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Taguchi Exercise Report

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Abstract

An experiment was carried out to apply the Taguchi design of experiments model to the operation of a catapult and identify key control factors. This involved the selection of key control factors, the creation of an experimental matrix, mathematical analysis of results, and verification of the identified key control factors.

Keywords:

Taguchi method, catapult, matrix, control factors

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1 Introduction

The Taguchi design of experiments method is a method of producing a robust design by identifying parameter settings that deliver consistent performance [1]. This is achieved through following an eight-step method [2]:

Step	Action
1	Identify main functions, side effects and failure modes
2	Identify noise factors, testing conditions and quality characteristics
3	Identify the objective function to be optimised
4	Identify the control factors and their levels
5	Select the matrix experiment
6	Conduct the matrix experiment
7	Analyse the data, and predict the optimum levels for performance
8	Perform a verification experiment

Table 1 - Taguchi method

This report will follow the eight step method to establish the control factors of a catapult and determine the optimal settings for catapult performance.

2 Apparatus

The experiment required the following apparatus:

- One catapult, wooden, with rubber band.
- One ball, rubber, blue
- One clamp
- One tape measure
- One laptop for recording results

2.1 Control factors



Figure 1 - Catapult example

Figure 1 shows a catapult of similar design to the one used during the experiment; the design of the catapult allowed for multiple key variables to be easily adjusted during the course of the experiment. The control factors identified were:

- Band front position (Factor A): Position 1 or 3.
- Band anchor position (Factor B): Position 2 or 4.
- Stop position (Factor C): Position 1 or 3.
- Pull back distance (Factor D): 140 or 170 cm.
- Operator (Factor E): Operator A or B.

2.2 Catapult operation

Prior to firing, the catapult was clamped to a table in order to keep the firing position consistent, and tape measure was extended from the base of the catapult to its maximum extension, a distance of roughly 15 feet.

The catapult settings were then adjusted according to the experimental plan and a ball fired along the line of the tape measure by the designated operator. The landing point of the ball was marked, and the distance travelled by the ball recorded. The settings were then changed, and the process repeated.

3 Matrix experiment

3.1 Phase 1

3.1.1 Firing Plan

Due to time constraints, it was not practical to perform a firing with every possible combination of factors. However, in order to ensure a broad range of combinations of factors, a firing plan was drawn up. This is illustrated in Table 2 below. This firing plan allowed for eight unique combinations of factors.

Firing	Band front position (Factor A)	Band anchor position (Factor B)	Stop position (Factor C)	Pull back distance (Factor D)	Operator
1	1	2	1	140	A
2	1	2	3	170	B
3	1	4	1	140	B
4	1	4	3	170	A
5	3	2	1	170	B
6	3	2	3	140	A
7	3	4	1	170	A
8	3	4	3	140	B

Table 2 - Phase 1 firing plan

The distance travelled by the ball for each shot was recorded.

3.1.2 Results

The results of the phase 1 firings can be found in Table 3:

Firing	Band front position (Factor A)	Band anchor position (Factor B)	Stop position (Factor C)	Pull back distance (Factor D)	Operator	Distance travelled (cm)
1	1	2	1	140	A	84
2	1	2	3	170	B	261
3	1	4	1	140	B	72
4	1	4	3	170	A	179
5	3	2	1	170	B	90
6	3	2	3	140	A	35
7	3	4	1	170	A	70
8	3	4	3	140	B	46

Table 3 - Phase 1 results

The following calculations were then made:

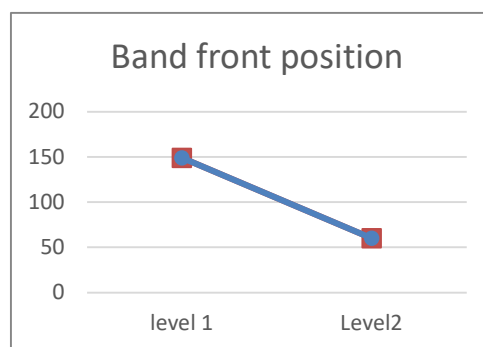
An average was taken of the results for each firing in which Factor A was in position 1 (firings 1, 2, 3 and 4):

