International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Available at http://inpressco.com/category/ijcet

Research Article

Design & Manufacturing of a Simple Catapult

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Accepted 31 Oct 2014, Available online 05 Nov 2014, **Vol.4, No.6 (Dec 2014)**

Abstract

A catapult is a device used to launch a projectile to a great distance without using explosive devices. Catapult has been used since ancient times and has been proven the most effective mechanism during warfare. This weapon is used to hurl projectiles to a distance. This is a simple device that can store energy to release a projectile when required. Catapult can be classified as tension catapult, torsion catapult or gravity type catapult. Through the process of sketching, constructing and testing, a simple catapult was constructed. The catapult was modeled on design software and proper testing for distance and average velocity was done.

Keywords: *Catapult, tension type catapult, torsion type catapult & gravity type catapult.*

1. Introduction

A military machine worked by a lever and ropes for hurling large stones or other missiles. Or we can say that a forked stick with an elastic band fastened to the two ends of prongs which are used by children for shooting small objects like stones. Catapults are an ancient device created to throw objects over walls, towers or at a distance. Using simple mechanisms, catapults can projectile objects at a very fast pace for long distances. The catapult was a new weapon for attackers, which made the advantage uneven for defenders during enemy siege. While the defenders still had the capability to prepare for attack by building great walls, attackers, using catapults, could physically defeat these obstacles. Even during the thirteenth century, after the invention of cannons and mortars, catapults were still utilized on battlefields because they were easy to build on the site and were still capable of doing damage**.** Catapult can be classified as tension catapult, torsion catapult or gravity type catapult.

Tension type catapult: A catapult works by storing tension either in twisted ropes or in a flexed piece of wood. The frame is built of wood, with iron bracings. (Robert C. Mott, 2003)

Assuming the catapult is built using some kind of lever and elastic band i.e. bungee cord. When the lever is pulled back by some external force, it is transformed into kinetic energy. As the elastic band is stretched most of the energy is transformed into elastic energy and this energy is in the form of potential energy.

Some of this energy is also transformed into heat energy as well as in sound energy if the catapult creaks. Both the energies i.e. heat energy and sound energies are lost from the system.

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By releasing the arm of catapult, potential energy is converted into kinetic energy that makes the lever to move. The lever in turn transforms this kinetic energy to the projectile that gains momentum.

There will be loss of some additional energy to heat and sound.

There is also a conversion of kinetic energy into gravitational potential energy during its projectile as it flies-up.

As the projectile flies through the air, some of its kinetic energy is transferred to the atmosphere as it pushes it out of the way. When it lands on the ground, that kinetic energy is transferred into the ground that will transform the kinetic energy for itself, or transfer it into sound and heat. (V.B. Bhandari, 2010)

2. Literature View

Catapults have been integral to hurl objects in warfare since antiquity. Various types of Catapults have been used by the Romans, Chinese and Greeks. The first catapults were early attempts to increase the range and power of a crossbow. Europe introduced catapult during middle ages. Catapults were used to launch missiles and to hurl stones (many different objects were utilized). These missiles or projectiles were either launched directly at the wall to cause maximum damage or were launched over the wall to lay siege on the population within the protective walls. Catapults were often used to hurl objects or to throw missiles at soldiers. Catapults were used extensively throughout Europe (predominantly by the French) until 885-886 AD when new defense systems rendered catapults ineffective. (Alexis Cooley *et al*, 2002). There were 3 main types of Catapults:

1. Ballista
2. Mangonel

3. Trebuchet

1. Ballista

The Ballista was similar to a giant crossbow. The Ballista catapult was basically designed to work through torsion. The word "Ballistes" means to throw. It is believed that it has been invented by the Greeks and then later it was modified by the Romans. The Ballista was the earliest catapult which was created to amply range and power of the crossbow. Two wood arms (looks similar to a bow laid on each side but with a middle section cut out and were attached to a piece of rope. The rope used in a ballista catapult was made of human hair or animal sinew. The rope was attached to a winch and was pulled back, bending the arm back. As the arm of the Ballista catapult would released, it might shoot large arrow, towards the enemy with deadly accuracy. Ballistas type catapult are basically known for their high degree of accuracy. (Mark Denny, 2003)

