Some Remarks on Corked Bats
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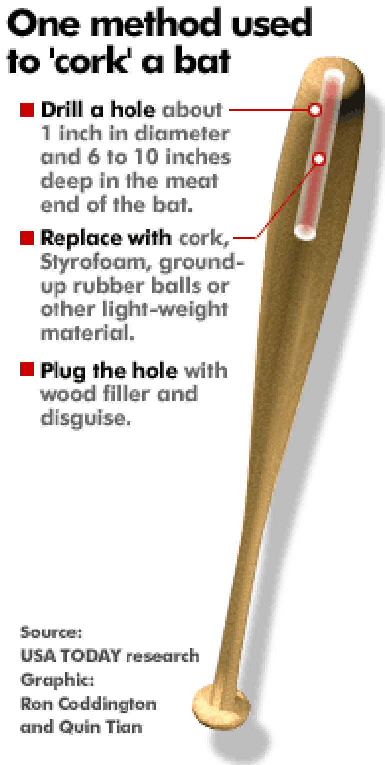
What is a "corked" bat?

A corked bat is one in which a cavity has been drilled axially into the barrel of a wood bat. Typically, the diameter of the cavity is approximately 1 inch and it is drilled to a depth of about 10 inches. The cavity may or may not be filled with some substance, such as compressed cork, small superballs, etc.



What positive effect does this have on performance?

Because wood has been removed from the bat and (possibly) replaced by some substance with a smaller density than wood, the bat is lighter by 1-2 oz, depending on the dimensions of the cavity and the density of the filling substance. Not only is the bat lighter, but the center of gravity, or balance point, of the bat moves closer to the hands. This means that the "swing weight" of the bat is also reduced. In technical physics language, the moment of inertia (MOI) of the bat about the knob is reduced for a corked bat. You can think of the MOI as the "rotational inertia" of the bat. Just like the "inertia" or mass of an object measures the resistance of the object to a change in its translational motion, the rotational inertia measures the resistance to a change in its rotational motion.

The effect is easy to understand: It is much easier to swing something when the weight is concentrated closer to your hands (smaller MOI) than when it is concentrated far from your hands (larger MOI). You can try such an experiment yourself. Simply take a bat by the handle and swing try to rotate it rapidly. Then turn the bat around, holding the barrel, and try doing the same thing. You should find that it is easier to rotate it in the second case. Therefore, a batter can often get a higher bat speed with a corked bat than with a comparable bat that has not been corked. All other things being equal, a higher swing speed gives rise to a higher hit ball speed and greater distance on a long fly ball. Of course, all other things are not equal, and the reduced mass in the barrel produces a less effective collision, as we shall see in the next section.

An additional effect is that the lighter weight and smaller swing weight also lead to better bat control, which has a beneficial effect for a contact-type hitter, who is just trying to meet the ball squarely rather than get the highest batted ball speed. The batter can accelerate the bat to high speed more quickly with a corked bat, allowing the batter to react to the pitch more quickly, wait longer before committing on the swing, and more easily change in mid-swing. As has been pointed out by Bob Adair in his book, a batter can achieve the same effect legally by choking up on the bat or by using a lighter (and therefore probably shorter) bat. Of course, there are reasons one might not want to either choke up or use a shorter bat, especially in situations where you need to protect the outside part of the plate. In such a situation, a corked bat can provide a definite advantage. Many fast-pitch softball players take the issue of bat control to the extreme. The fast-pitch game heavily favors the pitcher, so a batter is often more interested in making good contact than in swinging for the fences. These batters use very light bats—25 oz or less-- to improve bat control and reaction time. Since they are using primarily aluminum bats, they can achieve low weight with no cost in length.

What negative effect does this have on performance?

The efficiency of the bat in transferring energy to the ball in part depends on the weight of the part of the bat near the impact point of the ball. For a given bat speed, a heavier bat will produce a higher hit ball speed than a lighter bat. That is why the head of a golf driver is heavier than that of an iron: you want to drive the ball further. By reducing the weight at the barrel end of the bat, the efficiency of the bat is reduced, giving rise to a reduced hit ball speed and less distance on a long fly ball. This is the downside of using a corked bat.

So what is the net effect?

We see that corking the bat leads to higher swing speed but to a less efficient ball-bat collision. These two effects roughly cancel each other out, leaving little or no effect on the hit ball speed or on the distance of a long fly ball. A specific example showing how this happens will be given below.

But is there a “trampoline” effect?

