Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 00 (2011) 000–000

Procedia Engineering

www.elsevier.com/locate/procedia

APCST 2011: 5th Asia-Pacific Congress on Sports Technology

The Effect of Temperature and Humidity on the Performance of Baseballs and Softballs

Lloyd Smith[a], Warren Faber

Washington State Univeristy, School of Mechanical and Materials Engineerin,
201 Sloan, Spokane St., Pullman, WA USA 99164-2920

Abstract

Sports balls such as softballs and baseballs are made from materials that are natural (cork, wool, leather) and synthetic (rubber, polyurethane) and are sensitive to moisture and temperature. It is common practice, for instance, for major league baseball parks in dry climates to condition their baseballs at 50% relative humidity. Baseball and softball are played at temperatures ranging from less than 4 C (40 F) to more than 38 C (100 F). Standardized ball tests require controlled temperature and humidity test environments. Little information is available, however, to quantity the effect of temperature and humidity on a ball's response. The following describes test procedures used to condition softballs and baseballs to controlled levels of humidity and temperature and their effect on the ball's stiffness and elasticity. While the construction of the baseballs and softballs are quite different, their elasticity and stiffness show a similar trend with temperature and humidity. Their combined effect was shown to lower bat performance as both temperature and humidity were increased.

Keywords: baseball, softball, temperature, humidty

1. Introduction

Most manufacturers of hollow bats have a temperature limit, below which the bat warrantee is not valid. While many believe the temperature limit concerns the bat design, it is actually related to the ball. At low temperature, balls become stiffer. This increases the impact force, which in turn, can cause premature failure of the bat. The opposite is also true. At high temperature the ball becomes softer, which lessens the trampoline effect observed with hollow bats and the hit ball speed.

[a] Corresponding author. Tel.: 509-335-3221.
E-mail address: lvsmith@wsu.edu.

Humidity can also affect the response of the ball; in fact baseballs are now stored in humidors in Major League parks with dry climates to keep the offensive statistics on par with other parks. In Major League Baseball, the concern over ball humidity is not related to its stiffness (wood bats don't have a trampoline effect) but the coefficient of restitution. At low humidity baseballs become more elastic, while at high humidity the opposite occurs.

The combined effect of temperature and humidity is referred to as 'hygrothermal response.' While it can have a large effect on the performance of the ball, it is hard to measure and rarely reported. The works of Meyer and Bohn [1], Kagan and Atkinson [2], and Drane and Sherwood [3], for instance, represent nearly all that has been published concerning the effect of temperature and humidity on baseballs. The following presents some recent results of temperature and humidity on baseballs and softballs that support and expand on this previous work.

2. Test Facility

Baseballs are often described by their coefficient of restitution (COR). Ball COR is commonly measured by firing the ball at 60 mph against a flat rigid wall [ASTM F1887]. The ball COR is found from the ratio of the rebound to the inbound speed. In the following, a cylindrical COR was considered that more accurately captured the energy loss occurring in play. The cylindrical COR (CCOR) was obtained by firing the ball against a rigid cylindrical surface as shown in Fig. 1. The impact surface corresponded to the bat barrel, where a diameter of 57 and 67 mm (2.25 and 2.625 inches) were used for softball and baseball impacts, respectively. A 42.5 m/s (95 mph) incident speed was used for the CCOR measurements to represent the bat-ball impact force [4].

Balls were fired from an air cannon as depicted in Fig. 1. The ball traveled in a sabot which allowed control of the ball speed, impact surface and impact location on the cylinder. An arresting plate at the end of the cannon captured the sabot while allowing the ball to continue unimpeded. Three light screens were placed between the cannon and impact surface to make redundant ball speed measurements before and after impact. The location of the cylinder, relative to the cannon, was adjusted so that the ball rebound path was within 5° of the inbound path. The supply pressure to the cannon was adjusted to achieve an incident speed within 0.5 m/s (1 mph) of the target speed.