2. Mangonel

The word mangonel was derived from the Latin word "manganon" which means engine of war. It was invented by the Romans in 400 BC. The Mangonel type catapult consists of a long wood arm with a bucket with which a rope was attached to the end. The arm is then pulled back (from natural 90^{o} angle) and then energy was stored in the tension of the rope and the arm. Then the bucket would be loaded with projectiles. the equilibrium condition was achieved when the mangonel arm was released and when there is a contact of arm with the beam or block, the mangonel arm would stop but the missiles would continue to launch toward the enemy. The maximum distance of firing Mangonel catapult is about 1,300 ft. The Mangonel was easy to construct and further wheels were added to the design to increase mobility. These type of machines were designed to throw heavy projectiles from a "bowl-shaped bucket at the end of its arm". (Alexis Cooley *et al*, 2002)

3. Trebuchet

The Trebuchet was designed to transfer maximum force. It hurled the stones which were projected to demolish city/castle walls. It is believed that it has been created by the Chinese in 300 BC. It was most powerful type of the catapults. The Trebuchet came into existence in Europe around 500 AD. The Trebuchet consisted of a long arm (which could be up to 60 ft long) balanced on a fulcrum that was far from center. . A sling was attached to the end of the long arm. The short arm was attached to a counterbalance. A counterbalance is a heavy lead weight or a pivoting ballist box filled with earth, sand, or stones. A rope was attached to the long arm and was pulled down until the counterbalance was high in the air. The energy of the counterbalance was stored in the form of potential energy. The sling was then loaded with projectiles or with missiles. The rope was released and the counterbalance plummets down. There is a conversion of potential energy into kinetic energy. Trebuchets were of two different designs: Traction and counterpoise.(Mark Denny, 2003)

1. Traction: which were powered by people?
2. Counterpoise: where the people were replaced with "a weight on the short end".

3. Problem statement

The problem is in accuracy of delivery of object. Secondly there is problem in conversion of it from potential energy to kinetic energy.

4. Procedure

a) Design process

Catapult was modeled on design software taking following dimensions in mm.

Table1: Dimensions of Catapult

Dimensions	In mm
Length	200
Breadth	100
Height	25
Arm Length	550
Wheels Diameter	30
Rod Length	100
Head Rest Length	85

Designed Model

The figure below shows a 3-D model made on software Uni-graphics. The design is as per the dimensions shown in table-1.

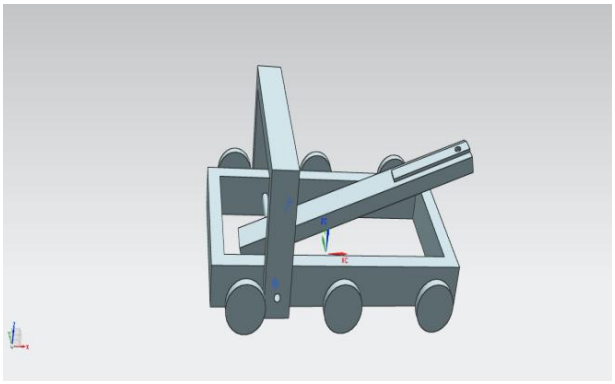

Fig 1: Catapult design

Material used

- Raw wood
- Elastic material – bungee cord
- Nails
- Metal
- Rope
- Screws
- Eye-bolts

