



Charles Hadley
DE&S OME Degree Student

+44 7919977349

Charles.Hadley104@mod.gov.uk

UWTSD IQ Campus,
Waterfront,
University of Wales Trinity,
Swansea
SA1 8EW

Charles Hadley

3-May-25

Our Reference: SECW_02

A TAGUCHI EXPERIMENT USING AN ELASTIC BAND CATRAPULT

References. See footnotes and references section

Abstract

The intent of this report is to explore Taguchi experiment based upon an elastic Band Catapult.

1. Table of Contents

Abstract	1
1. Table of Contents	1
2. Objective and Background	2
3. Method and Apparatus	2
4. Experimental Data and Interpretation of Results	4
5. Human Factors	6
6. Conclusion and reflections	7
7. References	7

2. Objective and Background

The experiment will consider 5 different variables and two sets of interactions between those variables these are listed below.

Variable	Variable Type	Options Range
Band Front Position (A)	Fixed Options	1-3
Band Anchor Position (B)	Fixed Options	1-4
Interaction AB	Fixed Options	1-2
Stop Position (C)	Fixed Options	1-3
Pull Back (D)	Operator Variable	110 - 180
Interaction BC	Fixed Options	1-2
Operator (E)	Fixed Options	Operator A / B

Table 1 - Variables

3. Method and Apparatus

Using the equipment detailed in Table 2 we set up the experiment as detail in Figure 1. Due to space constraints figure 1 depicts a short table but this was around 4m long with the tape measure starting from one end of the table where the catapult was secured.

Equipment	Purpose
Catapult	Project Ball
Elastic Band	Provide energy storage
Ball	Projectile
G Clamp	Secure Catapult to Table
Table	Provide
Tape Measure	Method to measure Range.