$$\frac{84 + 261 + 72 + 179}{4} = 596$$

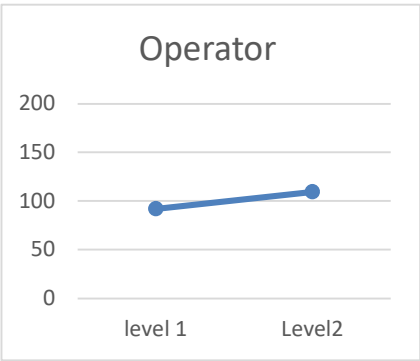
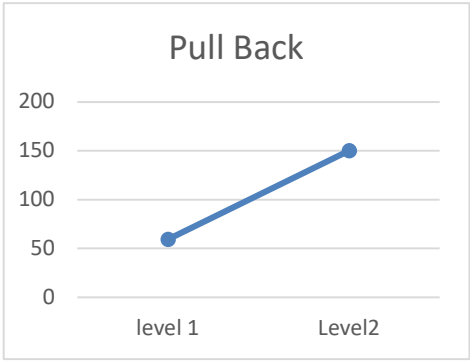
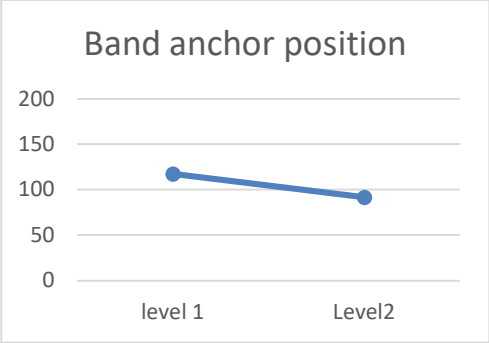
Another average was then taken of the results for each firing in which Factor A was in position 3 (firings 5, 6, 7 and 8):

$$\frac{90 + 35 + 70 + 46}{4} = 60.25$$

These averages were then graphed to illustrate the degree of difference:



The process was repeated for Factors B, C and D, giving the following results:



These graphs show that of the five variables, changes in stop position and pull back had the largest difference (51.25 and 90.75, respectively). This informed the firing plans for Phase 2.

3.2 Phase 2

3.2.1 Firing plan

The results of the first eight firings indicated two key control factors, these being the stop position (Factor C) and the pull back distance (Factor D). Phase 2 of the experiment focused upon these variables, changing them while keeping the other variables constant. The firing plans for this second phase is illustrated in Table 4:

Firing	Band front position (Factor A)	Band anchor position (Factor B)	Stop position (Factor C)	Pull back distance (Factor D)
1, 2, 3	2	2	1	140
4, 5, 6	2	2	3	140
7, 8, 9	2	2	1	170
10, 11, 12	2	2	3	170

Table 4 - Phase 2 firing plan

As the table shows, three firings were performed for each combination.

3.2.2 Results

The results of these firings are contained in Table 5:

Variable		Distance Travelled (cm)			Average distance (cm)
Stop Position (Factor C)	Pull back distance (Factor D)	Firing 1	Firing 2	Firing 3	
1	140	98	91	89	92.66
3	140	97	91	84	90.66
1	170	120	118	119	119
3	170	261	280	267	269.33

Table 5 - Phase 2 results

The average distance travelled by the ball was used to calculate the averages for each variable. For example:

The two averages for the firings where Factor A was in position 1 were averaged:

$$\frac{92.66 + 119}{2} = 105.83$$

And the same process repeated for the firings where Factor A was in position 2:

$$\frac{90.66 + 269.33}{2} = 180$$

An average was taken of these results to give the mean distance travelled:

$$\frac{105.83 + 180}{2} = 142.91$$

The same calculations were made for Factor D in both positions, and the average of these results used to give a final average distance of 142.91 cm.

3.3 Phase 3

In line with step 8 of the Taguchi methodology, a final confirmation shot was fired with the following settings:

Firing	Band front position (Factor A)	Band anchor position (Factor B)	Stop position (Factor C)	Pull back distance (Factor D)	Distance travelled (cm)
1	2	2	3	155	142.91

Table 6 - Phase three settings

The settings for Factors A and B were left unchanged. For factors C and D, which had been identified as key to the results, a position was chosen between those used for the firings in Phase 2.

This confirmation shot travelled a distance equal to the averages calculated using the results of the Phase 2 firings.

4 Conclusion

In line with the Taguchi method, the control factors for a catapult were identified and an experiment was conducted wherein a number of firings were performed with different combinations of these factors. This experiment correctly identified the key control factors, which were verified through a final confirmation shot.

The Taguchi process was therefore a practical and accurate method of control factor identification, enabling the team to produce a robust catapult setup which would perform consistently under varying conditions.

References

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- [2] S. K. Karna and D. R. Sahai, "An Overview on Taguchi Method," *International Journal of Engineering and Mathematical Sciences*, vol. 1, no. 1, pp. 11-18, 2012.