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TOPIC: Making and operating a model onager

INTRODUCTION

This guide will walk you through the construction and operation of a hand held scale Roman Onager, a type of medieval siege weapon. This model is fully functional, powerful enough to impress, and is small enough and can have its power adjusted down enough to be safely demoed indoors in crowded areas. It is an excellent example of physics, and some mechanical engineering, as well as a conceptually accurate (but design and materially wise inaccurate) historical model. Most importantly, it's a fun project, as well as a fun toy.

BACKGROUND

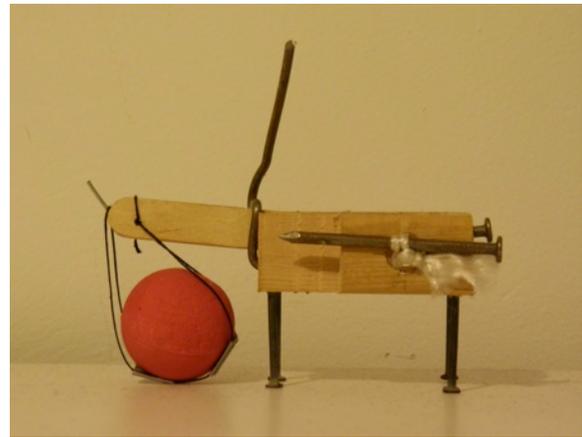
The following skills are assumed. Before continuing be sure you know:

1. How to safely and effectively operate all tools listed in the tools section.
2. How to tie an overhand loop.
3. How to locate and accurately drill holes.

TOOLS

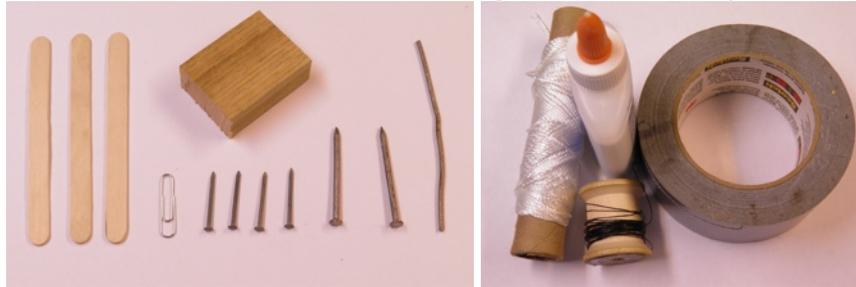
The following tools are required, unless marked optional:

1. Drill press (A hand drill can work if drill press is not available).
2. Measuring equipment for inches, accurate to 1/16", and up to 2" measurements.
3. 2 Clamps, appropriate scale for working with popsicle sticks.
4. 2 sets of pliers, appropriate scale for bending coat hanger and paperclip wire.
5. Coping Saw
6. Drills of the following sizes:
 - a. 1/16"
 - b. 9/64" (Roughly, this size is not critical)
 - c. 3/8"
7. Files and sandpaper (optional, for removing rough edges between each step)
8. Vice
9. Miter-box and matching saw (must be large enough for making cuts in wood up to 2 inches thick)
10. Wire cutters



MATERIALS

1. 3 Popsicle sticks
2. Small paperclip
3. 4 roughly 1" long 1/16" diameter nails
4. 2 roughly 2" long 1/8" diameter nails
5. 4" of coat-hanger wire (any roughly 3/32" steel wire will work)
6. 2" x 0.75" x 1.5" block of wood (hardwood recommended) with grain running the long way
7. Wood glue
8. Thick (strong) thread
9. 1/16" nylon string
10. Duct-tape
11. Projectiles/Ammo: 1" to 1/2" diameter roughly spherical objects



WARNINGS

Construction of this onager involves use of power tools, and other potentially dangerous tools. Knowledge of safe operating procedures is assumed and will not be provided. The produced onager is dangerous. It functions similar to a rat trap and can cause injury if used improperly. The onager can also be wound up to add more power until some part of it fails, possibly catastrophically, which can in-danger the operator. The onager may also throw the projectile, and or parts of itself larger than expected distances in any direction in the arm's plane of rotation. Keep all body parts, spectators and valuable property out of the arm's plane of rotation or at distances in excess of 20 feet at all times during operation. Projectiles can be thrown in excess of 20 feet, however most broken parts wont be going very fast after such distances. Use of soft projectiles is recommended, especially for indoor use.

