UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

PHYS 497 PROJECT

Using Statcast Data to Study the Baseball Bat Collision

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1 Introduction

Baseball players focus on obtaining a good launch angle with high exit velocity when hitting. These two factors play a key role in terms of predicting the outcome of a batted ball. For instance, a batted ball with low launch angle (less than 5 degrees) will likely result in a ground out regardless of its exit velocity, while a batted ball with launch angle of 25 degrees will result in a line drive single or could reach over the fence if the exit velocity is high enough. Of course, there are other factors that could change the outcome of a batted ball including spray angle and ball spin. But since they are hard to control by the hitter and are not as important as launch angle and exit velocity when predicting an outcome, we will only focus on these two for now.

Some might also argue that players like Ichiro Suzuki intentionally hit bloopers with high launch angle and low exit velocity to let the ball drop in between an outfielder and an infielder to earn a single. However, there are only few players in the MLB history that are capable of doing this, and most hitters tries to hit line drives with high exit velocity. So, we will obey the data and focus on the majority.

Notice that the launch angle that gives the maximum exit velocity occurs when the attack angle is parallel to the center line angle, but the resulting launch angle is not optimal for a home run. However, achieving highest exit velocity results in highest chance of getting a hit. In this paper, we will explore the correlation between players' launch angle that gives the maximum exit velocity and their Homerun percent, wOBA, Slugging, Whiff rate, and Foul ball percent. I will use the data from Statcast, a tool used in Major League Baseball primarily for tracking the baseball. In addition, I will use the software package R to analyze and develop graphs that establishes connections between these factors.

For the sake of this paper, I will call the launch angle that gives the maximum exit velocity, a peak launch angle. Since different players have different attack angle and swing path, this peak launch angle differs across players. After finding the correlation between peak launch angle and various hitting stats, I will explore how each batters adjust to hit home runs with their peak launch angle.

2 Method

First, I imported the 2021 season MLB data from Statcast by using Statcast scraper by Bill Petti. I filtered this data to those that resulted in in-plays since we are interested in data that contains exit velocity and launch angle. Then, in order to obtain peak launch angle for each player, I divided the launch angle of each player's data into 5-degree bins, and within each bin, I selected data that is in top 10 percent by exit velocity. Next, I made a quadratic fit of exit velocity versus launch angle for the selected data above. Finally, I found the maximum point of the fitted line, which gives the peak launch angle and its exit velocity. It turns out that adding foul balls to this data frame changes player's peak launch angle by few degrees. This occurs since when the launch angle is very high or low, the outcome tends to be foul balls, so foul balls are included in the top 10 percent by exit velocity for extreme launch angles. This effect will minimize if I filter the range of launch angles to those that likely results in in-plays.

3 Analysis

3.1 Exit Velocity versus Launch Angle

To begin with, I wrote a function that creates a scatter plot of exit velocity versus launch angle for a single player with quadratic fit for top 10 percent data (by exit velocity for each 5-degree bins), and including a vertical dashed line through the peak launch angle. Using this function, I created plots for the player with maximum peak launch angle (27 degrees) and the player with minimum peak launch angle (-21 degrees). The result shown in Figure 1 indicates that given a launch angle, exit velocity varies a lot across player to player.

Next, I color coded each point of above plot by events shown in Figure 2 for Shohei Ohtani. As expected, home runs tend to occur when the exit velocity is in the top 10 and launch angle is a bit