The trampoline effect is quite well known in hollow metal bats. The thin metal shell actually compresses during the collision with the ball and springs back, much like a trampoline, resulting in much less loss of energy (and therefore a higher batted ball speed) than would be the case if the ball hit a completely rigid surface. The loss of energy that I referred to comes mostly from the ball. During the collision, the ball compresses much like a spring. The initial energy of motion (kinetic energy) gets coverted to compressional energy (potential energy) that is stored up in the spring. The spring then expands back out again, pushing against the bat, and converting the compressional energy back into kinetic energy. This is a very inefficient process in that only about 25% of the stored compressional energy is returned to the ball in the form of kinetic energy. The rest is lost due to frictional forces, deformation of the ball, etc. You can see the effect of this energy loss for yourself. Drop a baseball onto a hard rigid surface, such as a solid wood floor. The ball bounces back up to only a small fraction of its initial height because energy was lost in the collision of the ball with the floor. The loss mainly came from compressing and then expanding the ball. When a ball collides with a flexible surface, like the thin wall of an aluminum bat, the ball compresses less than it does when colliding with a rigid surface, since the thin wall does some of the compressing instead. Less energy is stored and ultimately lost in the ball, whereas the flexible surface is very efficient at returning its compressional energy back to the ball in the form of kinetic energy. The net effect is that the ball bounces off the flexible surface with higher speed than it does off the rigid surface. This is the essence of the trampoline effect. By the way, the trampoline effect is well known to tennis players, where the effect comes from the strings of the racket. All tennis players know that to hit the ball harder, you should decrease rather than increase the tension in the strings. Many people who do not play tennis find this counterintuitive, but it really is true. The lower tension makes the strings more flexible, just like a trampoline. You can even try the following experiment. Drop a baseball from the floor and measure the ratio of final height to initial height. Now drop a baseball from the strings of a tennis racket, making sure that the frame of the racket is clamped down so it does not vibrate. You should find that the ratio of final to initial height is higher than when the ball is dropped onto the floor. That is the trampoline effect in action.

With that long introduction, we come back to our question: Is there a trampoline effect from the hollowed-out wood bat or the cork filler? My own understanding of the physics of the ball-bat collision suggests that the answer is “no”. Why not? A 1”-diameter hole in a 2-1/2” diameter wood bat means the wall thickness is ¾”, which is at least 7 times thicker than that of a typical aluminum bat. It requires much greater force to compress such a bat than it does to compress an aluminum bat. In the technical parlance of physics, the spring constant of the hollow wood bat is much larger than that of a typical aluminum bat. Therefore, very little compressional energy is stored in the hollow wood bat during the collision, so that any trampoline effect is minimal at best.

In order to test this idea, I did an experiment several years ago with Professor Jim Sherwood at the Baseball Research Center (which Jim directs) at the University of Massachusetts/Lowell. We took two identical Louisville Slugger R161 wood bats, each with a length of 34” and a weight of 32.5 oz. Into one bat I drilled a 7/8" diameter hole, 9-1/4" deep into the barrel, removing a total of 2.0 oz of wood. We then measured the ball exit speed when a 70 mph ball impacted the bat at a point 6" from the end of the bat. The speed of the bat at that point was set at 66 mph. Using the measured exit speed, the known inertial properties of the bats, and appropriate kinematic formulas, we extracted the ball-bat coefficient of restitution (COR), which is a measure of the liveliness of the ball-bat combination. We found the COR to be *identical* for the two bats, at least within the overall precision of the experiment. Had there been a trampoline effect, one would have found a larger COR for the hollowed bat. Armed with this information, I then did a calculation of hit ball speed that one would expect in the field, assuming a pitch speed of 90 mph and a bat speed that was slightly higher for the hollowed bat, based on a model for the relationship between bat swing speed and the swing weight of the bat. The model is based on the (unpublished) experimental study of Crisco and Greenwald, which gives a definite relationship between the MOI of the bat and the swing speed. The calculation shows that the unmodified bat actually performs slightly better than the hollowed bat (see figure below).

Moreover, filling the cavity with cork, which is much more easily compressed than the wood itself, is not likely to help. The response time of the cork is much too slow to provide a trampoline effect. The typical ball-bat collision time is less than 1/1000 of a second, which is much faster than the natural vibrational period of the cork. During the short collision time, the cork barely has time to compress. In effect, energy gets transferred to the cork in the form of an impulse, which actually results in more energy dissipation than would be the case if the cavity were empty. Moreover, adding cork restores some of the weight that had been removed, thereby at least partially negating the increase in swing speed that had resulted. It would seem that leaving the cavity hollow would be better than filling it with cork.