INSTRUCTIONS

Part One: Build the arm

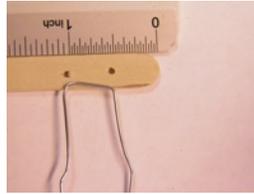
1. Cut one of the popsicle sticks in half



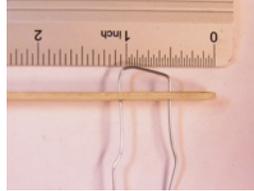
2. Straighten paperclip



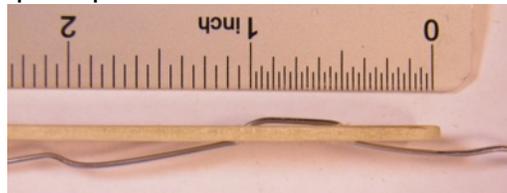
3. Fit the paperclip into one of the whole popsicle sticks
 - a. Drill $1/16$ " diameter hole $1/2$ " and 1 " from one end of popsicle stick
 - b. Bend paperclip into square cornered "U" shape $1/2$ " across



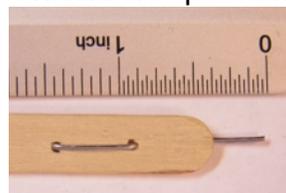
- c. Slide paperclip "U" through holes in popsicle stick



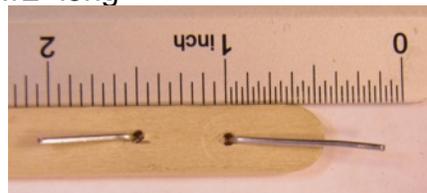
- d. Bend ends of paperclip outward



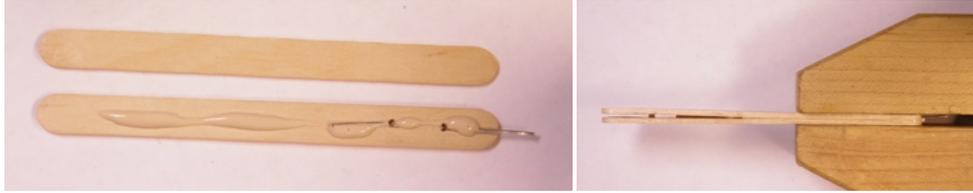
- e. Trim end of paperclip to extend $3/8$ " past end of popsicle stick



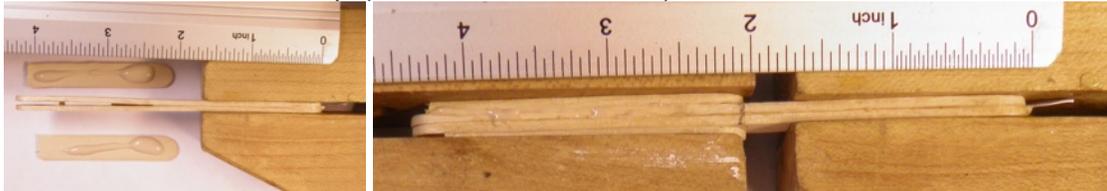
- f. Trim other end to $1/2$ " long



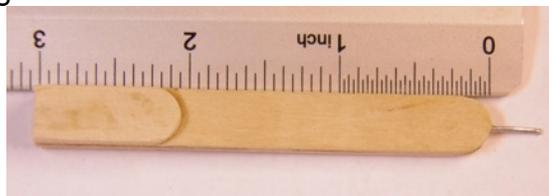
4. Glue together the arm
 - a. Glue 2 whole popsicle sticks together with paperclip ends sandwiched between
 - b. Clamp together end of popsicle stick sandwich containing paperclip wire (Note: this must crush the wire into the popsicle sticks so that the 2 flat sides can be flush and glued together. Clamps with large surface areas or some blocks to spread the load should be used to avoid splitting the sticks. Clamps must not extend past 2 " down the stick to stay out of the way of the next steps)



