

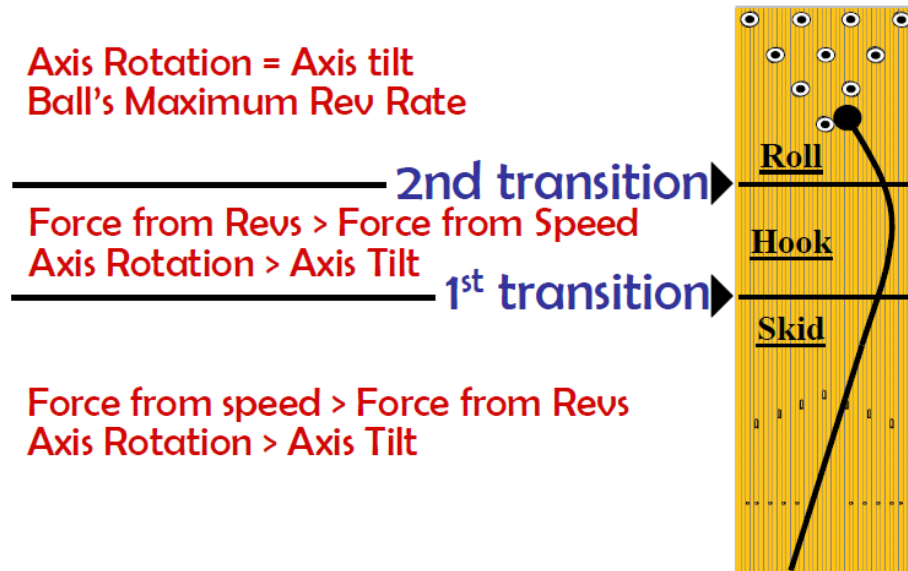
DIFFERENTIAL RATIO

A very important factor to ball reaction

Now that technology allows us to accurately measure the factors that affect ball reaction, differential ratio has emerged as a very significant force in determining the motion of a drilled bowling ball. The differential ratio of the drilled ball is the most significant factor that affects the shape of the ball's motion. Differential ratio is defined as the intermediate differential divided by the total differential. Before discussing the effect of differential ratio on ball reaction, let's review the three phases of ball motion. The USBC, combined with the ball manufacturers, did graphical analysis, using CATS, to accurately measure the resulting ball motion when a drilled ball was thrown, by an automatic ball throwing machine, on a lane with a 53 foot flat oil pattern. That graphical analysis showed the three phases of ball motion for each ball tested. The USBC received accolades from the scientific community in the form of an ASQ award for the detail and accuracy of this study. Congratulations to them for that. It's a feather in the bowling industry's cap. That award reinforces the creditability of the USBC study.

It is now time to accurately explain bowling ball motion. When a bowler delivers a ball, the bowler imparts four forces to the ball. They are initial ball speed, initial rev rate, initial ball axis tilt, and initial axis rotation. Those factors, plus the location of the PAP, are the only factors necessary to set for an automatic ball thrower to duplicate a bowler's delivery during ball motion testing. As the ball travels down the lane, it passes through three phases and two transitions. It happens as follows: the skid phase, the first transition from skid to hook, the hook phase, the second transition from hook to roll, and, finally, the roll phase. The diagram of ball motion looks like this:

USBC Ball Motion Study



During the skid phase, the force from the ball speed exceeds the force from the rev rate. As the ball travels down the lane, the friction between the ball and the lane reduces the ball's speed and increases the ball's rev rate. When the forces from the ball speed and the rev rate become equal, the ball transitions (first transition) into the hook phase. In the hook phase, the force from the ball's rev rate exceeds the force from the ball's speed. During the skid and hook phases, the ball's axis rotation always exceeds the ball's axis tilt. The ball will lose its' axis rotation faster than it loses its' axis tilt during the skid and hook phases. When the ball's axis rotation and axis tilt become equal, the ball will transition (second transition) into the roll phase. Once the ball enters the roll phase the ball will no longer hook and the ball's axis rotation will always equal the ball's axis tilt. The axis rotation and axis tilt will decrease slowly as the ball travels down the lane during the roll phase. The bowling ball will reach its' maximum rev rate at the second transition. The ball's rev rate will always be less in the skid and hook phases than it is in the roll phase. That's why a bowling ball always hits harder after it stops hooking (the roll phase), rather than while it's still hooking (the hook phase). Once the ball reaches its' entry angle at the second transition, the entry angle will remain the same until the ball hits the pins. No matter what you heard, or believe, that is a scientifically accurate description of bowling ball motion.