Table 2 - Equipment List

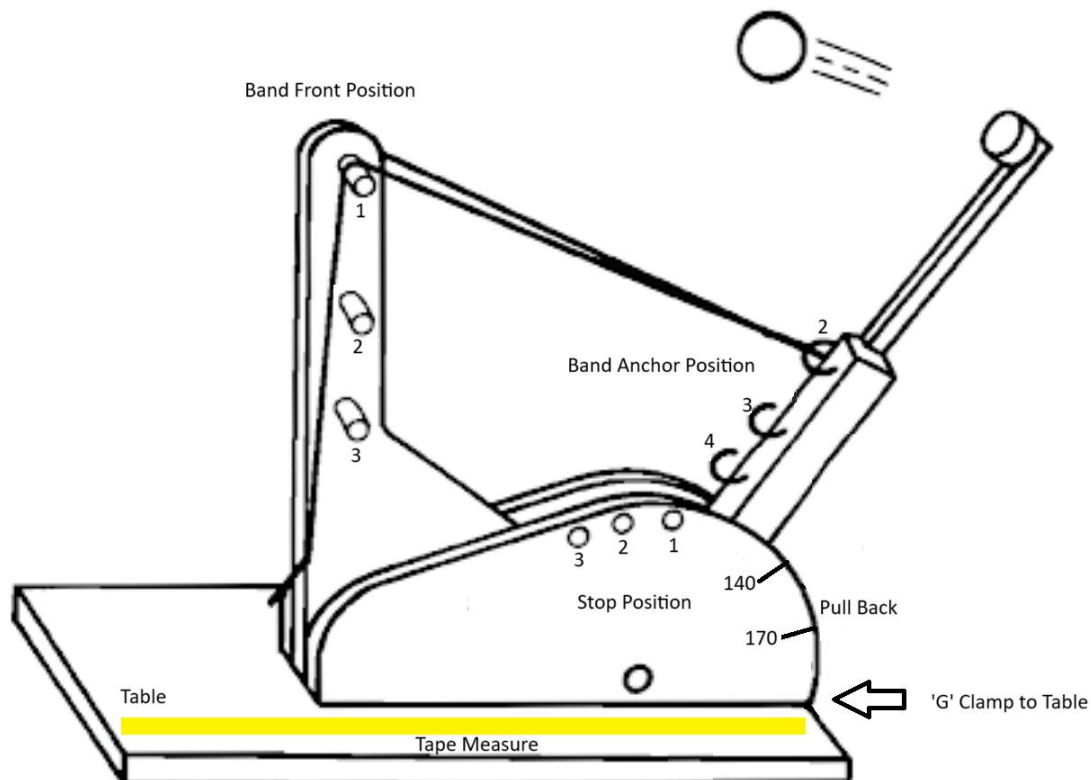


Figure 1 - Equipment Setup

To conduct the experiment a series of different trials will be conducted that change the variables in sequence to ensure consistency where possible in the results. The specific experiments run were determined by the lecturer and provided as below. This format is a standard L8 Orthogonal Array that is classic of the Taguchi method. [1]

Independent Variables							
	Band front position	Band Anchor position	A,B Interaction	Stop Position	Pull back	B,C Interaction	Operator
Independent Variables Sorted							
	Band front position	Band Anchor position	A,B Interaction	Stop Position	Pull back	B,C Interaction	Operator
Levels							
level 1	1	2	NA	1	140	NA	A
level 2	3	4	NA	3	170	NA	B
Dependent Variables							
	Range measurement from tape						
Array							
Factor	A	B	AB	C	D	BC	E
Expt 1	1	1	1	1	1	1	1
Expt 2	1	1	1	2	2	2	2
Expt 3	1	2	2	1	1	2	2
Expt 4	1	2	2	2	2	1	1
Expt 5	2	1	2	1	2	1	2
Expt 6	2	1	2	2	1	2	1
Expt 7	2	2	1	1	2	2	1
Expt 8	2	2	1	2	1	1	2
Array Populated							
Experiment	Band front position	Band Anchor position	AB Interaction	Stop Position	Pull back	BC Interaction	Operator
1	1	2	1	1	140	1	A
2	1	2	1	3	170	2	B
3	1	4	2	1	140	2	B
4	1	4	2	3	170	1	A
5	3	2	2	1	170	1	B
6	3	2	2	3	140	2	A
7	3	4	1	1	170	2	A
8	3	4	1	3	140	1	B

Table 3 - Variables and Experimental Array

After the equipment was setup, it was decided to conduct a set of 5 shots for each experiment set. This would then allow for an average to be calculated and then used in the results. Note that proper precautions for 'Range' Safety were taken. The range safety trace for this catapult is around 30cm horizontally from the line of fire with a rearward projection of 10cm and a forward projection of up to 4. Though the slight injury from projectile distance is around 10cm from the device. Anyone outside of this distance is unlikely to experience injury.

4. Experimental Data and Interpretation of Results

Table 4 below shows the table used and the results gained for each experiment. Then a mean average was calculated and used in the next stage of results processing.

Experiment Number	Shot Number					Average
	1	2	3	4	5	
1	122	106	106	118	116	113.6
2	305	295	290	298	294	296.4
3	115	109	110	109	109	110.4
4	189	154	146	179	172	168
5	148	139	137	133	130	137.4
6	78	30	30	76	30	48.8
7	92	91	102	110	92	97.4
8	88	89	89	89	87	88.4

Table 4 - Experimental Results Raw

It should be noted that at this stage where operators made significant errors or changes in style the shot was retaken as to best eliminate large operator variability.

Upon switching to operator B it was noted that operator A pressed the ball into the catapults cup instead of loosely placing it. This was noted and will be used in reflection on the results.

The averages were then used in below tables to create the final graphs.