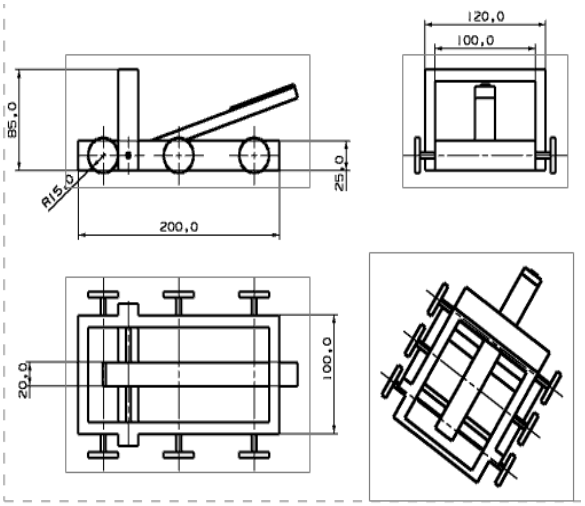

Fig 2: Cross-sectional Views of the model

Manufacturing process

1. As per the dimensions calculated from the design, a basic frame of the catapult was constructed using raw wood. The size of the frame was 200mm x 100mm.
2. After the frame was constructed a piece of wood of 85mm length and width 25mm was attached up straight at a distance of 50mm from one end of the catapult frame on both sides parallel to each other.
3. A piece of wood of length 200mm and width 25mm was placed horizontal of the up straight wood.
4. The arm was constructed of length 550mm and a hole of 5mm which was 25mm apart from one end was drilled through which a rod of 200mm was passed.
5. An elastic material known as bungee cord was used to move the arm when an external force is applied on it.
6. Bungee cord was used because it is an elastic material composed of one or more elastic strands forming a core. It is basically covered in a woven cloth or polypropylene sheath. Bungee cord is used to absorb shocks and to secure objects without tying knots.

Final Manufactured Catapult

Fig 3: Final manufactured catapult

5. Observation

Different set of experiments were conducted on the finally made projectile & the back angle of the arm & the average distance was observed.

Table 2: Calculations of distance and angles

Angle(θ)	Distance (m) Trials				Arm lengt	Average distance
	D1	D2	D3	D4		
63	9.8	10	10.2	9.8	550	10
53	6.8	7.0	7.2	7.0	550	7
43	3.3	3.2	3.7	3.6	550	3.5
33	2.2	2.0	1.8	2.0	550	2
23	1.5	1	0.8	0.7	550	1
13	0.4	0.6	0.3	0.3	550	0.4

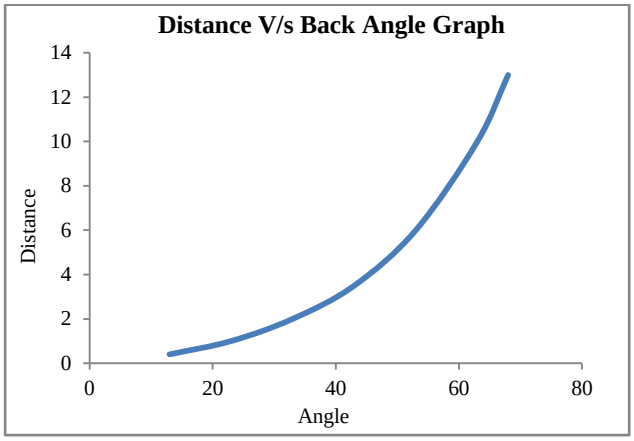

Fig 4: Graphical representation of Distance v/s back angle

The following are the observations taken during the experimentation.

Table 3: Observations of average time (in seconds) during experimentations

Angle (θ)	Average distance (in m)	Average time (in sec)
63	10	2.5
53	7	1.8
43	3.5	1.5
33	2	1.2
23	1	1
13	0.4	0.7

6. Results and discussion

On finding the average distance that a projectile covers, The average velocity of the projectile can be calculated. This can be calculated by using simple relationships of time, distance and speed.

From this data it can be analyzed that the average velocity of the projectile increases with the increase in back angle keeping the constant arm length.

Table 4: Calculations of average velocity (in m/s)

Angle (θ)	Average distance (in m)	Average time(in sec)	Average velocity (in m/s)
63	10	2.5	4.00
53	7	1.8	3.88
43	3.5	1.5	2.33
33	2	1.2	1.66
23	1	1.0	1.00
13	0.4	0.7	0.57

Conclusion

A catapult is a device used to launch a projectile to a great distance without using explosive devices. The catapult model was made on the design software and it was successfully manufactured. Analysis was done for velocity and back angle.

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