An array of three piezoelectric load cells was placed between the cylindrical surface and rigid wall to measure the impact force. By equating the kinetic energy of the incoming ball to the maximum stored energy during impact, a ball stiffness, *k*, was derived as

$$k = \frac{1}{m}\left(\frac{F}{V}\right)^{\frac{1}{2}} \tag{1}$$

where *m* is the ball mass, *F* is the peak impact force, and *V* is the incoming ball speed [4]. Ball stiffness is

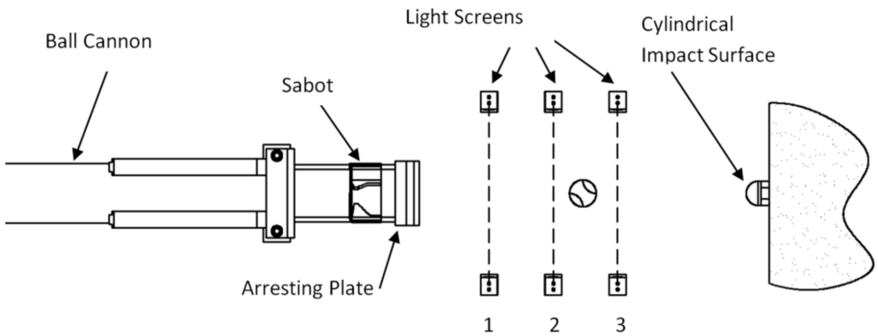

Fig. 1. Schematic of ball test apparatus

of interest in amateur play where it affects the trampoline effect observed with hollow bats. The reported ball stiffness and CCOR was an average of six valid impacts from each ball.

Bats were tested using an air cannon similar to that shown in Fig. 1. The rigid wall was replaced by a platform supporting a pivoted bat that was allowed to recoil after impact [ASTM F2219]. The bat was impacted six times at 13 mm (0.50 inch) increments along its length, until a maximum performance location was observed.

3. Humidity

Eight groups of baseballs and softballs were given a controlled humidity exposure, after which their weight, CCOR and stiffness was measured. The baseballs were MLB and NCAA approved and made from a cork/rubber pill with wool windings and a leather cover. The softballs were ASA approved and made from a polyurethane core with a synthetic cover. The softballs had a nominal COR of 0.44 and a compression of 1.67 kN (375 lbs). By convention they were denoted 44/375. Four dozen of each ball type were placed in a 50% RH conditioning environment for four months. The balls were then divided into groups (six baseballs and six softballs) and placed in separate conditioning chambers at relative humilities ranging from 11 to 97% RH for six weeks. The humidity was controlled by suspending the balls over saturated salt solutions in sealed containers. Humidity sensors were placed in half of the containers to verify the target humidity level was maintained throughout the study. A control group was left in the initial 50% RH environment for the duration of the study.

To determine when the balls had reached saturation, the weight of three baseballs and softballs (separate from the primary study) at 33% and 97% RH was continuously monitored. The balls in the 33% RH environment reached saturation in a little more than a week, while the balls at 97% RH required upwards of three weeks.

The average weight for each group is shown in Fig. 2 as a function of the humidity level. The error bars represent the standard deviation for each group. The weight change is remarkably similar between the baseballs and softballs, although the baseballs absorb slightly more moisture at the highest humidity levels. Meyer and Bohn measured weight gain with humidity using the Major League Baseball [1]. They reported a weight gain of 3.4% when the humidity was increased from 33% to 75%. This is considerably less than the average weight gain of the MLB balls considered in this study which gained 7.4% over the same increase in humidity. The large weight changes occurring at the extreme humidity levels in this study appear to contribute to a higher average moisture change. The softballs and NCAA baseballs gained less than half the weight of the MLB baseballs. The NCAA balls had a polymeric film under the cover to resist moisture effects, which may explain the lower saturation level. The polyurethane core of the softballs provided a similar attraction to moisture as the NCAA baseballs. If weight gain is considered as a percentage of the ball weight, however, the softballs gained 25% less weight than the NCAA baseballs.