- c. Glue half popsicle sticks onto the side of the sandwich with the round ends towards the arm tip (the end with the wire), and half an inch from the arm tip



- d. Clamp half popsicle sticks in place
 e. Leave clamped until glue is fully set (see glue's instructions for timing details)
 (Note: you can continue with part 2, and return to here to finish the arm when it is needed)
 f. Remove clamps
 5. Cut arm to 3" long



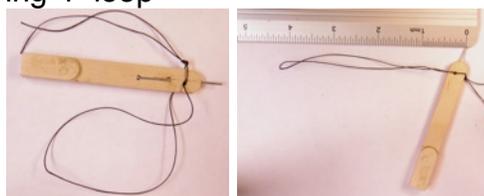
6. Drill 1/16" hole 1/2" from end right beside wire inside



7. Make the sling
 a. Cut 16" length of thread
 b. Thread both ends thread through hole in arm from opposite directions



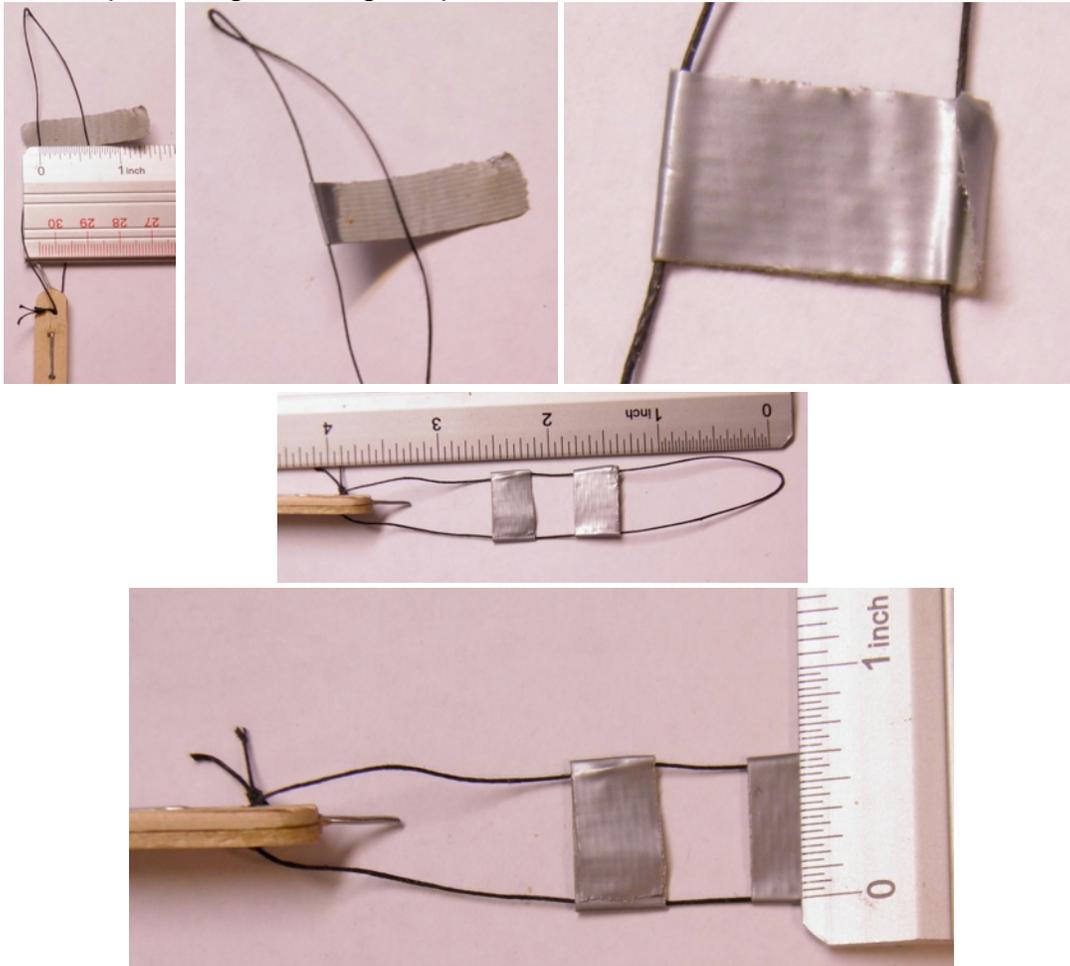
- c. Tie off ends leaving 4" loop



- d. Tear 2 3/8" by 1.5" pieces of duct tape

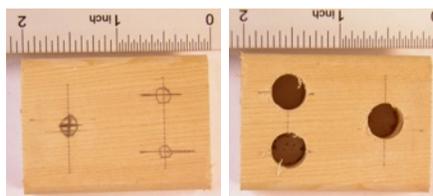


- e. Wrap tape strips around thread loop 3/8" apart on opposite sides of center of loop, making 5/8" long straps

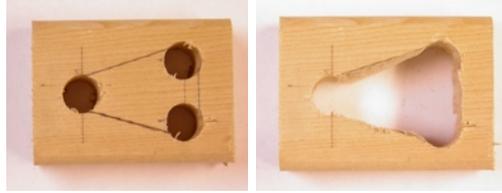


Part Two: Build the frame

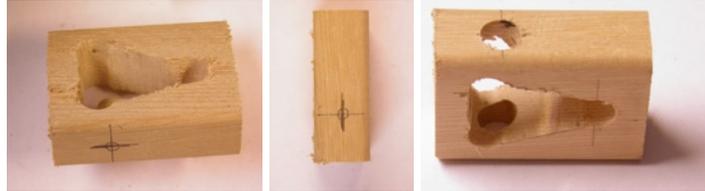
1. Drill 3/8" holes to hollow out frame
 - a. 1/2" from back, and centered, drill one hole
