How Can You Make A Trebuchet More Efficient?

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Hypothesis:

The efficiency of a trebuchet can be increased by various design enhancements, including:

- the addition of wheels
- the addition of a sling
- hinging the counterweights
- lengthening the sling
- making the arm lighter.

Methods

1. design trebuchet
2. build trebuchet
3. fire trebuchet
4. think of ways to make it shoot further
5. more designing
6. build changes
7. more firing
8. prepare report

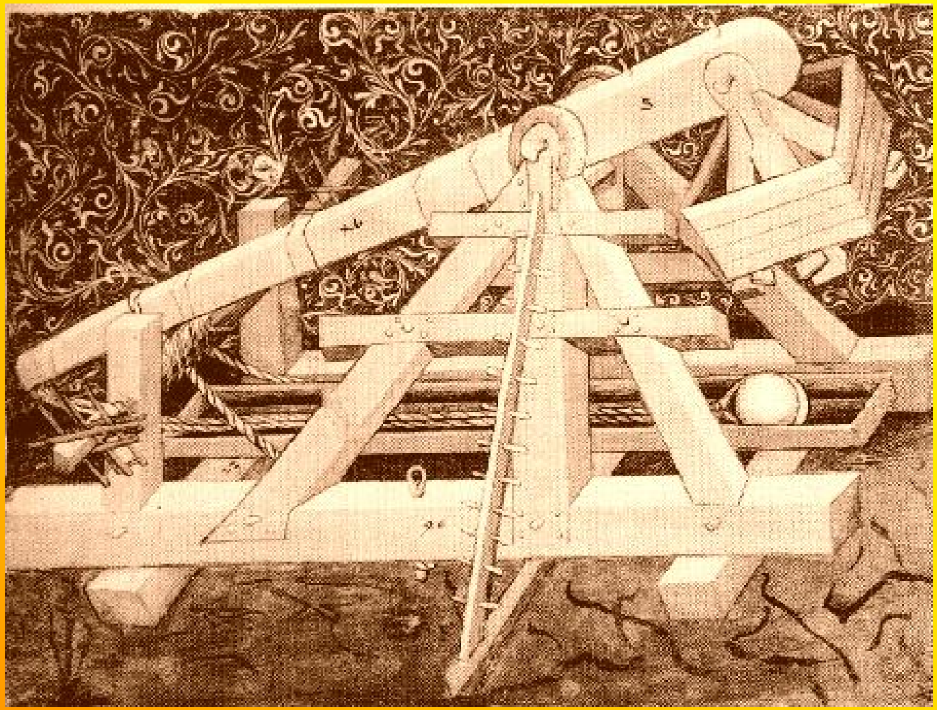
Materials

- Frame – wooden 1x4 and 2x4
- Arm - wooden 1x4
- Pivot – steel 1 Inch schedule 40 pipe
- Wheels – steel core polyurethane
- Sling line – aramid yarn
- Sling pouch – nylon onion bag
- Counterweights – cinderblocks (50 Ib_m)

Trebuchet

A trebuchet is a catapult based on counterweights. It was used in the middle ages as a siege weapon to break down castle walls. They seemed to be well developed by the 14th century.

Basic trebuchet design includes a frame supporting a pivot bar. A lever arm swings about the pivot bar. Counterweights are attached to one end of the lever arm. A projectile is placed at the opposite end of the lever arm.



Bellfortis II, ca. 1405

Operation

The trebuchet works by putting energy from the counterweights into the projectile. Newton's three laws of motion help explain how the trebuchet works. As the weights start to drop they cause the lever arm to rotate. This is resisted by the sling and projectile. The third law is in effect, for every action there is an equal and opposite reaction. This reaction force causes the projectile to accelerate. The second law is in effect , force is the product of mass and acceleration. When we release the projectile it flies in a trajectory with a horizontal and vertical component. The vertical component determines the duration of flight. The horizontal component is constant and determines the distance. The fist law is in effect, a body at motion stays at motion a body at rest stays at rest.

Analysis

Efficiency is the ratio of energy output to input.