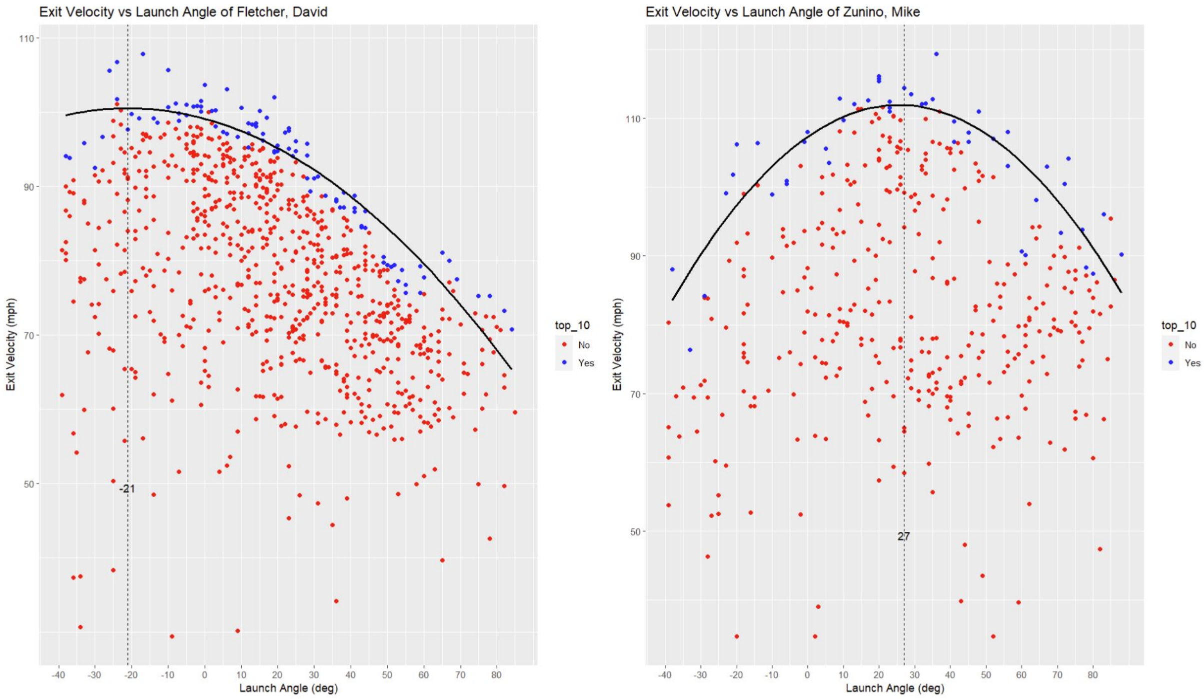

Figure 1: Comparison of Exit Velocity vs Launch Angle of player with lowest peak launch angle on the left and player with highest peak launch angle on the right.

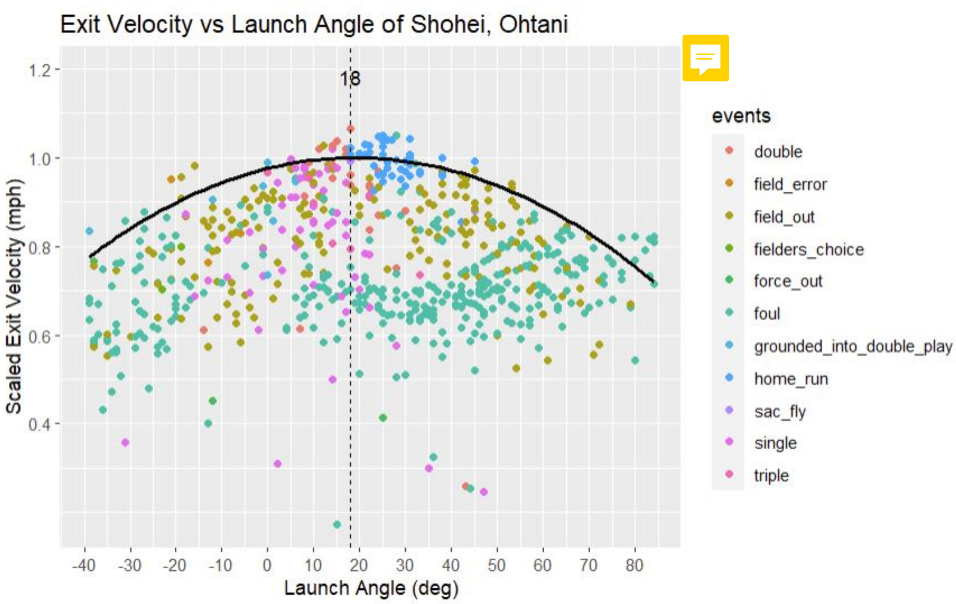

Figure 2: Exit Velocity vs Launch Angle of Shohei Ohtani, color coded by events.

higher than the peak launch angle. In addition, most hits occur when the launch angle is close to the peak launch angle.