 - b. 1/2" from front, drill a hole 7/16" from each sides



2. Use coping saw to remove material between holes



3. On the side, 5/8" from front and centered, drill another 3/8" hole, all the way through both sides



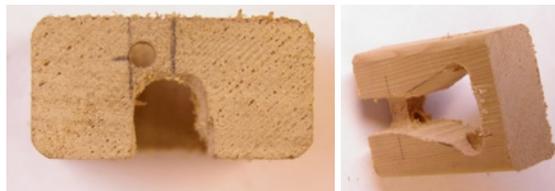
4. Make arm slot
 - a. 1/4" from top (choose one of the larger sides arbitrarily as top) and centered side to side on the back, drill another 3/8" hole, but only drill through the back, not all the way through to the front



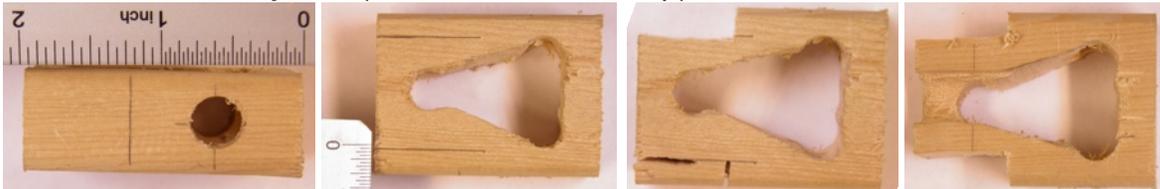
- b. Cut away thin wood between new hole and top



5. Drill 9/64" hole below one side of arm slot on back



6. Remove 1/4" by 3/4" (when viewed from top) blocks from both sides



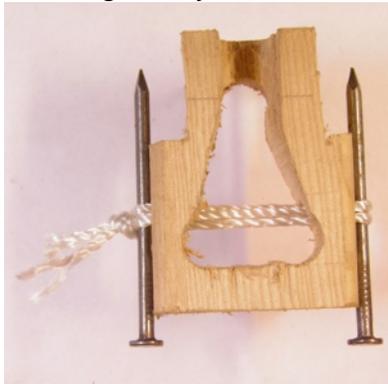
7. Make legs
 - a. Drill 1/16" diameter, 1/4" deep holes near all 4 corners of bottom
 - b. Fit smaller nails into holes



8. Make torsion bundle
 - a. Cut 10" piece of nylon string
 - b. Tie string into 3" long loop
 - c. Double over loop



- d. Feed doubled over loop through holes in sides of frame
- e. Slide large nails through loop on either side of frame
- f. If loop is too short, or not tight, adjust knot and try again

