Franklin W. Olin College of Engineering

Miniature Juicer

ENGR 2330: Intro to Mechanical Prototyping

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Executive Summary

As a final design project for ENGR 2330: Mechanical Prototyping, teams constructed various transmission systems using a variety of transmission elements including spur gears, timing belts, chains and sprockets, and lead screws. All teams were given the same components along with other stock materials and told to design the best possible transmissions as judged by the following criteria:

- Functional (10/10)
- Lowest weight (1st place)
- Least backlash (1st place)
- Lowest friction (3rd place)
- Most useful (2nd place)
- Best looking (2nd place)

Our team decided to build a miniature, hand-powered juicer that could be used with grapes, raspberries, etc. We placed 2nd in the in-class competition (with the results shown above). In addition to the specified goals, we also designed our juicer to be as simple and easy to manufacture as possible. The basic structure is provided by an aluminum clockcage that holds all of the shafts in line. Inside of this cage the transmission elements are all precisely placed to minimize backlash. Turning the input shaft causes a crushplate to move down the lead screw and crush a fruit of choice. The juice then runs down a channel and into a standard shot glass. Our final prototype was fully functional and can successfully crush grapes and/or other (harder) objects.

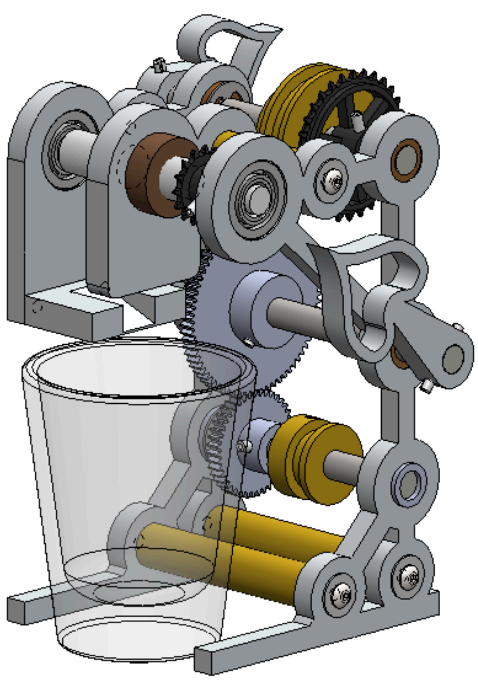

Figure 1: Final CAD of Juicer

Design

As mentioned before, we were already given a set of components and specifications to design with. Given the fact that one of the parts we had to use was a lead screw which works to transmit rotary motion to linear motion (and not so well in the other direction), we decided that our final output should be something that required linear motion. We quickly thought up the idea of some sort of crushing device, which eventually evolved into a juicer.

As we were looking to minimize the weight of our juicer, we wanted to make it as compact as possible, while still making it pretty and functional. After calculating the distances required between out particular transmission elements, we began to figure out how it could all fit together. We eventually decided on including the crushplate inside of the clockcage, so that it would have better support and we could use one of the clockcage sides as a crushing surface. We also decided to use one of the clockcage posts as a guide rail for the crushplate. Other notable features include the fact that the design allows for the juice from crushed fruits to flow directly into a shot glass. Finally, the clockcage faces were also made into a nice, geometric design that minimizes weight, looks nice, and enhances functionality. Along that theme, the input hand and backlash-measuring arrow are both spade shapes.