3.2 Peak Launch Angle Trend Comparison between Good Hitters

To observe the trend of peak launch angle and batting stats, I selected top 10 players from baseball savant in following categories: most home runs, highest batting average, and highest slugging percentage. Then I obtained peak launch angles for the 10 players in each category and computed the average. The results are as follows:

Mean peak launch angle for top 10 hitters with:
- Most home runs ~ 13.0 $degrees$
- Highest batting average ~ 7.20 $degrees$
- Highest slugging percentage ~ 14.90 $degrees$

Although the peak launch angle varies a lot within each category, on average, hitters with top home runs and slugging percentage tend to have higher peak launch angle than hitters with top batting average. I also computed the peak exit velocity of the 10 players in each category, which is shown below:

Mean peak exit velocity for top 10 hitters with:
- Most home runs ~ 110.2 mph
- Highest batting average ~ 107.39 mph
- Highest slugging percentage ~ 110.2 mph

This shows that on average, hitters with top home runs and slugging percentage tend to have slightly higher peak exit velocity than hitters with top batting average. Although the data is not abundant, we could draw from this that hitters with high peak launch angle tends to hit home runs more frequently and hits the ball harder than hitters with low peak launch angle.

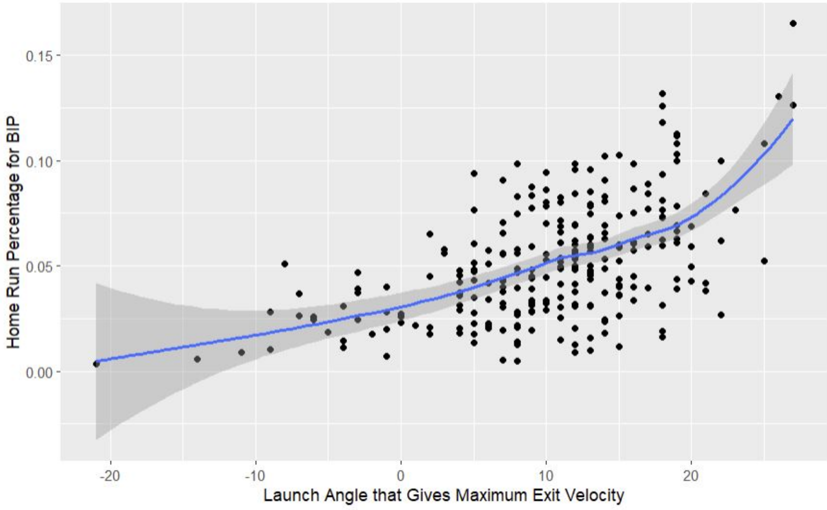

Figure 3: Scatter plot of home run percentage versus peak launch angle with smooth fitted line.

3.3 Correlation between Peak Launch Angle and Batting Statistics

To begin this section, I was interested in finding how batter's peak launch angle affects their performance. In order to observe the correlations, I plotted various batting statistics with respect to peak launch angle, and each point of the plots in this section represents a value for a single player.

3.3.1 Home Run Percentage for Balls in Play

First, I analyzed the correlation between peak launch angle and home run percentage for balls in play. To do this, I computed the home run percentage for balls in play of each batter by dividing their total home runs in a season by their total in play events per season. Then, I made a scatter plot of home run percentage for balls in play vs peak launch angle for each player, and fitted a smooth curve on it. The result displayed in Figure 3 shows that home run percentage for balls in play tends to increase as the peak launch angle increases, but with wide uncertainties. The points are scattered away from one another so having a high peak launch angle won't necessary result in a high home run percentage.

3.3.2 Slugging Percentage & Batting Average for Balls in Play

Similarly to what I did for Figure 3, I created correlation plots for slugging percentage for balls in play and batting average for balls in play, both with respect to peak launch angle. The slugging percentage shown in Figure 4 has similar relationship with home run percentage, and the value increases as the peak launch angle increases. In contrast, Figure 5 depicts batting average for balls in play, which has a flatter smooth fitted line in the range where most batter's peak launch angle is located. Therefore, batting average isn't much determined by the peak launch angle.

3.3.3 Strikeout Percentage & Whiff Rate

Then, I computed the correlation between peak launch angle and strikeout percentage. I did this by using the original 2021 Statcast data to calculate the total strike outs for each player and dividing that number by total at bats for each player to find the strike out percentage. After that, I graphed a scatter plot of strike out percentage vs peak launch angle and fitted a smooth line over it. The result depicted in Figure 6 shows that strikeout percentage increases gradually as the peak launch angle increases.