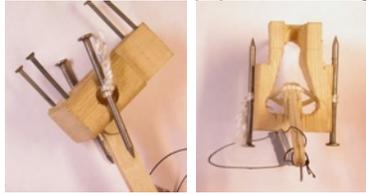


Part Three: Final Assembly

1. Insert fat end of arm into torsion bundle

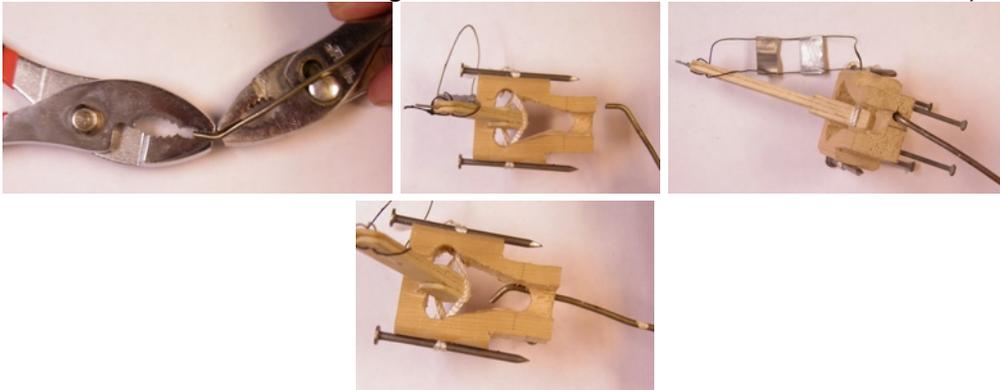


2. Tension bundle by twisting large nails (both the same amount) in the forward arm rotation direction until the arm is solidly pressed against the front of the frame



3. Bend the trigger

- a. Bend 1/4" at the end of the coat-hanger wire 45 degrees (Note: the bend should be able to fit through the small hole in the back of the frame)



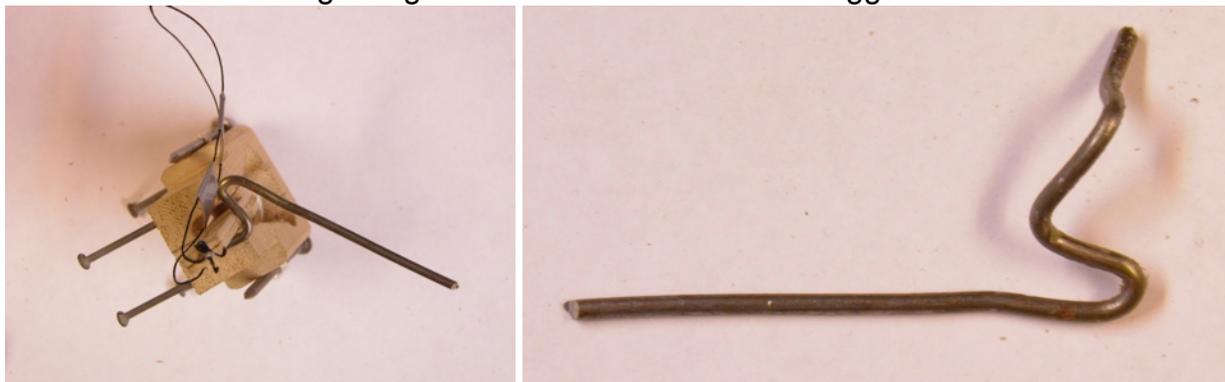
- b. Bend a 90 degree bend 1/4" further along the wire in the opposite direction