Input energy is calculated by the work done on the counterweights. It is stored as potential energy until fired.

$$W=Fd$$

Where:

- W = work, input energy
- F = Force, weight of counterweights
- d = Distance, height counterweights are raised

Output energy is calculated based on the velocity of the projectile. This is kinetic energy.

$$E = (mv^2)/2$$

Where:

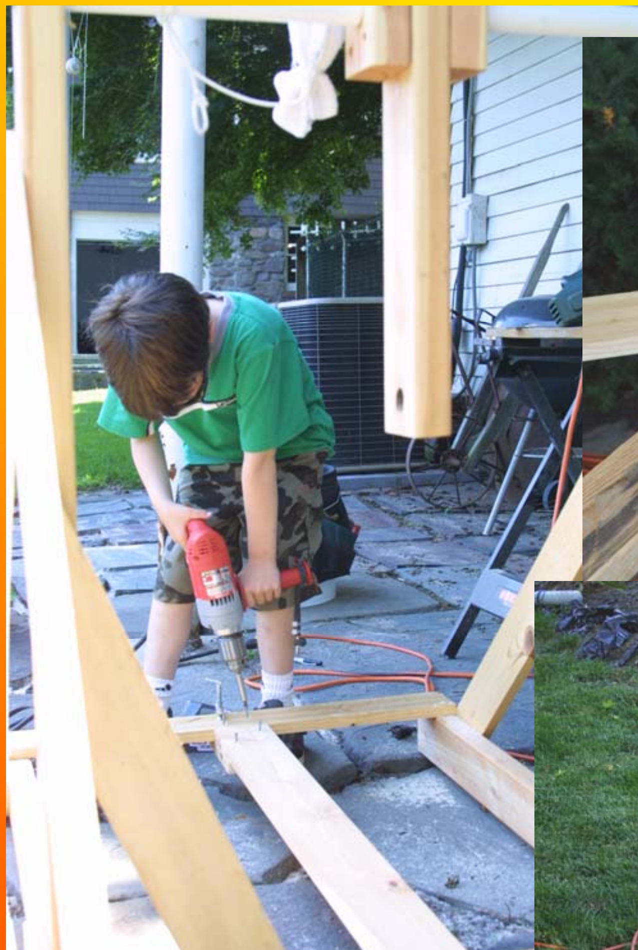
- E = Output energy
- m = mass of projectile
- v = velocity of projectile

We can calculate the velocity from the distance traveled. During the experiments we change the release angle to get the longest distance. this occurs at a release angle of 45°, or when the vertical and horizontal velocity components are the same. For this special case the output energy simplifies to:

$$E=px/2$$

Where:

- p = weight of projectile
- x = distance traveled by projectile



Results

pin angle	ft	in	corrected distance, ft	mass, lbm	Drop height, ft	Counter weight, lbf	Energy in, ft-lbf	Energy out, ft-lbf	Efficiency	Maximum
Baseline										
6	37		37	1.1875	3.7	50	185.0	21.96875	12%	
13	61		61	1.1875	3.7	50	185.0	36.21875	20%	
17	52		52	1.1875	3.7	50	185.0	30.875	17%	
14	56		56	1.1875	3.7	50	185.0	33.25	18%	
14	59		59	1.1875	3.7	50	185.0	35.03125	19%	
14	68		68	1.1875	3.7	50	185.0	40.375	22%	**22%**
No wheels										
14	87		87	1.1875	3.7	50	185.0	51.65625	28%	
14	74		74	1.1875	3.7	50	185.0	43.9375	24%	
14	69		69	1.1875	3.7	50	185.0	40.96875	22%	**28%**
No hinge										
14	58		58	1.1875	2.7	50	137.1	34.4375	25%	
14	75		75	1.1875	2.7	50	137.1	44.53125	32%	**32%**
Short sling										
14	-3		-3	1.1875	3.7	50	185.0	-1.78125	-1%	
32	7		7	1.1875	3.7	50	185.0	4.15625	2%	
41	9	9	9.75	1.1875	3.7	50	185.0	5.789063	3%	
51	42		42	1.1875	3.7	50	185.0	24.9375	13%	
48	26		26	1.1875	3.7	50	185.0	15.4375	8%	
51	33		33	1.1875	3.7	50	185.0	19.59375	11%	**13%**

Conclusions

- The addition of wheels and hinges had an adverse effect on trebuchet efficiency
- Both the lengthening of the sling and lightening the lever arm had a positive effect on efficiency
- The data may be inconclusive as it was difficult to isolate variables