To explore deeper into this, I created a graph of whiff rate (swing and miss percentage) versus peak launch angle for all pitches that were swung at. The result shown in Figure 7 is similar to strikeout percentage, and whiff rate increases as the peak launch angle increases. Since the peak launch angle is directly related to attack angle of the bat, the above two graphs depicts that players with leveled swing tend to have lower swing and misses, and lower strikeout percentage than players with non-leveled

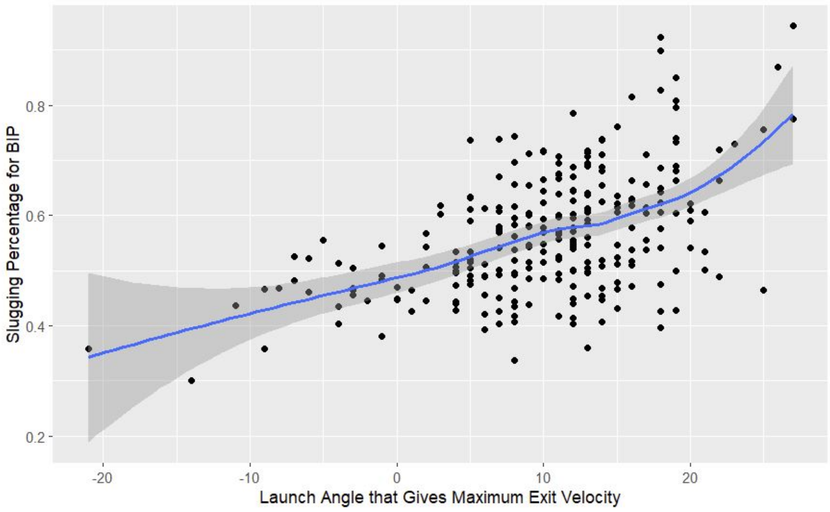

Figure 4: Scatter plot of slugging percentage for balls in play versus peak launch angle with smooth fitted line.

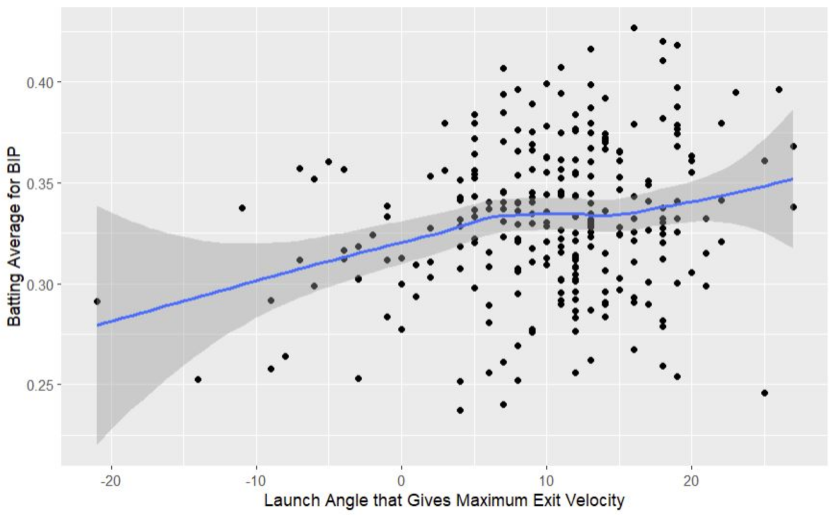

Figure 5: Scatter plot of batting average for balls in play versus peak launch angle with smooth fitted line.

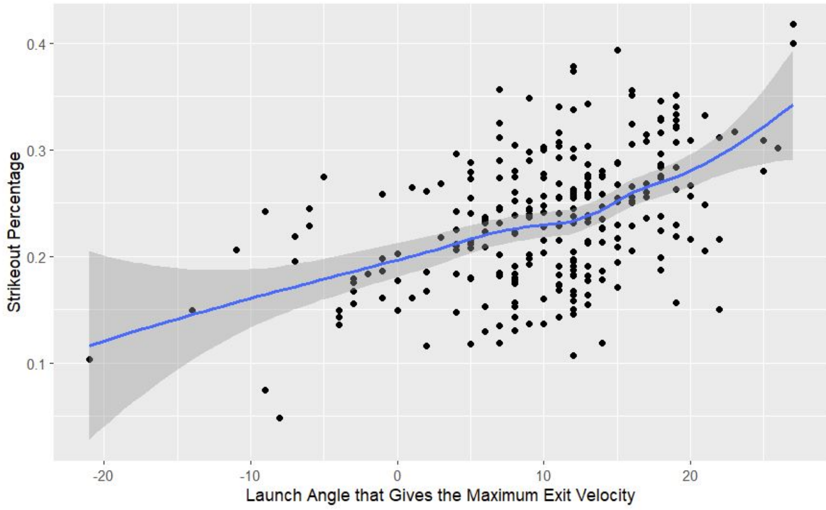

Figure 6: Scatter plot of strikeout percentage versus peak launch angle with smooth fitted line.