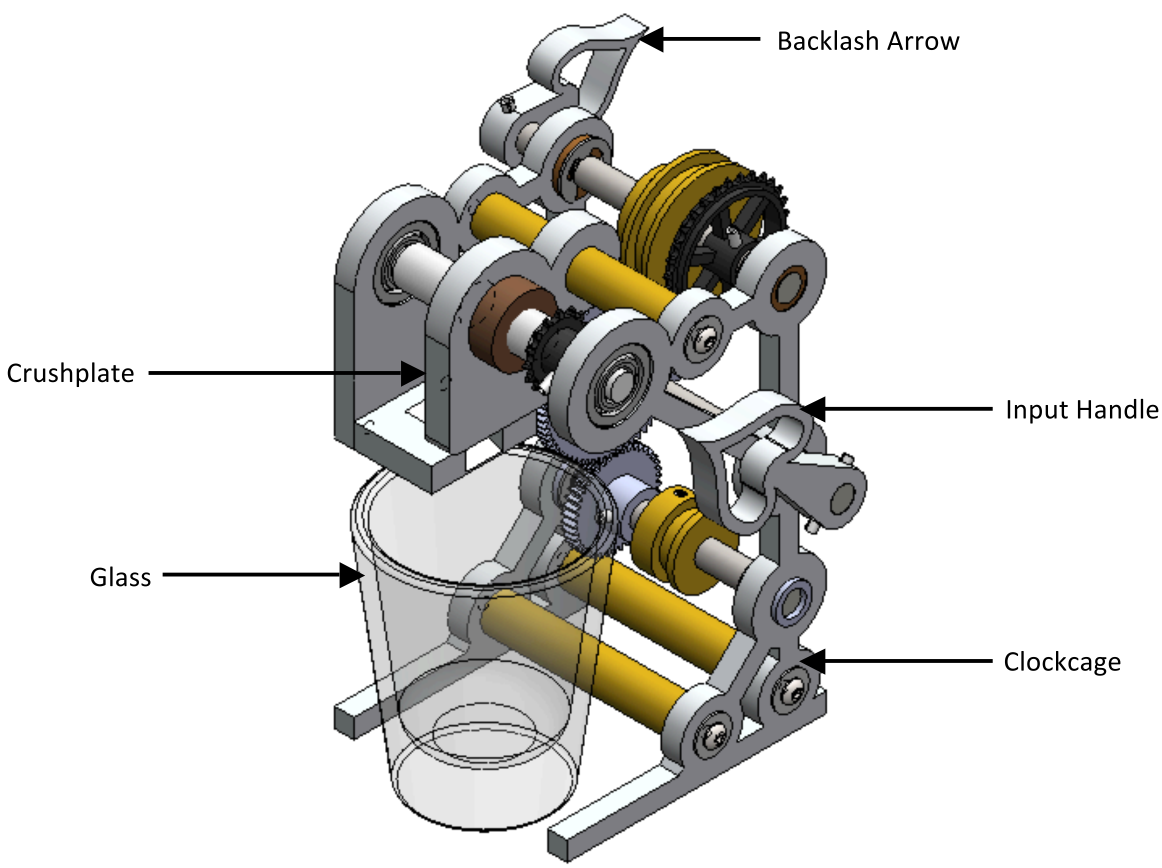

Figure 2: System Overview

Structure

As discussed earlier, we were juggling many goals when designing our juicer. We wanted it to be light, efficient, manufacturable, pretty, and functional. Many of these goals can be accomplished by just keeping the design simple. We did this by taking full advantage of our clockcage. From using posts as guide rails to using the clockcage side as a crushing surface, we made the most out of this design element. The clockcage is a box that can hold all of the tramsission elements. It is also a “C” structure that places the crushing region over a glass so that the juice can flow down. The clockcage posts themselves are held in place with secure mortise and tenon joints. We also included a shelf for the crushed fruit with a channel for the juice to flow down. This is held in place by a butt joint. We could very well have used a rabbet or dado joint, but decided that a butt joint was simpler to manufacture and more than adequate for the forces the place would see.

Another nice aspect of clockcages is that they are relatively easy to manufacture and also guarantee in-line shafts. This is done by milling both clockcage faces at the same time. Since the holes are drilled and reamed together they are, by definition, in line. Our design also minimizes the chance for error in manufacturing, but placing all of the shafts in line with one another (either in the x or y axis).