Experiment	Band Front position	Band Anchor position	AB Interaction	Stop Position	Pull back	BC Interaction	Operator	Shot Average
1	1	2	1	1	140	1	A	113.6
2	1	2	1	3	170	2	B	296.4
3	1	4	2	1	140	2	B	110.4
4	1	4	2	3	170	1	A	168
5	3	2	2	1	170	1	B	137.4
6	3	2	2	3	140	2	A	48.8
7	3	4	1	1	170	2	A	97.4
8	3	4	1	3	140	1	B	88.4

Table 5 - Results Processed 1

Table 6 was created by averaging the experiments containing each respective level for a particular Independent Variable. These results allow the comparison of the different levels of each variable, this is a key benefit for the Taguchi approach.

Experiment Level	Band Front position	Band Anchor position	AB Interaction	Stop Position	Pull back	BC Interaction	Operator
1	172.1	149.05	148.95	114.7	90.3	126.85	106.95
2	93	116.05	116.15	150.4	174.8	138.25	158.15

Table 6 - Results Processed 2

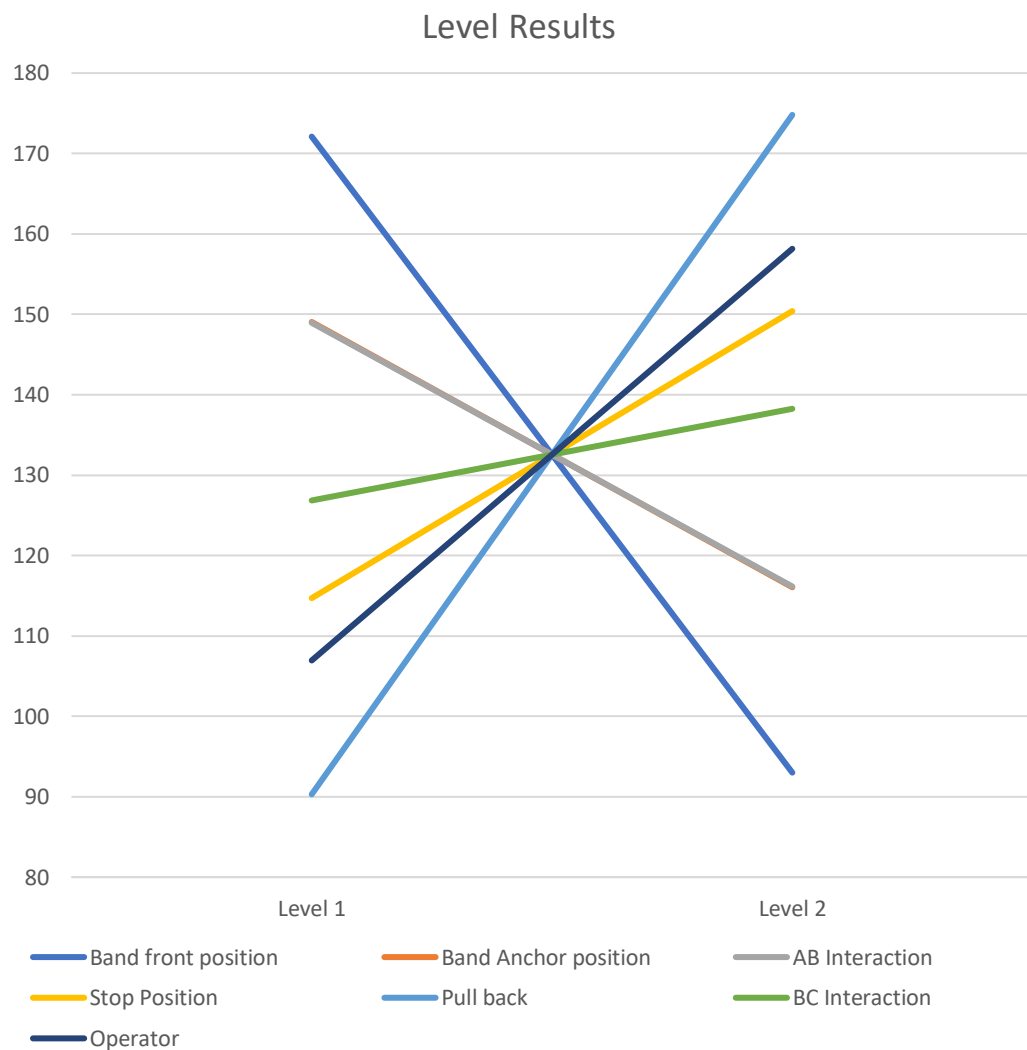


Figure 2 - Level Results

Note that in this chart AB interaction and Band Anchor Position are colinear.