There's one more fact that must be mentioned before discussing all the factors that affect the shape of the drilled ball's motion. To me, it's very obvious that we are only concerned with drilled bowling balls. No one cares how undrilled balls roll. It may not be widely understood by bowlers, but it has been proven that all drilled bowling balls are asymmetrical, whether they are either symmetrical or asymmetrical before drilling. To be considered asymmetrical, a bowling ball must have a measurable intermediate differential and a Preferred Spin Axis (PSA). And, all drilled bowling balls have both those measurable properties. All this information was verified during the Ball Motion Study, which was conducted by the Ball Motion Task Force. The Ball Motion Task Force consisted of the USBC Equipment and Specifications Department and the ball manufacturers. In reality, the intermediate differential is the measure of a bowling ball's degree of asymmetry.

Now, for the nitty gritty of this article. "How is ball motion affected by the different factors studied in the Ball Motion Study?" According to that study, ball motion is affected by coverstock, mass properties (ball dynamics), and static weight balance. The study proved that the most important factor in determining ball motion is the ball's coverstock. Next in importance is the mass properties of the ball, followed, finally, by the least important factor, the ball's static weight balance. I will be expressing the mass properties in this article in terms of RGs, total differential, and differential ratio. Remember, differential ratio is defined as the intermediate differential divided by the total differential. Diff. ratio is expressed as a decimal. The larger the diff. ratio, the more asymmetrical the bowling ball is. Conversely, the smaller the diff. ratio, the less asymmetrical the ball is.

Coverstock aggressiveness (chemistry plus surface texture), RGs and total differential have similar effects on a drilled ball's motion. They all affect the location of the first transition on the lane to various degrees. In plain words, they determine how soon a ball starts up on a given lane condition. The coverstock of the ball has the most impact, followed by both the RGs and the total differential of the ball. The previous information was verified by the Ball Motion Study. My latest research now shows that those factors have very little effect on the shape of the ball's motion after the first transition.

The most important factor in determining the shape of a drilled ball's motion is differential ratio. It will determine the length of the hook zone, which

determines the location of the second transition on the lane, once the first transition has been determined by the ball's coverstock, RGs, and total differential. You may ask, "Exactly how does this affect a drilled bowling ball's motion?" The diff. ratio affects the ability of lane friction to steer the ball and, also, pin carry. WOW! Those are the two most important factors in scoring! Diff. ratio affects both the bowler's margin for error on any given lane condition and the bowler's strike percentage. That seems very important to me. It doesn't mean that we always want the maximum diff. ratio possible. On flatter oil patterns, where there is less friction differential on the lane to steer the ball, larger diff. ratios are very beneficial. For bowlers that are speed dominant, or have less hand, larger diff. ratios are, also, very beneficial. On oil patterns with bigger crosswise blends (much more oil in the center of the lane compared to the outside boards of the lane), like typical house shots (THS), smaller diff. ratios are preferred. Smaller diff. ratios are usually preferred by bowlers that are rev dominant, or have more hand.

The diff. ratio of a drilled bowling ball is determined by the design of the ball and the drilling technique used. The drilling technique consists of the layout and the balance hole location and size (if one is used). In my experience, the layout of any given bowling ball is about 40% of the ball reaction, created by the drilling technique, and the balance hole location and size is 60% of the reaction created by the drilling technique. I have also observed that a designed ball's reaction may be reduced by as much as 29%, or increased by as much as 55%, by the drilling technique used on that ball. Again, WOW!