- c. Bend wire so that it can hold the arm in place when cocked

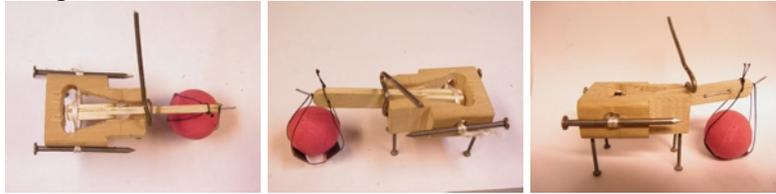


- d. Bend the long straight end of the wire back as a trigger handle



Part Four: Operation

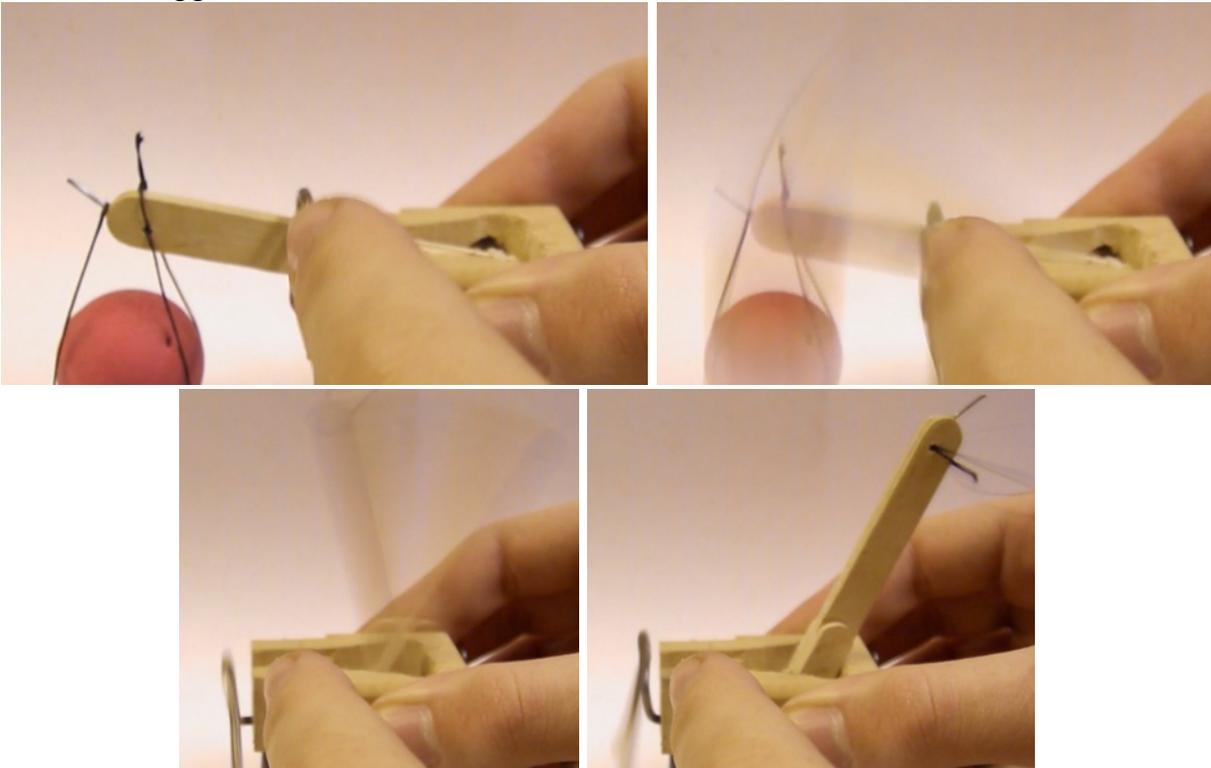
1. Read and follow operation warning at beginning of guide
2. Cock the arm back
3. Latch the trigger over the arm to hold it in place
4. Load the sling



5. Hold frame in a way that will not get you hand hit by the arm when firing



6. Pull trigger handle out/down



Part Five: Optional Adjustments

1. Twist the large nails forwards or backwards to adjust the force on the arm (Note: set the force too high and it will break, and possibly hurt you)
2. Bend the firing pin (the paperclip wire extending from the arm) to adjust the sling release point (Note: This controls the angle at which the projectile is thrown)
3. Throw different weights and shapes of projectiles

4. Make new slings or arms of different lengths (Note: it can be interesting to see the effects on throw angle and range with different weights of projectiles combined with different arms and slings)

CONCLUSION

After completing these steps, you will have built and operated a model Onager. You will have laminated a tapered throwing arm, attached a sling, and built the frame. The assembled onager should have a range over 20 feet with some projectiles, and makes an excellent example of some principals of physics and engineering. This particular design, especially the scale and materials, are not historically accurate, but the concept is the same as the Romans used.