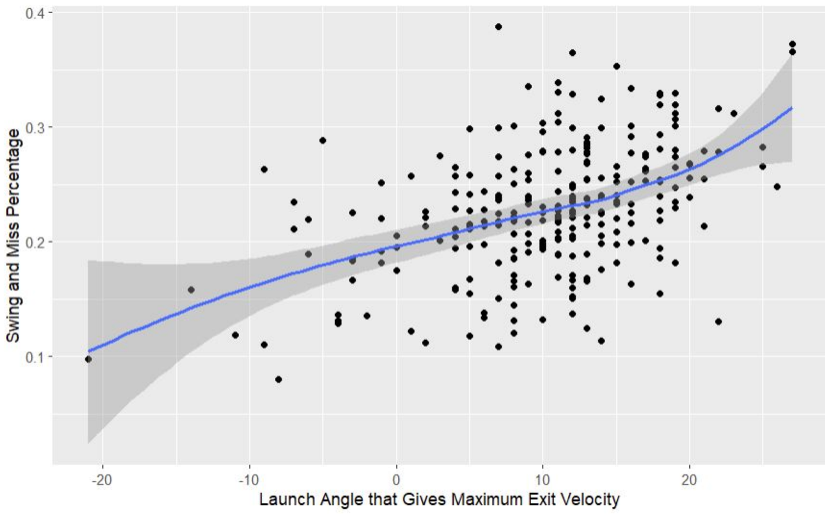

Figure 7: Scatter plot of swing and miss percentage versus peak launch angle with smooth fitted line.

swing. This result is reasonable since batters with leveled swing have a higher duration of time where they could contact the ball, where as batters with non-leveled swing can only contact the ball at the proper timing.

3.3.4 Foul Percentage

Furthermore, I explored how foul percentages relates to peak launch angle. The result shown in Figure 8 has a flat smooth fitted line over the range where the most players' peak launch angles are. This demonstrates that the foul percentage isn't much determined by player's peak launch angle.

3.3.5 wOBA

Finally, I computed the relationship between wOBA and peak launch angle, shown in Figure 9. wOBA measures overall hitter's performance, including all sorts of events, with home run being weighed the highest. So this technically represents the combination of all previous plots. From Figure 6 and 7, I concluded that hitters with high peak launch angle tends to strikeout more often than hitters with low peak launch angle. However, Figure 3 and 4 depicts that hitters with higher peak launch angle also has higher slugging and homerun percentage. From looking at Figure 9, the smooth fitted line indicates a slow increase in wOBA as peak launch angle increases, thus the effect of the later one seems to

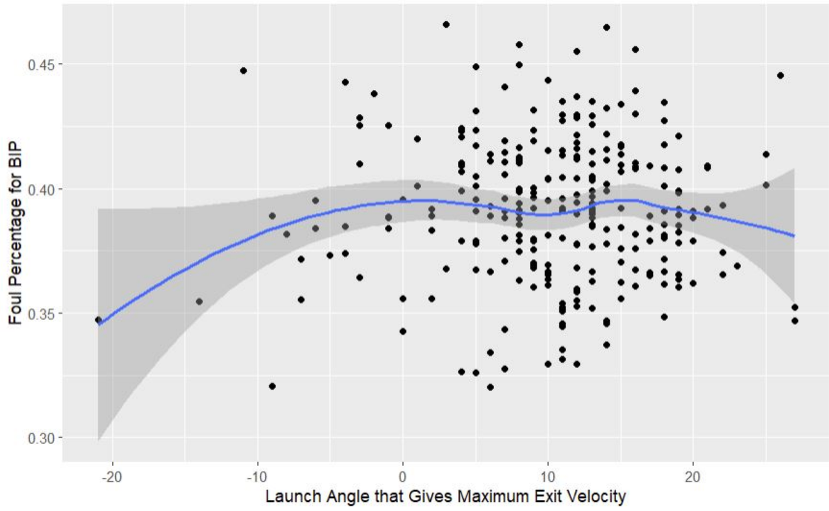

Figure 8: Scatter plot of foul percentage versus peak launch angle with smooth fitted line.