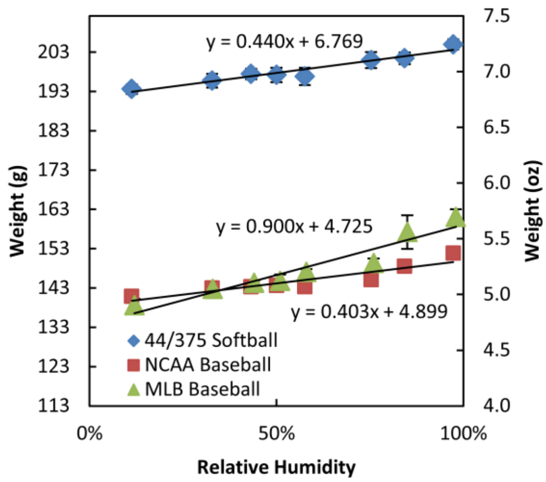

Fig. 2. Ball weight as function of relative humidity.

The CCOR is presented as a function of humidity level in Fig. 3. The CCOR is approximately 20% higher for baseballs than softballs. The difference in CCOR between softballs and baseballs is comparable to that found with the standard flat plate COR. Kagan and Atkinson measured the COR using a flat laminated ash impact surface with NCAA approved baseballs [2]. They reported a slope of d(COR)/d(%RH) = -5.4×10^{-4}. The slope of the CCOR from this work was considerably lower than that found by Kagan and Atkinson (-3.3×10^{-4}). While the baseballs used in this work and by Kagan were NCAA approved, they were produced from different manufacturers. The polymeric film which helped reduce the weight change of the balls used in the current study appears to also keep the CCOR more uniform. The MLB baseball showed the highest sensitivity to humidity, which was more than three times higher than the NCAA baseball and more than five times higher than the softballs.

Ball stiffness is shown as a function of humidity in Fig. 4. The stiffness of the MLB baseballs was more than seven times more sensitive to humidity than the NCAA baseballs, but only 25% more sensitive to humidity than the softballs. The formulation of the polyurethane softball core allows independent control of ball stiffness and COR. The polyurethane cure process is sensitive to the ambient moisture content, which may contribute to the sensitivity of the softball stiffness to the humidity level.

The error bars in Figs. 2-4 represent the standard deviation for each six-ball group. The softballs and baseballs have a comparable weight coefficient of variation (COV). The trend changes with CCOR and stiffness, however, where the baseball COV is twice that of the softballs. This difference in COV is surprising as the winding process used to make baseballs is usually considered to be more repeatable than the formulation and cure of polyurethane. The comparison suggests that the repeatability of baseballs may need at least as much scrutiny as softballs receive.

4. Temperature

In the temperature study, the balls were first conditioned at 22 C (72 F) and 50% RH for a minimum of two weeks. The balls were then placed in a cooler or oven at the desired temperature for 24 hours prior to measuring their CCOR and stiffness. Since the testing environment was maintained at 22 C (72 F) and the ball temperature could change over the six impacts needed for the study, the balls were placed back in their respective cooler or oven between the impacts. The balls were tested sequentially in groups of 12, so that each ball had nearly 30 minutes in their conditioned temperature prior to subsequent impacts. A

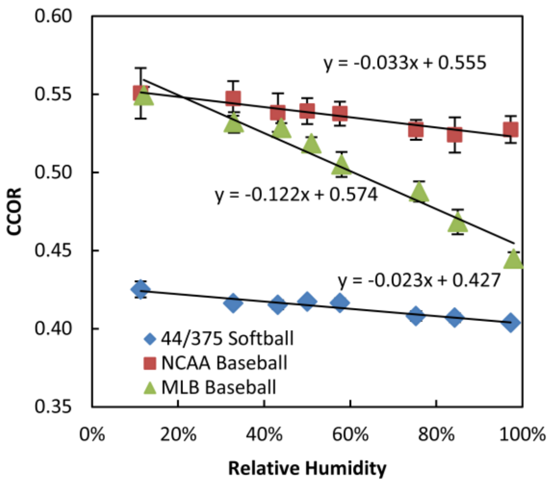

Fig. 3. Ball CCOR as a function of relative humidity.