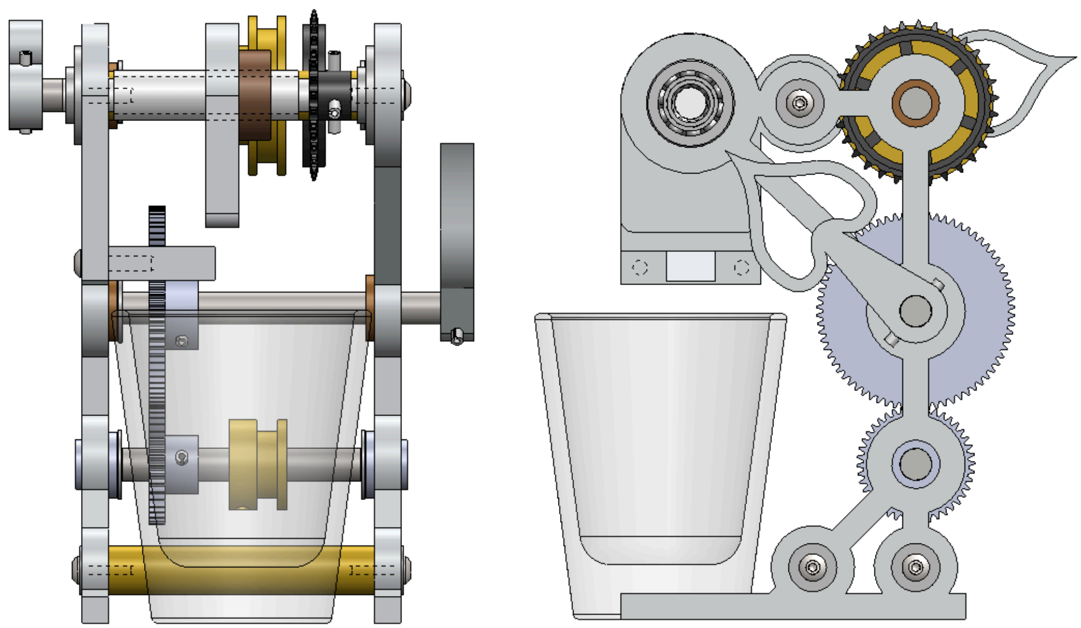

Figure 3: Profile Views of Design

Between clockcage faces, we placed transmission shafts at precise distances apart such that the transmission elements had minimal backlash and friction. The input shaft has a long spade-shaped hand attached to give some mechanical advantage to the device (given that it is hand powered). There is also a second spade hand attached to measure backlash. In our final prototype there is almost no backlash at all, so these hands move in unison. Also note that the transmission travels in both directions, allowing the crush plate to move both in and out.

Another important element is the crushplate. It runs along the lead screw with the help from a precision nut. This is the final output of the device and moves to squish grapes or other fruits and release the juices inside of them. In order to ensure that it moves along the shaft instead of rotating with it, there is a guide rail (which is actually also one of the clockcage posts).

