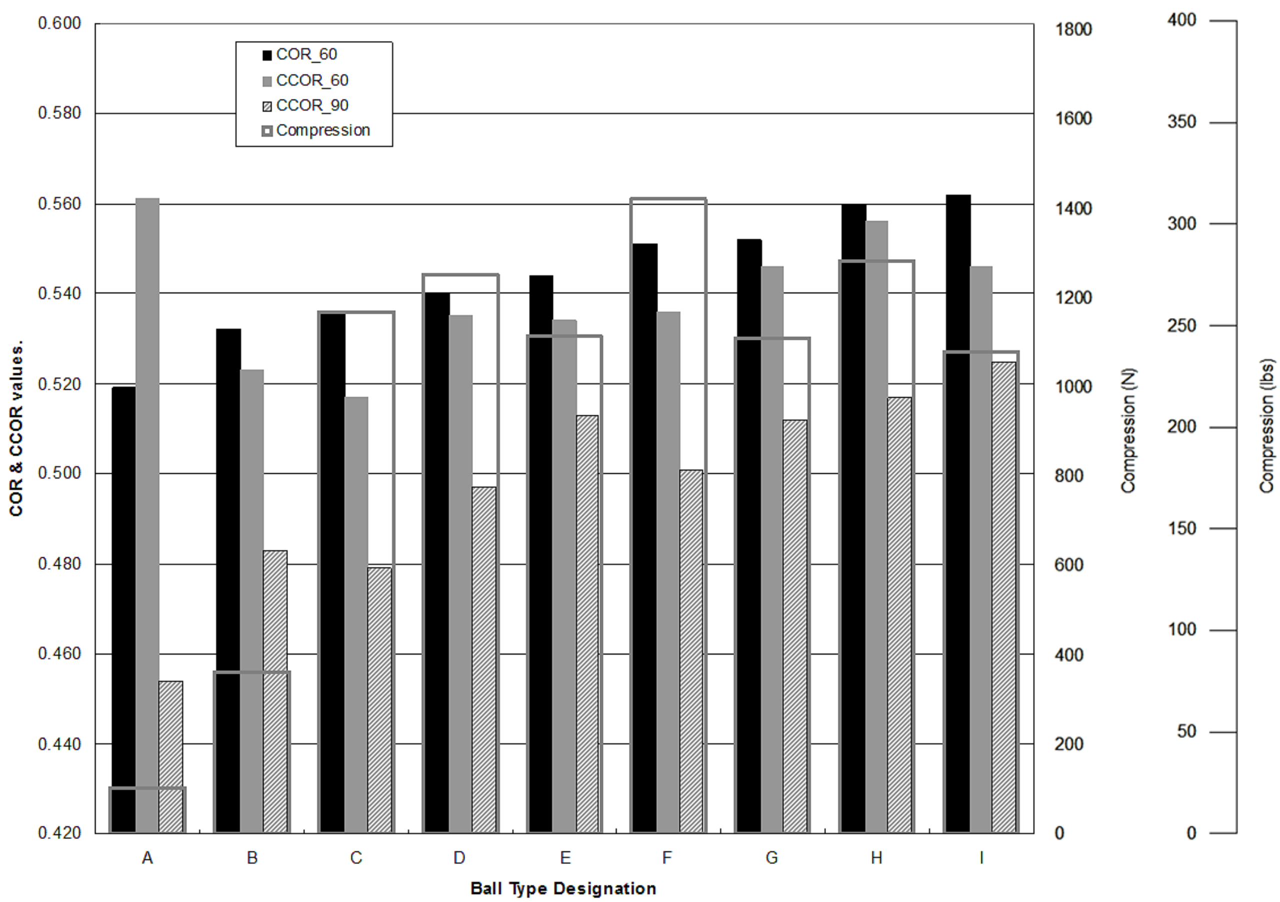

Figure 2: Average COR, CCOR and Compression values for each ball model

The ball construction can result in differences of performance at different impact speeds and different impact surface contours, not only because of the nonlinear behaviors of the individual materials, but also because of the combination of materials that compressed during the significant deformation of the baseball during impact. The compression of the baseball models on the cylindrical surface during the CCOR tests at 26.8 m/s (60 mph) are shown in Figure 3. High-speed video was recorded during an impact of each model at a frame rate of 5000 frames per second. The frame of maximum deflection is displayed in Figure 3 for each model. All nine frames show that an impact speed of only 26.8 m/s (60 mph) results in deformation of each ball model that can be significant. Model A, which has a very low static compression value, shows a dramatic compression with high-speed impacts. Frames B through I show the ball models with very similar deformation magnitudes relative to each other during the 26.8-m/s (60-mph) impact.