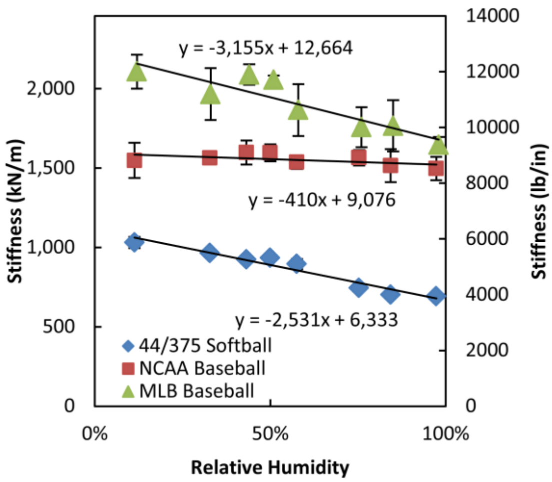

Fig. 4. Ball stiffness as a function of relative humidity.

relatively new softball, designed to have high CCOR and low stiffness, is becoming popular with a number of associations. It is purported to be less sensitive to temperature than current softball designs, and was included in the temperature study under the designation 52/300.

The CCOR is shown as a function of temperature in Fig. 5. The CCOR of the NCAA and MLB baseballs and the 52/300 softball show a similar dependence on temperature. The MLB baseball again had the highest sensitivity, which was seven times larger than the least sensitive 44/375 softball. The trends changed when the effect of temperature on stiffness was considered. The ball stiffness is shown as a function of temperature in Fig. 6. The stiffness of the 44/375 softball is the most sensitive to temperature, which was more than 30 times larger than the least sensitive MLB baseball. The reduced temperature dependence of the 52/300 softball is apparent in Fig. 6, where it's stiffness changed less than half that observed with the 44/375 softball.

5. Bat Performance

The foregoing has shown that temperature and humidity play a complex roll in their contribution to ball performance. The primary interest of ball performance usually concerns the bat, however. The bat-ball coefficient of restitution, *e* or BBCOR, can be accurately described as a function of the properties of the ball according to

$$e^2 = \frac{r e_o^2 + 1}{1 + r} \quad (2)$$

where e_o is the CCOR of the ball and r is the ratio of the bat and ball stiffnesses [5]. Accordingly, the BBCOR of a hollow softball bat is shown as a function of humidity and temperature in Figs. 7 and 8, respectively. The bat performance is observed to decrease with both increasing humidity and increasing temperature. Temperature has a larger effect than humidity, which suggests that the changing ball stiffness has a larger effect on bat performance than the changing ball COR. In Fig. 7, the BBCOR is shown as a function of temperature for both the 44/375 and the 52/300 softballs. The claims of reduced temperature dependence of the 52/300 ball appear correct, where the BBCOR of the 44/375 ball was four times more sensitive to temperature than the 52/300 softball. To put the effect of temperature in terms of play conditions, going from 4 to 38 C (40 to 100F) decreases the hit distance by 7 m (23 ft).

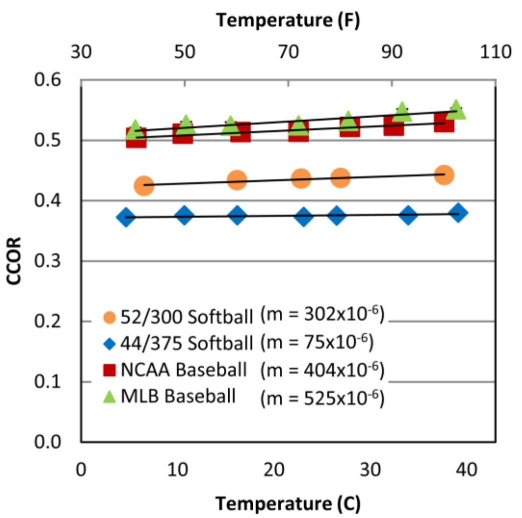

Fig. 5. Ball CCOR as a function of temperature.

