Bryan Braun

Stat 332

Sect 9

Lab #8

Experiment Write-up

To Whom It May Concern:

Due to the company's interest in catapult performance we designed and performed an experiment to help us understand what factors influence the distance an object is thrown by a catapult. Using a model catapult, we identified the following three factors that we felt influenced the distance an object is thrown:

1. Release Angle
2. Stop Angle
3. Pivot Height

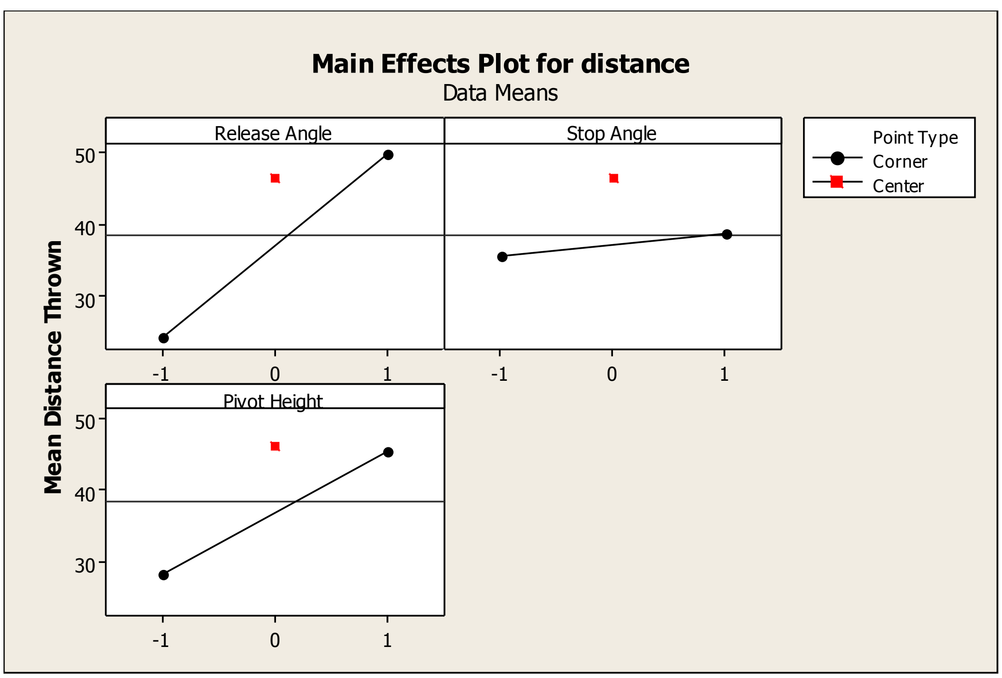
We needed to perform an experiment which allowed us to test each of these factors at different levels. For example, we wanted to test both low medium and high pivot heights to see how they influenced the resulting distance. Therefore, we selected a low, medium, and high level for each factor. In order to see how each factor influenced the result, we needed to test every combination of the levels of the factors.

Experiment

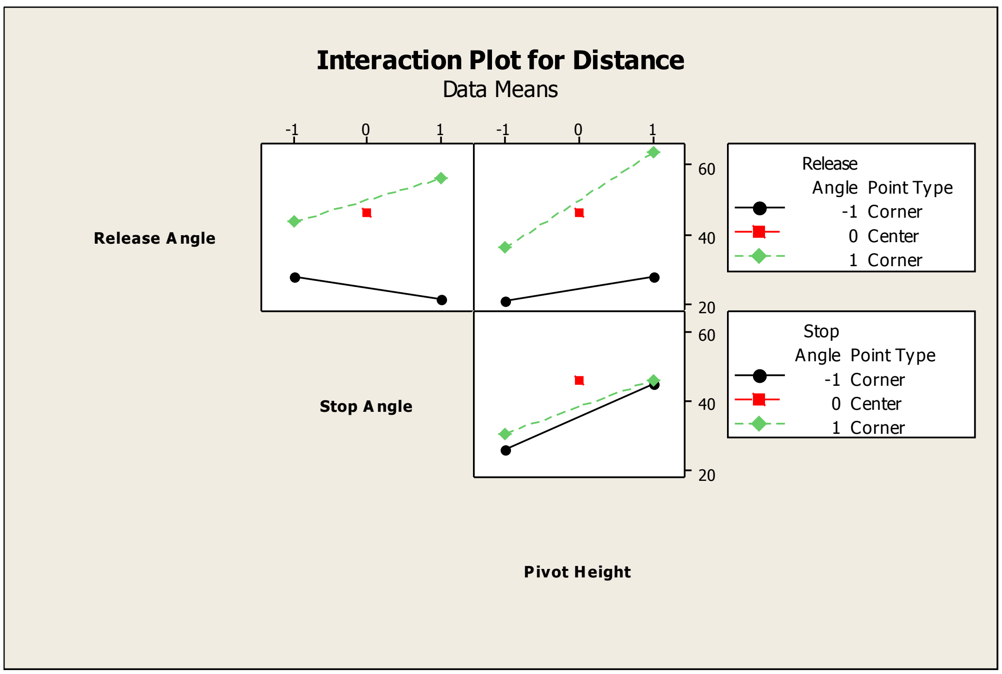
Each time the experiment was run a ball was launched and we measured the distance the ball traveled before hitting the ground using a tape measure. It must be understood that even if we launched an object under the same conditions twice in a row, the resulting distance would not be exactly the same. Because we want to make accurate predictions we cannot afford to let this variation influence our data. For this purpose we performed two replications for each combination. This means that we ran each setting twice so that we could understand how much variation is in the result and how much variation to account for in our statistical model. Another precaution we took to ensure the purity of our data was that we randomized our experiment. This means that we mixed up the combinations that we needed to test into a random testing order, so that the data wouldn't be tainted by things that could change over the process of our testing. For example, if our elastic band began to stretch more over the experimentation process, this could cause the final distances we recorded to be shorter than expected. Without randomizing, this could cause us to inaccurately assume that a factor is affecting the distance traveled in a way that it isn't. Finally, by recording our experiment all in one block or session, we prevented our data from being tainted from changes that could have occurred over the space between testing times.