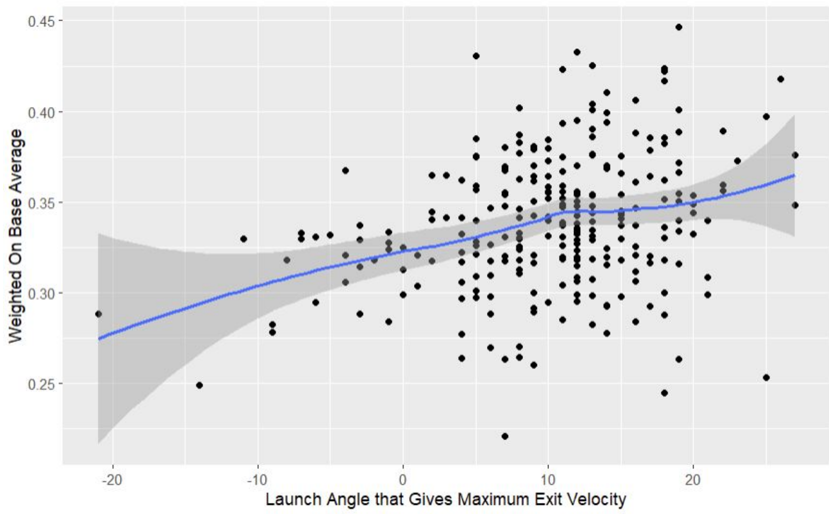

Figure 9: Scatter plot of weighted on base average versus peak launch angle with smooth fitted line.

overcome in this case.

4 Traverse Ball Bat Collision

In this section, I analyzed how attack angle and center line angle are related to launch angle and exit velocity. Figure 10 depicts what attack angle and center line angle means in ball-bat collision.

First, using Alan Nathan's calculations on Traverse-Ball-Bat-Collision, I obtained a function that returns a data frame of batted ball parameters from two inputs: attack angle and center line angle. Then I made a contour plot of scaled exit velocity from 0 (lowest) to 1 (highest) with attack angle in the y-axis and center line angle in the x-axis, and launch angle included as a dashed line. By tweaking the code above to obtain scaled peak exit velocity for each player, I plotted several players' peak exit velocity at their peak launch angle (shown in Figure 11), which all lined up at a line where attack angle is equal to the center line angle. This makes sense since peak exit velocity is achieved when the attack angle is parallel to the center line angle.

In addition, on a new contour plot, I plotted a scatter plot of Shohei Ohtani's launch angle and scaled exit velocity (Figure 12). As a result, when the launch angle is close to the peak launch angle, the scaled exit velocity is close to 1, and when it's far away, the scaled exit velocity gets closer to 0. This verifies our calculation that peak launch angle is the angle that gives the maximum exit velocity.