Now we get to the real purpose of this article. "How do I use knowledge of differential ratio to benefit my bowling?" Knowledge of diff. ratio benefits us in two ways. By choosing the correct ball to drill, and, then, choosing the correct drilling technique for that ball provides the bowler with the best possible drilled ball for the conditions for which the ball is being drilled. The first decision to be made is to choose the ball to be drilled to provide the ball motion desired. After choosing the ball, the drilling technique has to be chosen to lock in the desired reaction. The drilling technique consists of the layout and the balance hole location and size (if a balance hole is desired).

First, the correct ball to be drilled must be chosen. Here is where symmetrical vs. asymmetrical comes into play. Obviously, the coverstock is a major factor in choosing the right ball. After deciding on a cover, the next

decision to be made is symmetrical or asymmetrical. Symmetrical balls yield drilled balls with smaller differential ratios. This will produce a drilled ball with a smoother, more controllable motion when compare to an undrilled asymmetrical ball. Varying degrees of longer transitioning (longer hook zone) ball motion can be obtained by choosing to drill a symmetrical ball. The degree of control and continuation that the drilled ball will have will depend on the exact ball chosen. You're going to have to rely on a knowledgeable ball driller to help you make that decision. Asymmetrical balls yield drilled balls with more defined, more angular break points. These balls can create more area at the break point and will respond to friction faster at the break point. Again, there is a wide variety of ball motions available from asymmetrical balls by choosing different covers and balls with different diff. ratios, total diffs., and RGs.

Finally, the drilling technique for the drilled ball must be chosen to guarantee the exact ball reaction for that bowler. Drilling techniques will result in the drilled ball having a wide range of diff. ratios and total diffs. I refer back to a previous statement made in this article. A designed ball's reaction may be reduced by as much as 29%, or increased by as much as 55% by the drilling technique used on that ball. That fact should emphasize the importance of choosing the correct drilling technique. Detailed information on drilling techniques may be obtained from the www.morichbowling.com home page by reading the technical articles listed on that page. Discussions, or questions, about all technical issues can be handled by logging on to www.forum.bowlingchat.net and getting involved there. Technical bowling subjects are discussed on "bowlingchat" daily. Examples of the diff. ratios, and diffs., can be achieved by choosing different drilling techniques. The following charts show that.

15# RipR Sharper Breakpoint Layout: 55 x 3 3/4" x 25				
RipR Drilled Ball Specs				
Balance Hole	None	P1	P2	Double Thumb
Int Diff	0.023	0.021	0.030	0.037
Total Diff	0.047	0.046	0.055	0.061
Ratio	0.48	0.45	0.55	0.60
RG of PAP	2.565	2.581	2.579	2.575

15# RipR Control Layout: 85 x 4 1/2" x 45			
RipR Drilled Ball Specs			
Balance Hole	None	P1	P2
Int Diff	0.023	0.008	0.025
Total Diff	0.040	0.037	0.048
Ratio	0.57	0.21	0.53
RG of PAP	2.566	2.583	2.578

Looking at the charts of the two different layouts, it can see how much difference there is in diff. ratios and diffs. between the two layouts with

different balance hole locations. I chose to use the MoRich **RipR**, our latest ball, for these charts because I have all the information on this ball available to me. Notice that by changing the chosen drilling technique, we can end up with drilled balls with diff. ratios from .21 to .60, intermediate diffs. from .008" to .037", and total diffs. from .037" to .061". I hate to repeat myself, but WOW! By the way, the specs. for an undrilled **RipR** are: diff. ratio of .25, intermediate diff. of .013", and total diff. of .042".

By understanding the importance of differential ratio to the resulting reaction of a drilled ball, bowlers have a much better chance of getting the ball reaction they desire out of a new ball. Good decisions in choosing the correct ball and the correct drilling technique make it much easier for bowlers to enjoy their new ball and make sure they're getting the desired results from that ball. Knowing how much these decisions play in the resulting ball reaction is why I say, "Once an oil pattern is applied to the lanes, the decisions made by the ball driller are the single, most important factor in how much a bowler enjoys bowling on that lane condition." Make good decisions and enjoy!