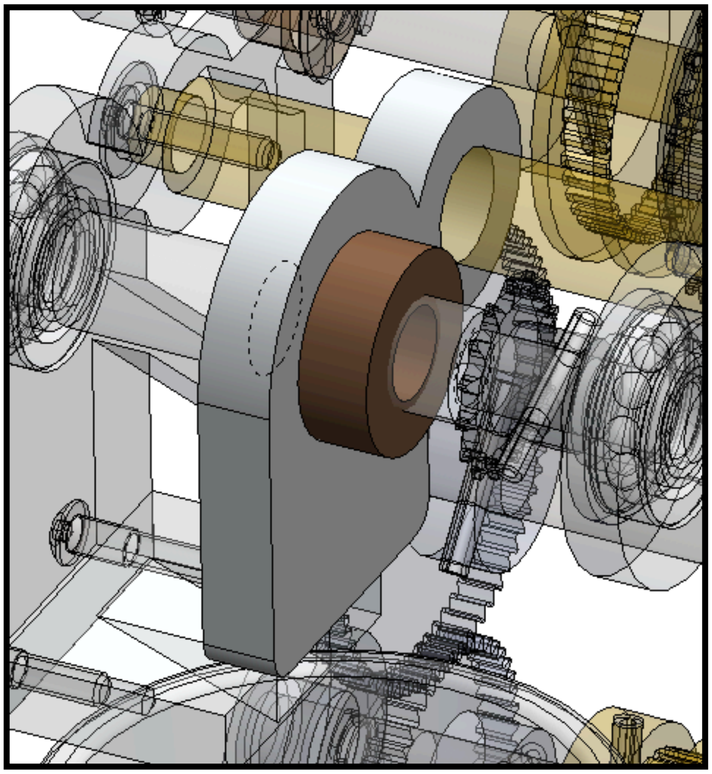

Figure 4: Crushplate

We manufactured our device in the Olin College machine shop. The contours of the spade hands, crushplate, and clockcage faces were waterjet cut out of ¼" 6061 aluminum stock. The parts were then placed in the mill so that the holes could be precisely drilled and reamed. We also turned down the brass clockcage posts and steel shafts on the lathe and made modifications to some of the stock parts to make them fit together well. Drawings for each part are included in attached drawing package.

Power

This simple juicer is hand powered (though it could be adapted to accept some other power source). The long hand attached to the input shaft gives some mechanical advantage to overcome the friction of the device and any additional force required to crush and juice the fruit. It is the transmission that is really key in using this power well.

Transmission

The key to this project is a well-designed transmission. The overall design was quite defined, given the parts that we were given, but finding the correct distances and setup completely changes how the components act. Since squishing fruit does not require an extreme amount of force, we were not necessarily interested in maximizing the output torque. Instead, we were interested in making sure the crushplate moved at a good speed relative to rotating the input hand. After discussing it for a while, we decided to actually use the timing belt and chain and sprocket to cancel each other out (they both have a 2:1 ratio). This way they don't change the speed or torque; they only transmit the power over a distance. We used to spur gears to increase the speed slightly (they have a 42:72 ratio). This, along with the 0.1" of travel per rotation of the lead screw, led to a reasonable crushplate speed. Each of the transmission components is briefly described below.

Bearings

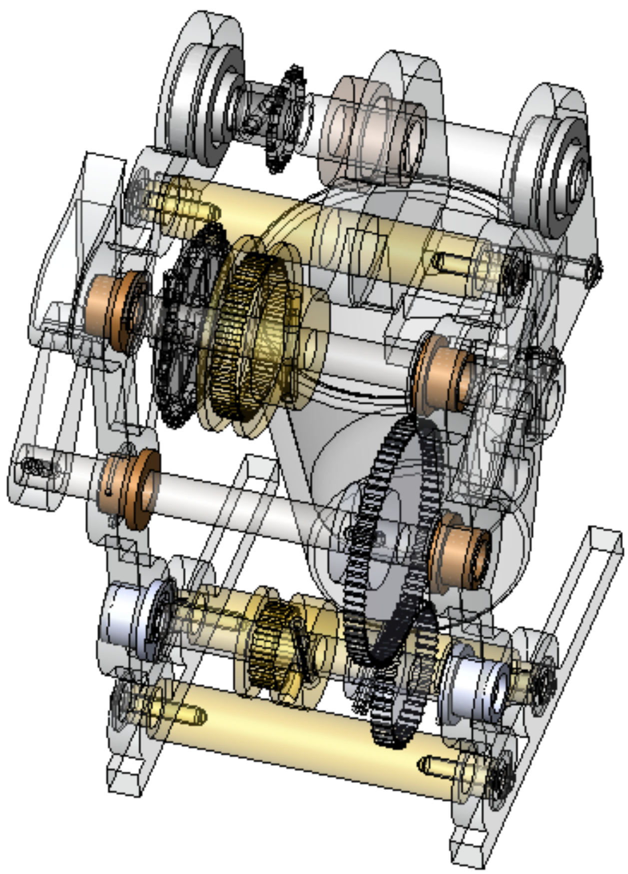

Figure 5: Bearings in Assembly

Our design used steel ball bearings, PTFE-lubricated bronze journal bearings, and nylon journal bearings. These components minimized the friction in the device while still ensuring accurate placement. The steel ball bearings (McMaster 6383K213) were used to hold the lead screw in because they were a little oversize for the ¼" steel shaft. The bronze bearings (McMaster 1677K1) were used at the inputs as they would presumably have less deformation from outside forces, and the smooth nylon bearings (McMaster 6389K231) were put on the fastest moving shaft.