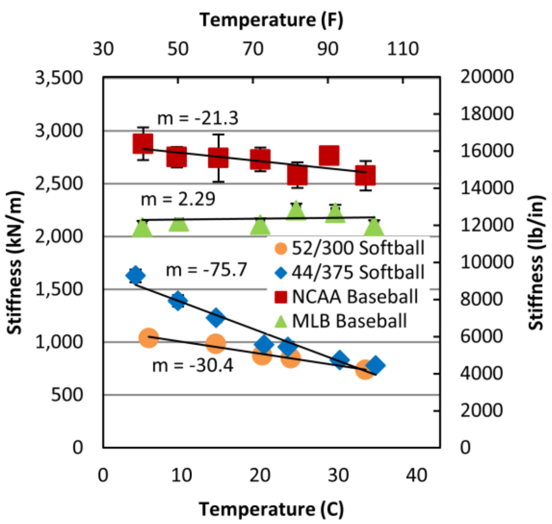

Fig. 6. Ball stiffness as a function of temperature.

6. Summary

This study has considered the effect of temperature and humidity on ball and bat performance. The stiffness of baseballs and softballs was shown to decrease with increasing temperature and humidity. The CCOR of baseballs and softballs was shown to decrease with increasing humidity and increase with increasing temperature. The competing effect of temperature and humidity on the ball CCOR and stiffness were combined by considering their effect on the performance of a softball bat. Bat performance was observed to decrease with increasing temperature and humidity. The effect of temperature on bat performance was significantly diminished using a relatively new high CCOR and low stiffness softball.

References

[1] Meyer, E. R., Bohn, J. L., 2008. “Influence of a humidor on the aerodynamics of baseballs,” American Journal of Physics,76.11:1015.

[2] Kagan, D., Atkinson, D., 2004. “ The Coefficient of Restitution of Baseballs as a Function of Relative Humidity,” The Physics Teacher, 42: 89-92.

[3] Drane, P., Sherwood, J., 2004. “Characterizing the effect of temperature on bsaeball COR performanc,” The Engineering of Sport 5, Vol. 2, pp. 59-65.

[4] Smith, L,. V., Duris, J. G., Nathan, A. M., 2009. “Describing the Dynamic Response of Softballs,” Sports Engineering,12.4:163-169.

[5] Nathan, A. M., Smith, L. V., Faber, W. L., 2011. “Reducing the effect of the ball on bat performance measurements,: Sports Technology, *to appear*.

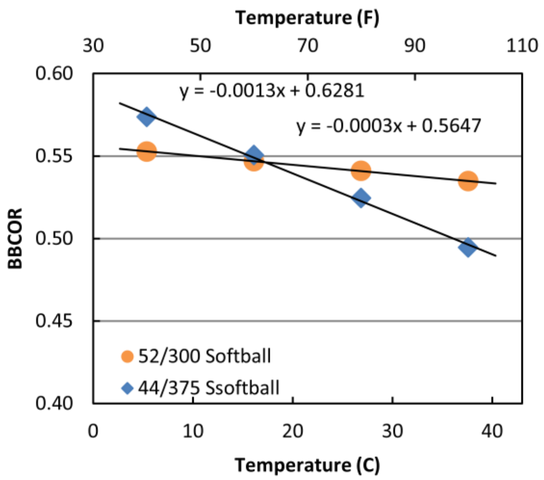

Fig. 7. The bat-ball coefficient of restitution as a function of temperature.

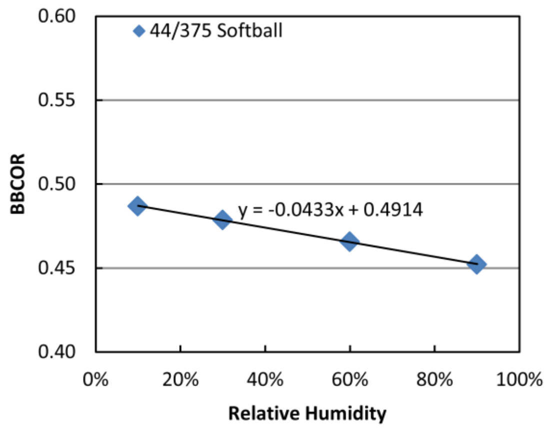

Fig. 8. The bat-ball coefficient of restitution as a function of relative humidity.