

ENGINEERING REPORT

Subject: Imbalance Effects with Fixed Pin Placement

Date: 1/4/2018

Place: International Training & Research Center

Present: Tom Frenzel

Purpose: Evaluate the effects of Side and Thumb weights without changing pin to PAP distance.

Summary: Side weight is the largest factor in manipulating ball motion

- 1 ounce of side weight correlates (R^2 : 95.2) to Approximately 0.36 degrees of total angle change
 - +/- 1 ounce spec limits the effect to 0.72 degrees
 - +/- 3 ounce spec limits the effect to 2.16 degrees
- 1 ounce of side weight correlates (R^2 : 84.3) to approximately 0.6 boards of hook
 - +/- 1 ounce spec limits the effect to 1.2 boards of hook
 - +/- 3 ounce spec limits the effect to 3.6 boards of hook
 - Thumb Weights tend to add skew E.A.R.L.'s Launch Angles
- 1 ounce of thumb weight causes a -0.1 degree shift in launch angle
 - When E.A.R.L. is set to 350 RPM.
 - The effects of static weight appear to be speed dependent
- This study showed greatly reduced effects compared to the original static weight study test with balls of similar static weights

Procedure:

A single ball was chosen that had 2.6 ounces of top weight and a 6.5-inch pin to CG distance. The ball was thrown with E.A.R.L., we kept the pin directly in the center of grip with a PAP of 5 inches over and zero up. The center of grip was rotated in 45-degree increments such that the side weights and thumb weights of the ball would change without changing the pin to PAP distance. The actual point on the balls that was the PAP would change, but the distance from pin to PAP, moment of inertia of the PAP point (the ball was symmetrical), and overall flare of the bowling ball did not change throughout the test. Five shots were to be thrown at each orientation of the center of grip. All key ball motion variables were tracked, such as total hook, and total angle change.

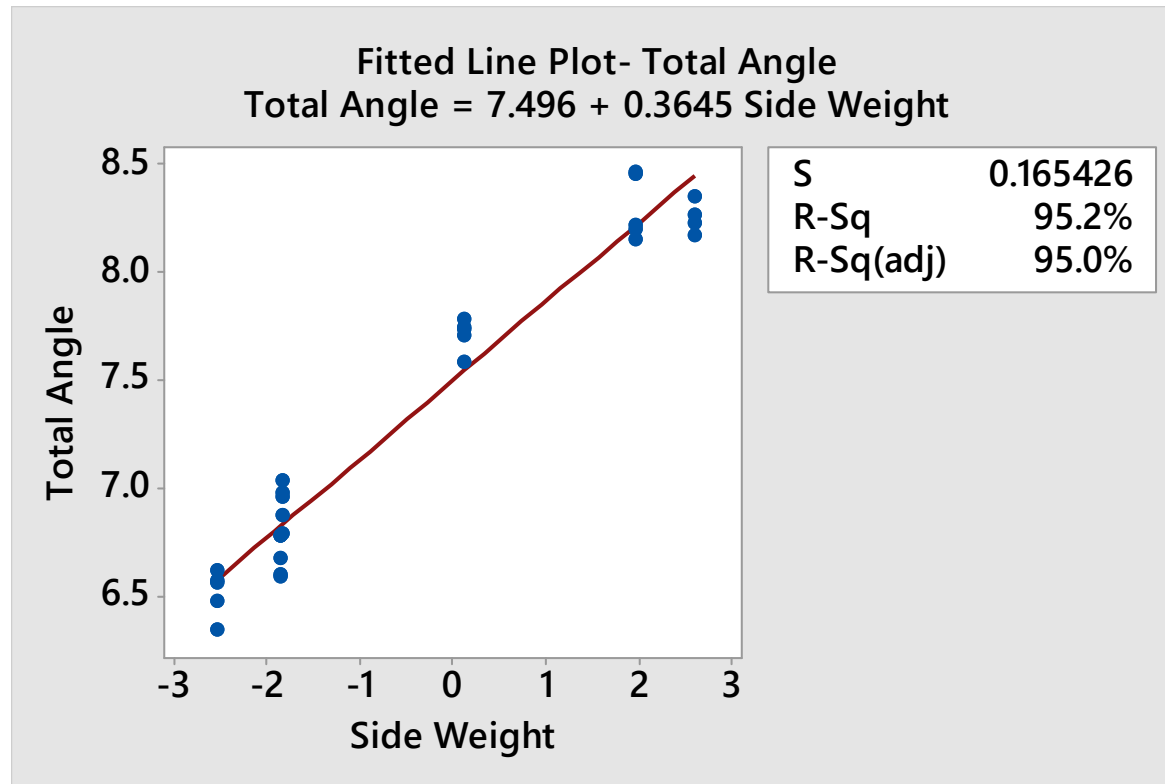
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Discussion:

This test is another step in the re-evaluation of the department's static weight study. The original static weight study showed very large effects of static weights including a 4th phase of ball motion where the ball would "fade" one direction or another – towards or away from the original direction of hook based on side weight. However, the test was conducted at very slow speeds, approximately 14 mph. Our goal was to see how these effects would change at faster speeds.

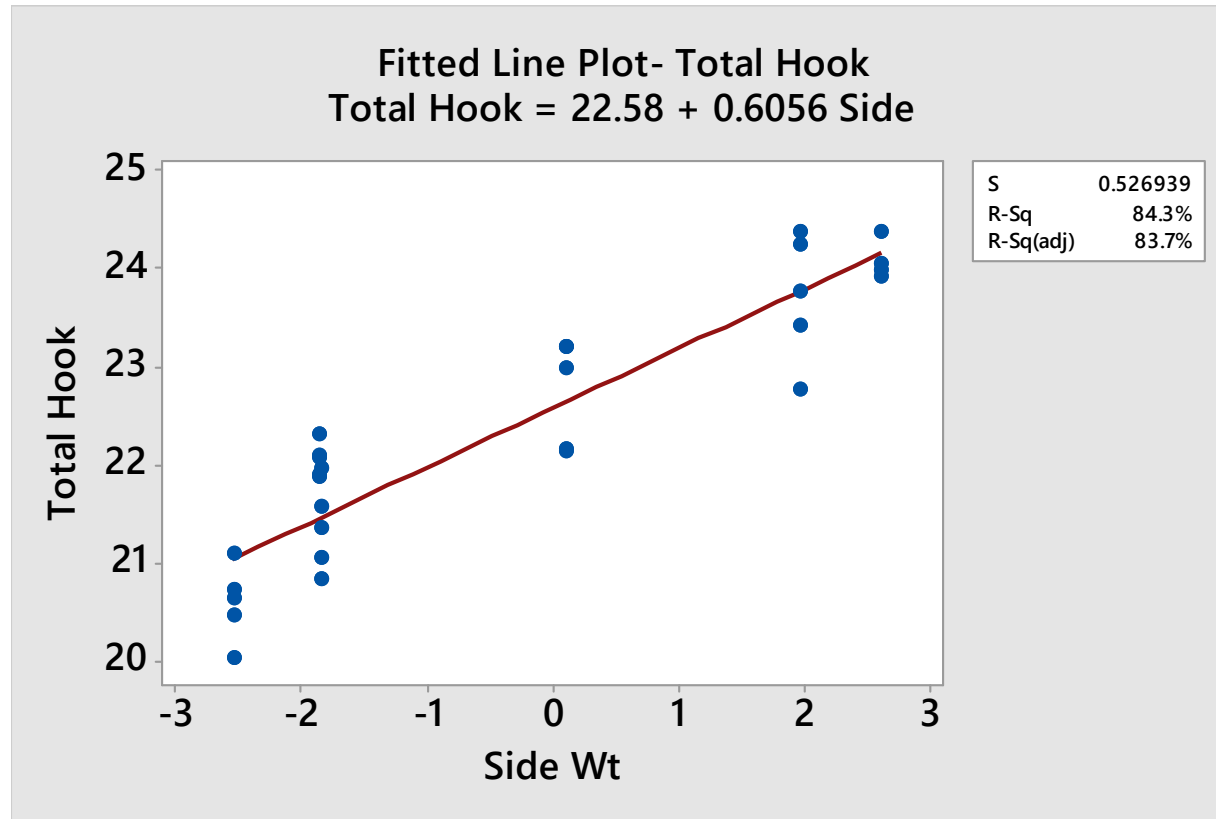
For this test, E.A.R.L. was set to throw the ball at 17 MPH, 350 RPM, -2 degrees of launch angle, 50 degrees of axis rotation, and 10 degrees of tilt. The test was conducted on a 35 foot, 1:1 ratio testing pattern with lengthwise taper. After every five shots the gripping orientation for the ball was changed and E.A.R.L.'s laydown setting was increased by one board. By rotating the ball about the center of grip, where the pin was also located, we were able to adjust the static weights of the layout without changing the pin to PAP distance. The results highlighted three main takeaways:

1. Side weight is strongly correlated to Total Angle Change: 0.3645 degrees per ounce.



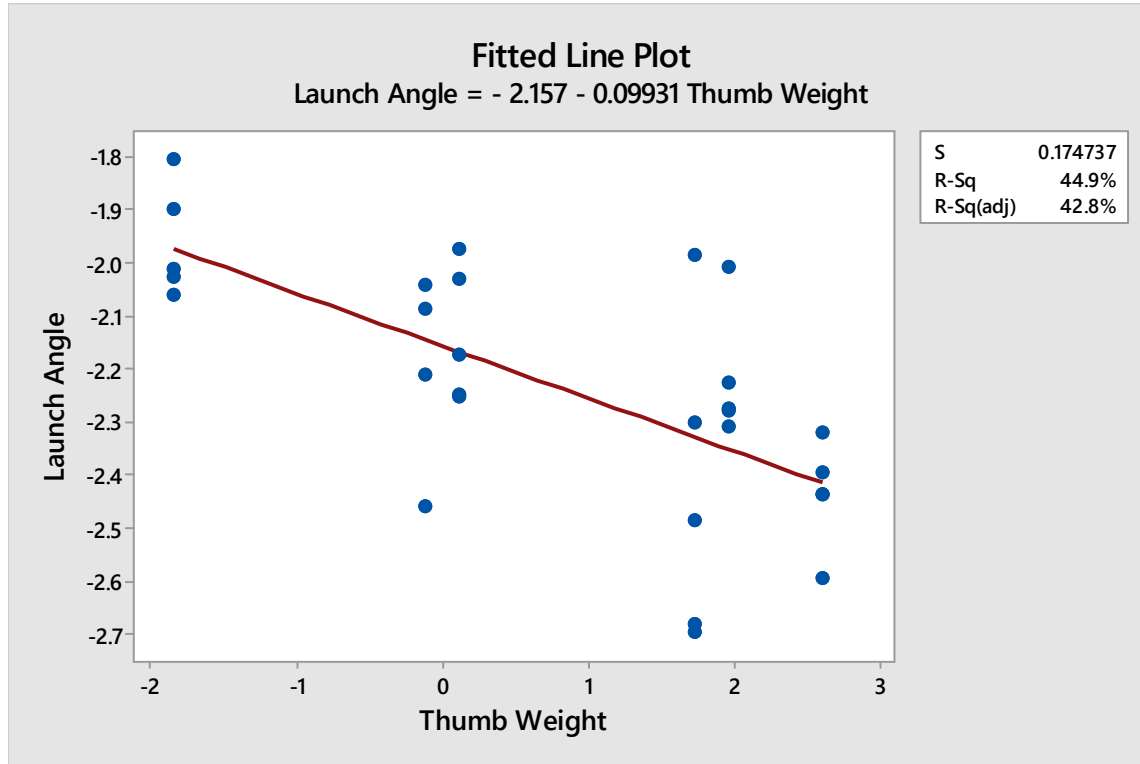
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2. Side Weight is strongly related to total hook of the ball: 0.6056 boards per ounce.



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3. E.A.R.L.'s Launch Angle is effected by Thumb Weights (likely top weights as well). ~-0.1 degrees per ounce