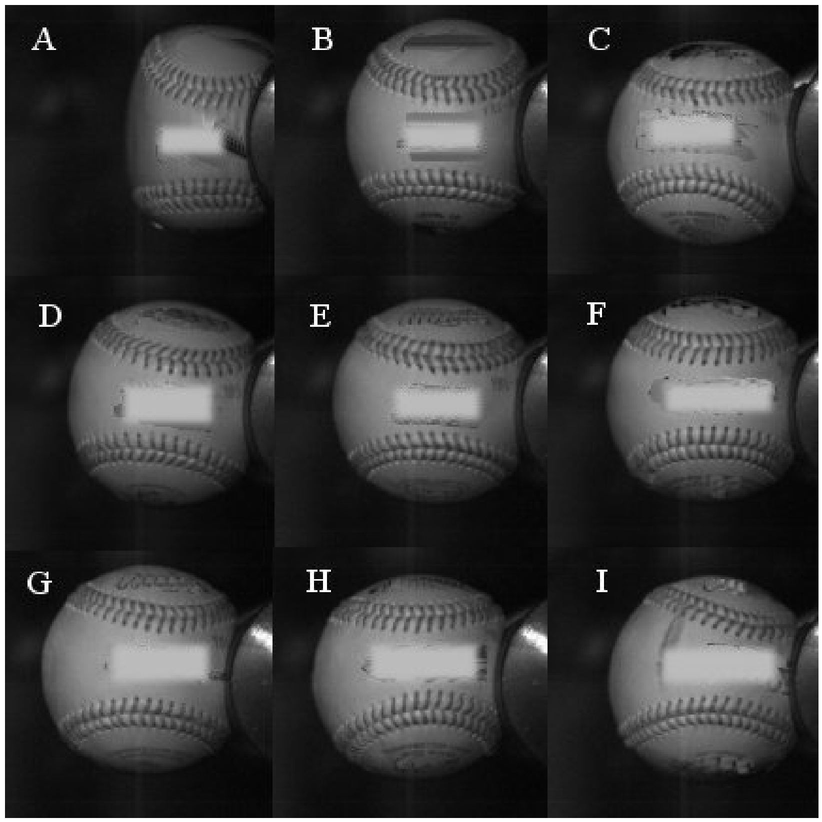

Figure 3: CCOR tests of each ball model at 26.8 m/s (60 mph)

The deformations of the baseballs during impact were significant and varied with both the shape of the impact surface and the speed of the impact. The high-speed video frame of maximum impact during the three test configurations are shown for ball models A and C in Figures 4 and 5, respectively. Ball model A, which has a significantly lower static compression value than the other ball models, shows a very dramatic compression during all three test configurations. Ball model C, which is typical of the other baseball models examined in this study, shows a representative compression of the baseballs that are used at the different levels of play which include most competitive youth leagues, high school and college baseball.

Figure 4: High-speed video frames of impact for Model A [Left: 26.8 m/s (60-mph) COR, Middle: 26.8 m/s (60-mph) CCOR, and Right: 40.2 m/s (90-mph) CCOR]

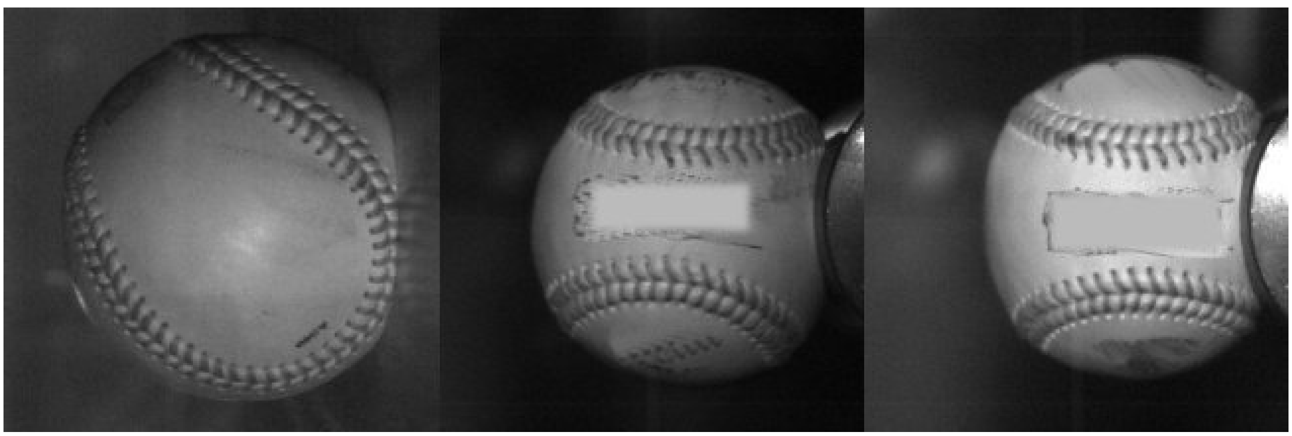

Figure 5: High-speed video frames of impact for Model C [Left: 26.8 m/s (60-mph) COR, Middle: 26.8 m/s (60-mph) CCOR, and Right: 40.2 m/s (90-mph) CCOR]

4- Conclusion

Performance and construction results for nine different baseball models used throughout the different levels of amateur baseball were presented. The wool-wound baseball models performed essentially the same and exhibited similar trends for the different COR and CCOR tests. The ball construction can result in differences of performance at different impact speeds and different impact surface contours, not only because of the nonlinear behaviors of the individual materials, but also because of the combination of materials that compressed during the significant deformation of the baseball during impact. Though the trends have similarities, the data show that it may be important to use CCOR at the proper impact speeds to obtain at true measure of the baseball's performance especially when using a COR value in a bat/ball collision model to predict batted-ball speed.

5- References

[A1] ASTM F1888, Test Method for Compression-Displacement of Baseballs and Softballs, 2002.

[A2] ASTM F1887, Standard Test Method for Measuring the Coefficient of Restitution (COR) of Baseballs and Softballs, 2002.