Spur Gears

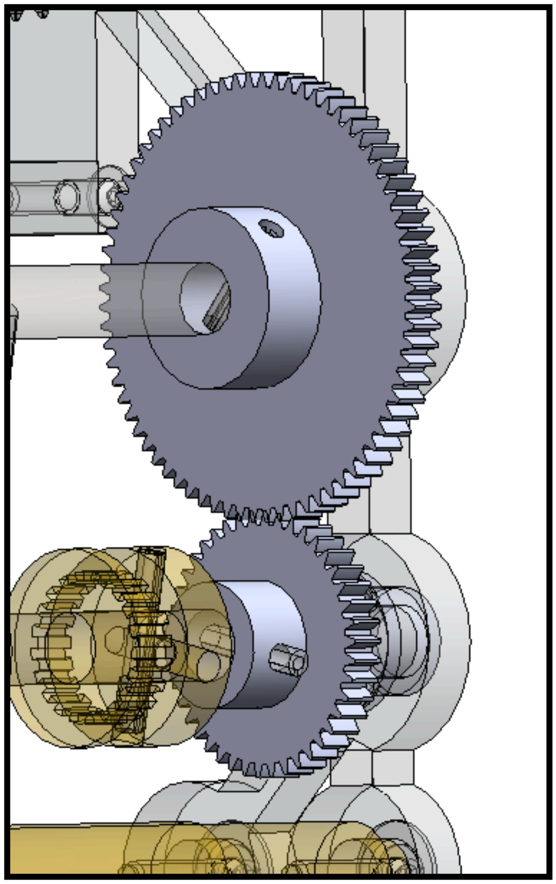

Figure 6: Nylon Spur Gears

We used two nylon spur gears (McMaster 57655K22 and 57655K28) as the first transmission stage. One gear had 72 teeth and a pitch diameter of 1.5”. The other had 42 teeth and a 0.875” pitch diameter. From this we knew that the ratio was 72:42 and that two shafts should be placed 1.1875” apart.