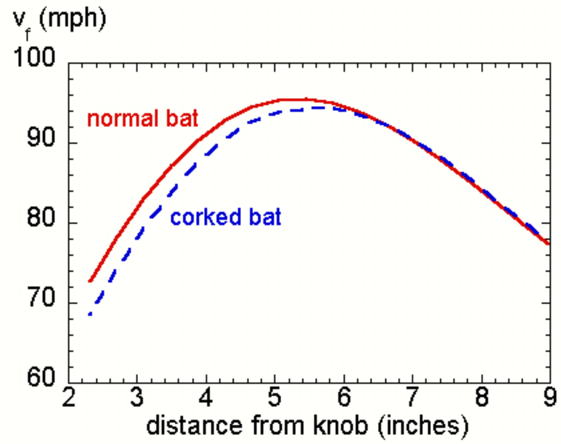


Figure 1. Calculation of hit ball speed from two otherwise identical wood bats. Relative to the normal bat, the corked bat had a cavity in the barrel of diameter 0.875" and depth 9.25", thereby removing a total mass of 2 oz from the barrel of the bat. The calculation assumes that the ball-bat COR is the same for each bat, as shown from experiment, and assumes a particular relationship between the bat swing speed and the moment of inertia of the bat. The calculation shows that the normal bat slightly outperforms the corked bat.

What about filling the cavity with superballs?

This is an interesting question. A more generic question is whether there is some substance that is compressible (so as to store energy) but not so compressible that it does not return the energy to the ball. This is a question that is worth thinking hard about and worth doing some experimental measurements to study the effect. Such experiments are currently in the planning stage.

And the bottom line?

It is quite unlikely that corking the bat will produce any appreciable effect, either of a beneficial or a detrimental nature, on the distance of a long fly ball. It is likely to result in higher batting averages for contact-type hitters.

Update: December 1, 2004

In July 2003, the crack team of Professor Dan Russell of Kettering University (http://www.kettering.edu/~drussell/bats.html), Professor Lloyd Smith of Washington State University, and I did a series of measurements on several wood bats provided by Rawlings, to whom we express our thanks and gratitude. The measurements utilized the bat testing facility at the Sports Science Laboratory at Washington State (http://www.mme.wsu.edu/~ssl), of which Lloyd is the founder and director. The test consists of firing a baseball from a high-speed cannon at a speed of approximately 110 mph onto a bat that is clamped at the handle to a pivoting structure. The speed of the incoming and rebounding ball are measured, and kinematic equations are used to determine the ball-bat COR.

The primary bat we used was a 34” bat with an unmodified weight of 30.5 oz. The unmodified bat was impacted a total of 6 times. Then a cavity 1” in diameter and 10” deep was drilled into the barrel of the bat, reducing the weight to 27.6 oz. This “drilled” bat was impacted a total of 6 times. Then the cavity was filled with crushed-up pieces of cork (from wine that I had enjoyed the preceding two weeks!), raising the weight to 28.6 oz. This corked bat was impacted 12 times. Then the cork was removed and the drilled bat was impacted again 5 times. Unfortunately, the bat broke at the handle on the last impact. We had intended to fill the cavity with superball material, but that part of the experiment was cut short by breaking the bat. All impacts used the same baseball and all were at the same location, 5” from the barrel end of the bat. Various checks were done to assure that the properties of the ball did not change in the course of the measurements. A summary of our results is given in Figure 2. These data demonstrate that there is no measurable trampoline effect when a wood bat is drilled or corked.

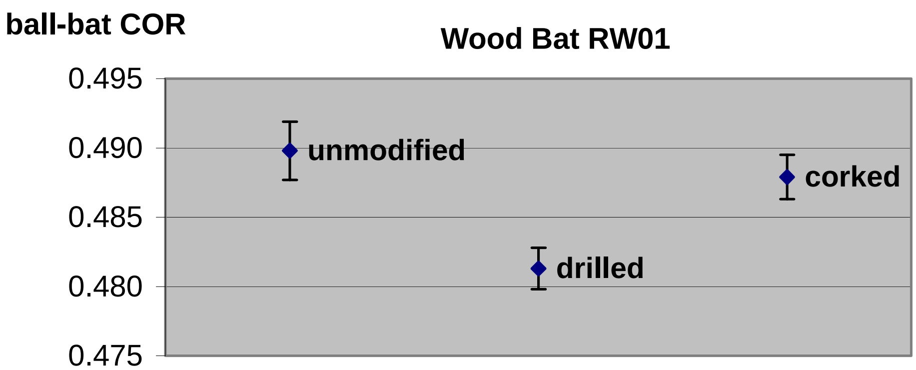


Figure 2. Measured values of the ball-bat coefficient of restitution (COR) for an unmodified, drilled, and corked wood bat, as explained in the text. The error flags indicate the standard deviation of the mean of the measurements. These data demonstrate that there is no measureable trampoline effect when a wood bat is drilled or corked.