From these results we can identify two key features for further testing, these features are the variables that have the greatest impact when changing the input. This is indicated on the graph by the steepest gradient. In the case of these results the steepest gradients are seen with the Band Front Position and Pull Back.

The results from the initial experiment show that for the variables not identified as key features below configuration is the optimum to allow for the longest achievable range.

Variable	Optimum Level	Experimental Position
Band Anchor Position	1	2
Stop Position	2	3
Operator	2	B

Table 7 - Optimum Positions

Using the optimum positions a second trial was conducted to evaluate the two key features identified in the previous round of testing and to validate the initial results.

Experiment	KF1	KF2	Shots					Ave
			1	2	3	4	5	
1	1	140	138	138	138	140	140	138.8
2	3	140	110	105	106	106	105	106.4
3	1	170	283	283	293	290	284	286.6
4	3	170	208	208	207	207	210	208

Table 8 - Experiment 2 Results

Key Factor Comparson	Results	Individual Average	Total Average
KF 1 : 1	212.7	184.95	184.95
KF 1 : 2	157.2		
KF2 : 1	122.6	184.95	
KF2 : 2	247.3		

Table 9 - Results Processing 2

The results achieved from the second experiment further validate the results from the first achieving results that are greatly similar between previous experiments run. In addition, the results demonstrate that when setting the catapult for optimum range in experiment 3 we were able to predict the location of the first shot landing without the need for a trial shot. This was the case for each of the experiments run in the second round.

5. Human Factors

The impact of human factors is largely reduced in this style of experiment due to the fixed locations of the variables and deliberate intention to minimise variability. Although this was the intention when executing the experiment it was noted that the way that the operator places the ball in the cup of the catapult significantly impacts the range.

Operator A noted that they were pressing the ball in to the cup of the catapult for security. This was causing there to be additional resistance to remove the ball from the cup before the ball would release from the arm and fly freely. This result was clearly demonstrated in the reduction in range results using operator A. As this process was identified during the experiment a conscious decision was made not to change the process for operator A but it was noted and operator B ensured that they did not press firmly and subsequently achieved greater range results. This kind of variation is

inevitable when adding a human operator in to the loop as humans are inherently variable.

6. Conclusion and reflections

In conclusion the experiment was a success. Stage 1 of the experiment allowed us to identify the key variables and then take those forwards to the second round. The first round also allowed us to predict the results and anticipate the range bracket that the shots would land in. The second round of testing also confirmed the first round, further providing validity to the initial results.

Although the experiment ran smoothly taking additional time to understand the experiment, variables and required outcomes would have supported understanding of the results. In this case a backwards approach was required to fully explore and detail the results that was not fully understood initially. Lastly despite effort being made to standardise inputs and measuring techniques the method for capturing the point that the ball landed was based upon human judgement on where the ball first bounced. This provided results that were within a few centimetres of the actual location but due to human error is largely variable. This could have been improved by using a different method such as filming the shot but given the scenario and time would have been excessive for the required investment. Overall the experiments were a success, demonstrating how a Taguchi trial is utilised to explore a range of variables.

7. References

- [1] University of York, "Orthogonal Arrays (Taguchi Designs)," 05 2004. [Online]. Available: <https://www.york.ac.uk/depts/maths/tables/orthogonal.htm>. [Accessed 04 22 2025].
- [2] UWTSD, "L5 - Systems Engineering & Work-Based Group Project (ACDA5021&ACDA5022)," [Online]. Available: <https://moodle.uwtsd.ac.uk/course/view.php?id=12137>. [Accessed 04 04 2025].