Timing Belt

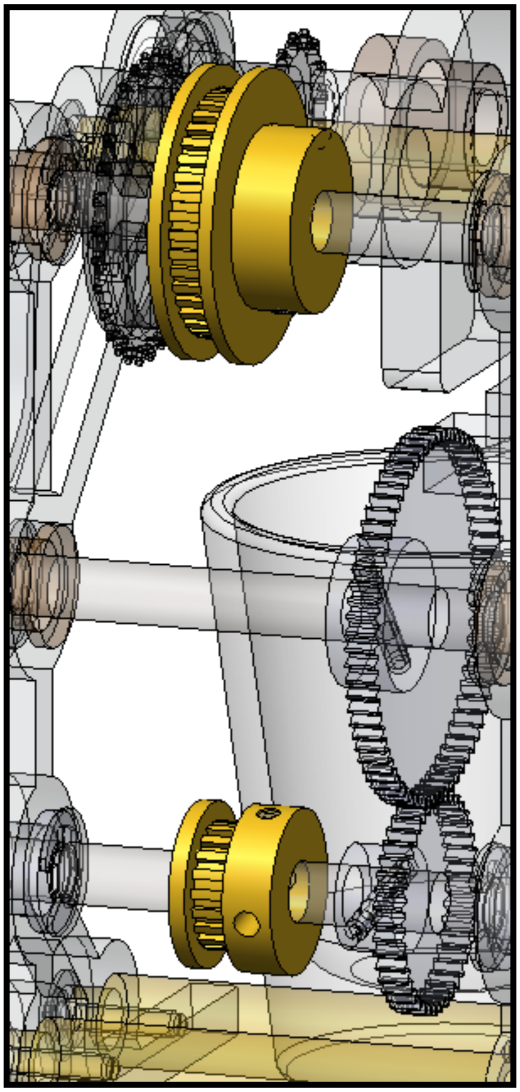

Figure 7: Timing Belt

The timing belt was the most difficult element to place. We were given an 8” 0.08”-pitch neoprene belt (McMaster 7887K2) and two aluminum pulleys (McMaster 1375K21 and 1375K51). One pulley had 20 teeth and a pitch diameter of 0.509”. The other had 40 teeth and a pitch diameter of 1.019”. This provides a 2:1 reduction. After communication with McMaster, we decided to only minimally tension the belt (it does not stretch much). With a few calculations, we found that a shaft spacing of 2.8” would put the belt in a slight tension without stressing the shafts and increasing friction too much.

Chain and Sprocket

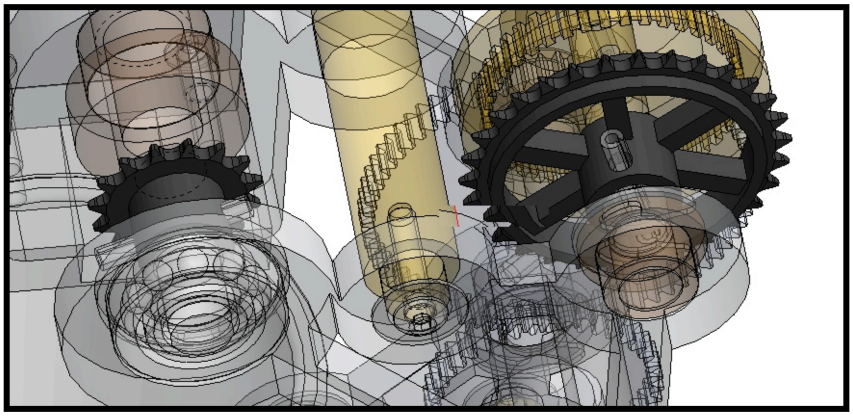

Figure 8: Chain and Sprocket

Our next transmission element is a plastic chain and sprocket with 0.1227" pitch (McMaster 64225K711, 64205K12, and 64205K15). We placed this near the crushing surface because it would be less likely to get clogged by debris from juicing. One sprocket has 15 teeth and the other has 30. This results in a 2:1 ratio which we used to cancel out the timing belt. The chain is slightly more forgiving in terms of placement because we can easily adjust the length of the chain. We ended up placing the shafts 1.75" apart.

Lead Screw

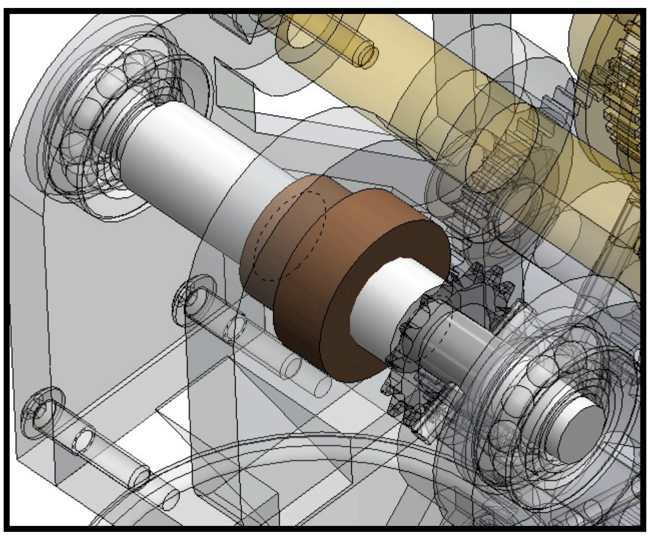

Figure 9: Lead Screw

Our final transmission element is a steel lead screw and nut (McMaster 99030A327 and 95072A127). It is a 3/8" -10 thread that provides 0.1" of motion per rotation. This transfers the rotational motion from the rest of the transmission into a linear motion to crush the fruit. We had to turn down the nut and shaft in order to fit it into our assembly (since we were missing the necessary tap for the nut). Nevertheless, it ended up working very well.