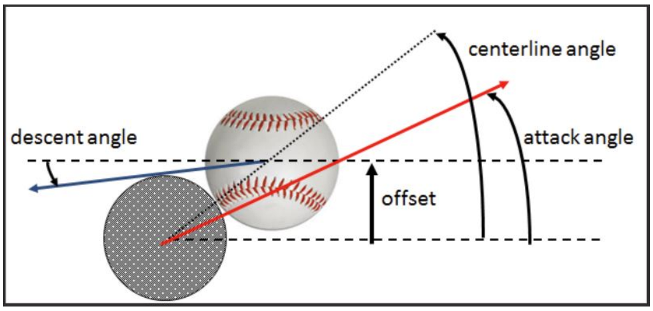

Figure 10: Terminology used in ball-bat collision

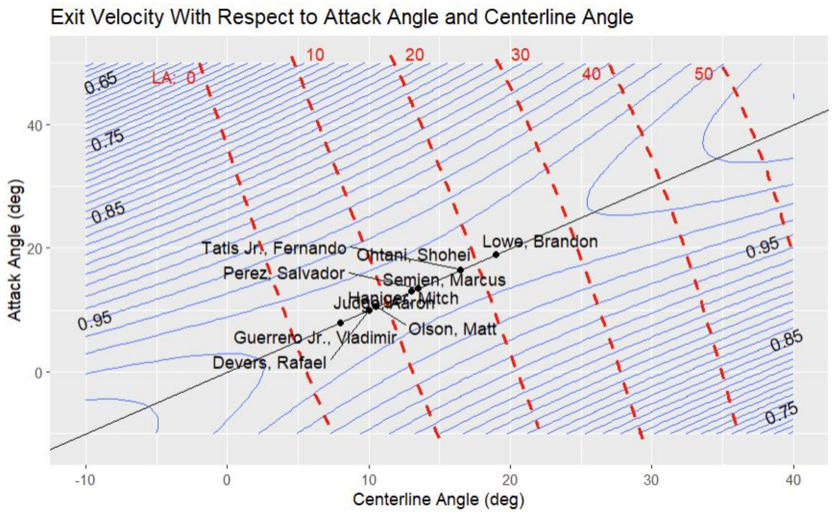

Figure 11: Exit Velocity with respect to attack angle and center line angle of several players at their peak launch angle.

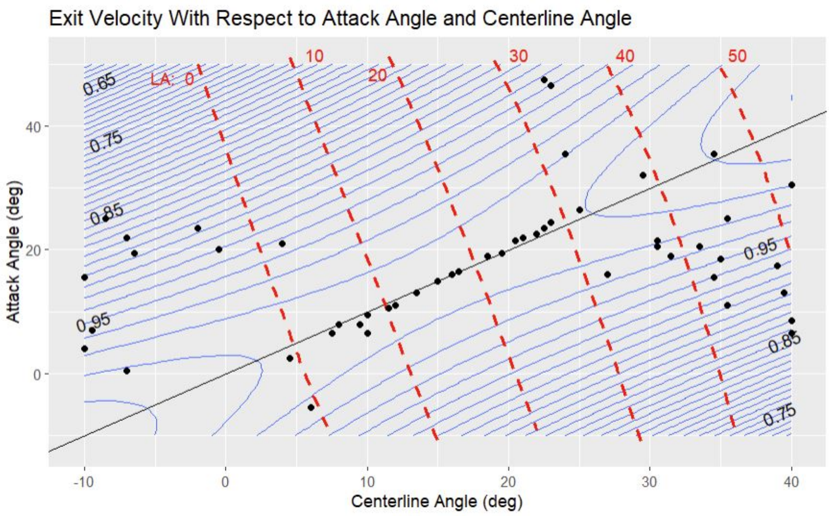

Figure 12: Exit Velocity with respect to attack angle and center line angle of Shohei Ohtani for multiple launch angles.

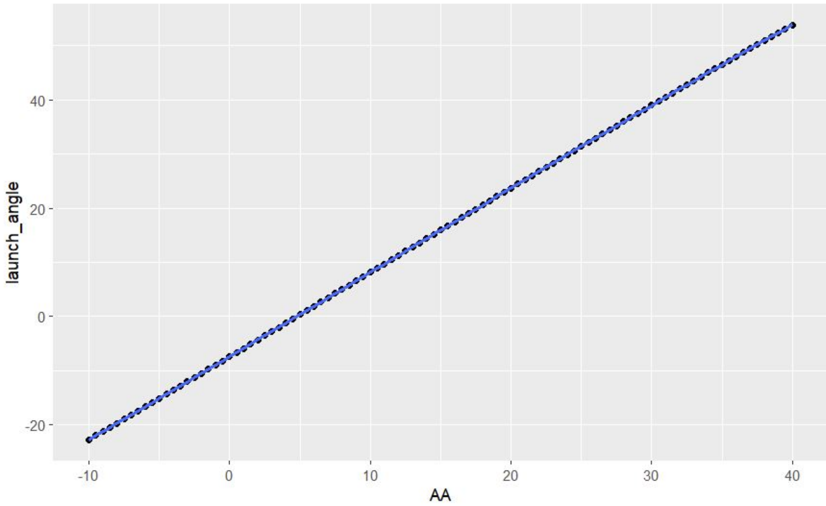

Figure 13: Scatter plot of attack angle versus launch angle with smooth fitted line.

Furthermore, I filtered data to where attack angle is equal to the center line angle, which is when the peak exit velocity occurs, and plotted launch angle verses attack angle. The resulting graph shown in Figure 13 is linear, which proves that launch angle is directly related to the attack angle. However, the attack angle is not equal to the launch angle for most of the time. This is because the momentum of the ball created by the pitcher and the descent angle also affects the launch angle of the batted ball.