Results

Upon running all possible combinations of our factors and recording the distances the ball was thrown, we were able to make a statistical model which would help us find out what relationships existed between the different factors and the distance thrown. The following "Main Effects Plot" helps us understand which factors had a big influence on the distance thrown.

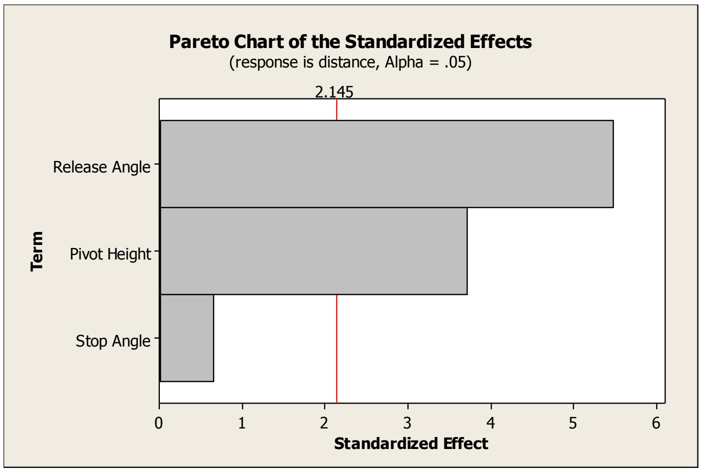


The three settings of each factor is represented by the values -1, 0, and 1, and we can see that the distance thrown increases significantly when both the release angle and pivot height is increased from the lowest setting to the highest setting. This is a hint that these factors are significant, or that they have a tangible influence on the resulting distance thrown. This is very important for us to know, so we can know how to predict the distance a ball will go when the factors are set at any given setting. Another important piece of knowledge is to understand how the factors interact. An "Interaction Plot" can help us understand how certain combinations of factors have an influence on the distance thrown.



This gives us information about how the distance is affect when one factor is held at a constant level but another factor changes from a low to a high level. When the two lines in a graph are not near parallel, it indicates that some interaction is having an effect. For example, from the upper left graph we see that when the release angle is low, the increase in stop angle tends to decrease the distance thrown, but when the release angle is high, the increase in stop angle tends to increase the distance thrown. Knowing this also helps us build a more accurate model to predict the behavior of the catapult.

To know for certain if a factor has a significant effect on the outcome, we performed statistical tests known as the T-test and P-value test. In short we compared the values in our data to a measurement in the variation of our data to see if the change in results could be attributed to more than just mere variation. If it was proven that it was attributed to more than variation, then it passed the test and was considered significant. The Pareto chart (left) shows us that both release angle and pivot height were considered significant. We also calculated a value known as the S-value to help us understand how much variation there was in our results. This can help us understand how accurate our tests are.



Conclusion

Through the mentioned statistical methods we were able to use the effects and interactions we found to create the following mathematical model for predicting the distance (in inches) an object will be thrown:

$$(\text{Distance}) = 37+12.75(\text{Release Angle}) + 8.625(\text{Pivot Height})$$

By converting the value we set the catapults factors at to the appropriate values (between -1 and 1) we can use this model in making predictions. In order to use this model use the below table in assigning values to the angles you wish to try, and interpolate for angles between the given ones.

	Low Level (-1)	Middle Level (0)	High Level (1)
Release Angle	140º	155º	170º
Stop Angle	95º	110º	125º
Pivot Height	Low Tension	Mid Tension	High Tension

In testing the model we created a combination never tested before, made a prediction using our formula, and then tested it physically, finding that the actual distance travelled was within 6 inches of our prediction. Although the accuracy is commendable a few adjustments could help us improve the experiment and model. First, a more accurate technique for measuring the distance the ball travelled can be used to ensure accuracy of the data we collected. Because the values were collected through only the visual observation of one individual the data was only accurate to the nearest inch or two and could not be confirmed. Also because the catapult was not secured to the floor it rested on, some energy from the launch could have been absorbed by movement of the catapult from time to time causing a greater variation in the resulting distances. By securing the catapult we could further reduce variation in our results. Finally, in making our statistical models we assumed linear relationships in the effects of the different factors. By using curvature we could add quadratic terms to our model and perhaps more accurately predict distances the ball will be thrown. These steps will be implemented on any further experimentation.

How will this experiment and future research benefit our company? Through this model we can optimize the settings of our catapults to see what settings will yield the longest throw. Also, when we desire to hit a specific target, we can use our model to know what levels to set our factors at in order to achieve a launch of a specific distance. Future research will allow us to include factors such as wind resistance into our model which will improve our accuracy over long distances. By hitting our target accurately on the first try, we will save time and resources which are wasted in using the trial-and-error method. Clearly, the benefits of future research will outweigh the possible costs.

We appreciate your review of our statistical analysis and await further instruction concerning the future testing of catapult performance.

Regards,

Bryan E. Braun