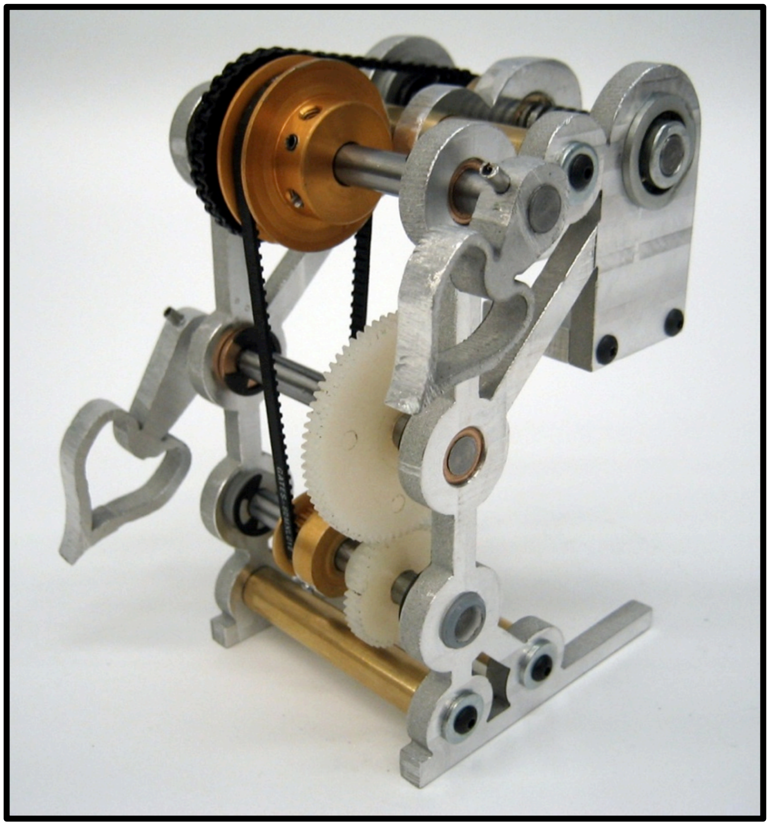

Figure 10: Assembled Transmission

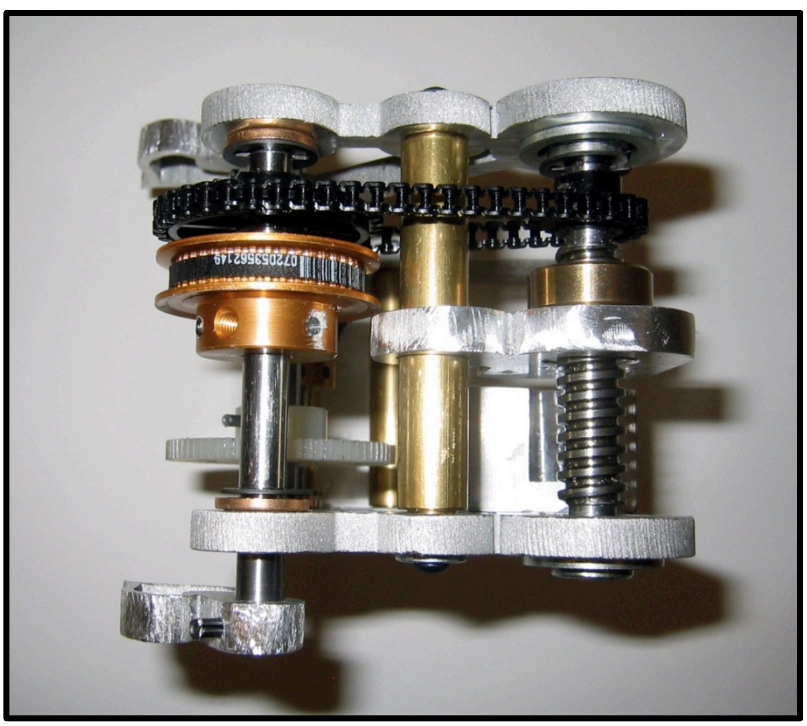

Figure 11: Top View of Assembled Transmission

Conclusion

This project was successful in a lot of ways. In addition to making a functional juicer and placing well in the competition, we learned a lot about transmission design and construction. It was a great exercise in teamwork, design, and machining. Figure 12 shows our final, assembled juicer.

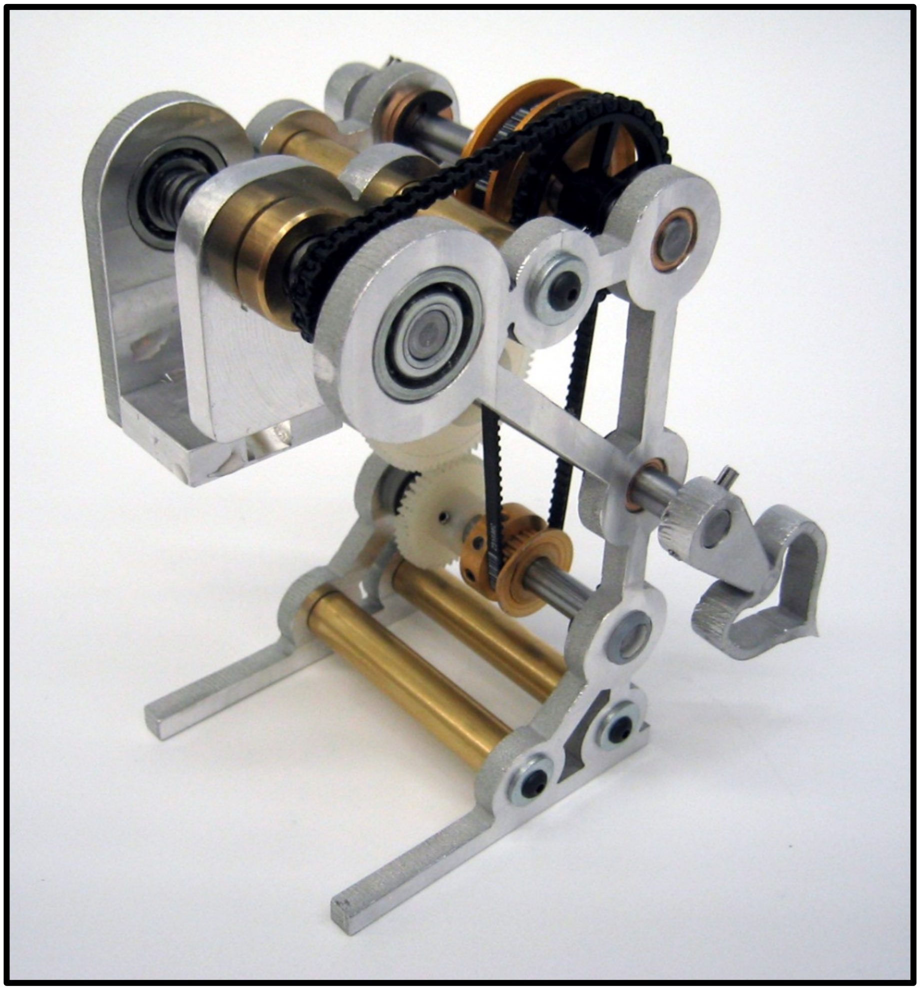

Figure 12: Final Assembled Juicer

Appendix

My personal contributions to the project included the following: CAD of stock gears, clockcage design and CAD, initial CAD assembly, clockcage machining, crushplate machining, holder machining, shaft modifications, and final assembly. If there are any questions about this report or my knowledge of the contained material, please email me at raphael.cherney@students.olin.edu.

Drawings

Attached are my drawings for this project.