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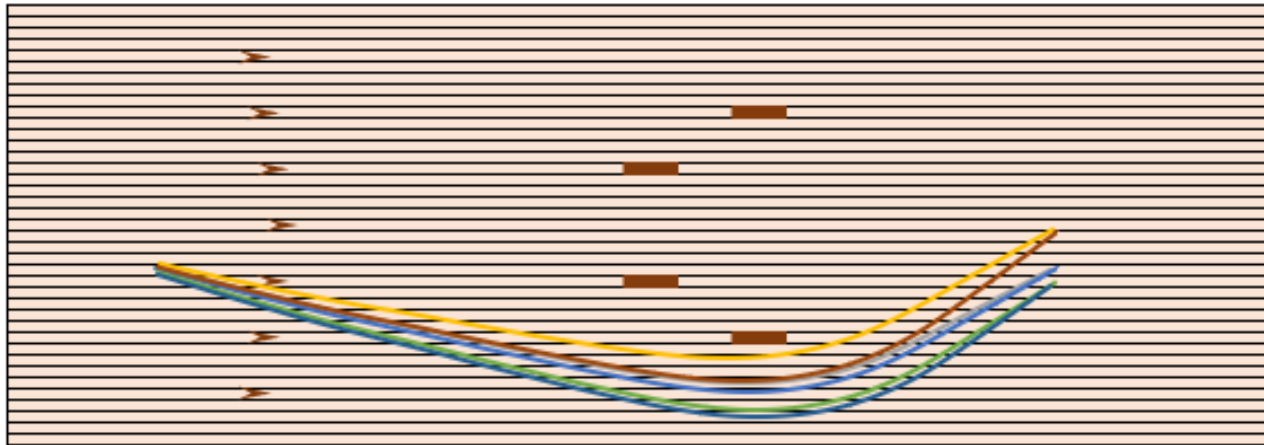
These results clearly show that opening the static weight specs will also increase the overall performance that can be achieved with static weights. The table below highlights the potential changes of increasing the specification.

Side Weight Specification (oz.)	Entry Angle Range (Degrees)	Total Hook Range (Boards)
+/- 1	0.729	1.2112
+/- 2	1.458	2.4224
+/- 3	2.187	3.6336
+/- 4	2.916	4.8848

The results showing us that thumb weights are affecting E.A.R.L.'s launch angles make sense. When a ball with imbalance rotations – like in E.A.R.L.'s back swing – it tends to oscillate back and forth as the center of mass goes around in a circle. Combine that with E.A.R.L.'s axis rotation and now that ball is also oscillating left and right while E.A.R.L.'s is spinning the ball up. As E.A.R.L. follows through and releases the ball, balls with thumb weight will cause the weight to be on one side of the oscillation, balls within negative thumb, or finger weight, will be on the opposite side of the oscillation. Our measurements on total hook and total angle were unaffected by this since we measure hook and angle from the initial trajectory. However, the launch angles needed to be adjusted to make sense of the average ball paths. By using this information, we were able to adjust the launch angles by rotating the ball paths. The unadjusted and adjusted ball paths can be seen on the next page.

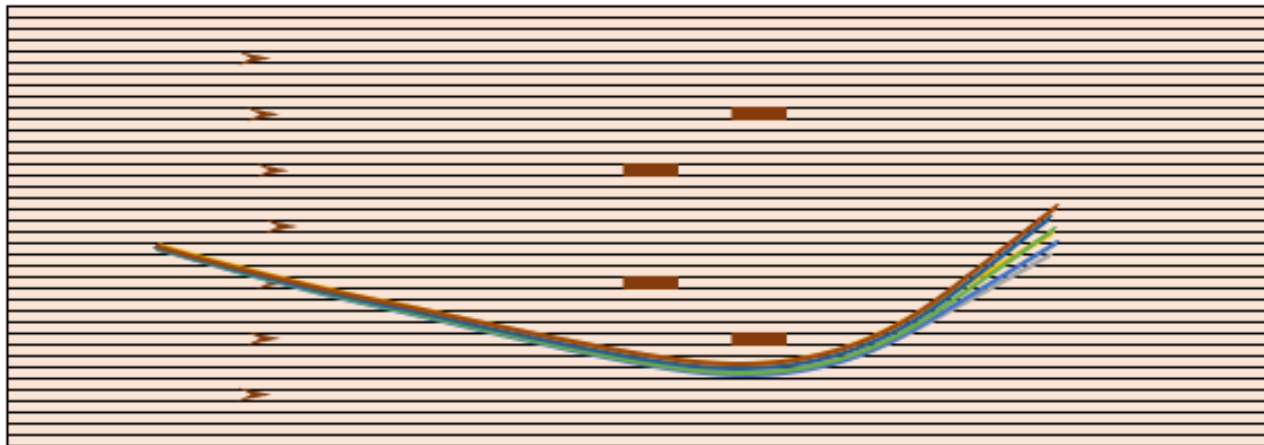
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Average Ball Paths



- Negative Side
- Finger and Negative Side
- Thumb and Negative Side
- Thumb Weight
- Thumb and Positive Side
- Positive Side

Average Ball Paths (Corrected Launch Angles)



- Negative Side
- Finger and Negative Side
- Thumb and Negative Side
- Thumb Weight
- Thumb and Positive Side
- Positive Side