The Development of the HANSCycle RLT

Spring 2017 Project Scope Report

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Abstract

Team 8 was given the task of continuing last year's senior design Team 20's work on the HANSCycle. The HANSCycle is a bicycle that utilizes a reciprocating lever transmission (RLT) that was invented and patented by our sponsor Gordon Hansen. Team 8's main goals for this project included making sure that the (RLT) was in complete working order, the bicycle is capable of rolling backwards freely (when pushed not pedaled) without locking up, and testing the RLT in various setups to compare it to the traditional bicycle as well as determine its capabilities. New crank arms that are made entirely of steel to make sure shearing doesn't occur have been designed and are going to be built and implemented at the beginning of next semester. A new shaft material has been sourced and will be machined as well as case hardened. Lastly new ratchet and pawls and continued research on possible alternatives are also being looked. When all the failed components have been fixed Team 8 will be able to test the RLT at full capacity and receive the data that Gordon Hansen requires.

1. Problem Statement

"A traditional bicycle is difficult to ride up hill due to its limited torque output and can also be damaging to a rider's joints."

Team 8 has been tasked with developing a working HANSCycle implementing the Reciprocating Lever Transmission (RLT). The goal of this design is to improve upon a few aspects of the traditional bicycle, including two 'dead spots' at the top and bottom of a normal pedal rotation, as well as alleviating joint damage to the user from these dead spots. If successful, the HANSCycle will be more power efficient and ergonomically comfortable for the user. Once a working prototype has been developed, the team must test it and compare values such as torque, cadence, work, and speed, with values of a Traditional Bicycle. This project hopes to prove that a reciprocating lever transmission on bicycle can obtain similar results in performance compared to a traditional bicycle, while also causing less stress and damage to the rider's joints.

2. Project Scope

Gordon Hansen, the HANSCycle sponsor, believes his redesign of the traditional bicycle will lead to a new age of bicycling. The goal of the Reciprocating Lever Transmission is to maximize efficiency and ease stress on the user's joints due to the "dead spots" in a traditional bike's transmission. These "dead spots" can cause joint harm and are unconducive to an efficient ascent uphill. He believes that the short crank arms on traditional bikes require more work from the bicycle rider, which led him to patent his RLT design. The RLT incorporates larger crank arms that can produce more torque and travel in an arc no greater than 100 degrees, which avoids the dead spots.

Below, Figure 1 displays the disassembled bicycle components that were used to construct the bicycle last year.

Figure 1: Disassembled bicycle components

The bicycle is still intact with the above parts, but certain aspects require improvement. Specifically, the driveshaft and clutches must be made stronger in order to be able to support the increased torque from the longer cranks and Reciprocating Lever Transmission, seen below in Figure 2.

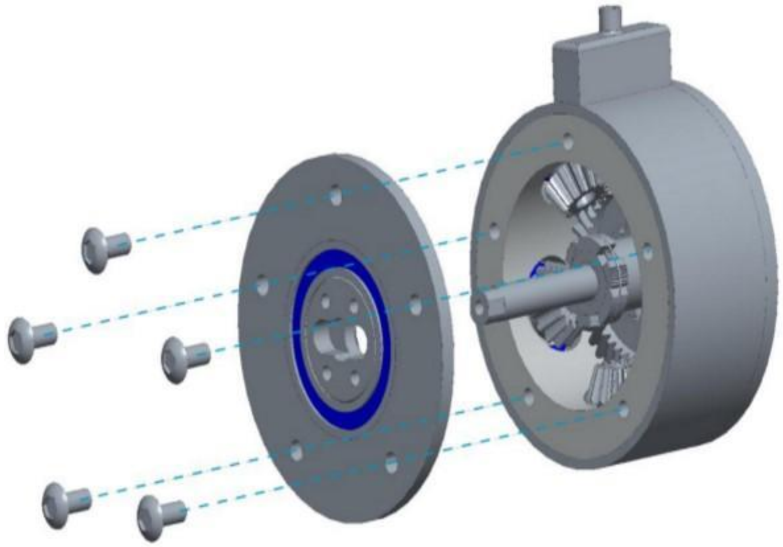

Figure 2: Reciprocating Lever Transmission CAD exploded view

Gordon Hansen has also requested, if possible, that the team try to find a way to alter the position of the bike rider. Currently, the seat and handlebars are at a position that cause the rider to lean forward. For optimum comfort and use, an upright position is favored. While this is a request from the sponsor, it was not one of his priorities, so the team will focus on the actual function of the mechanism before adjusting the design for rider comfort.

3. Project Objective

The primary objective of Team 8 is to develop the RLT into a fully functional transmission that is capable of safely and consistently delivering enough power to the ground to be on par with a traditional bicycle. For this to be accomplished, the primary objective has been broken down into several subsections. The first and most important being the crank-arms, as those have caused the most issue. The second being the output shaft, which transfers power from the crank arms to the sprocket. Last is finding a possible alternative to the ratchet and pawl mechanism that is currently only available from one vendor Triton Cycles in England.

An alternative to the ratchet and pawl mechanism is either to buy a similar design from a local bike shop which would allow us to modify it to accept the current ratchet and pawl mechanism. Another viable option after speaking with Jeremy in the machine shop, is to draw up and build identical pieces of the ones we need. Lastly, we can outsource the production of a similar design to online metal workers or a specialized bike manufacturer in California. Currently, the purchasing of the similar device or making the piece in house at the machine shop are being looked into. The outsourcing would take much longer and would be much more expensive.

To achieve the goals previously stated, the new designs must incorporate up to 12” crank arms that reciprocate in arcs no greater than 100 degrees. The new design should improve the comfort ability of uphill riding. Using the test rig to provide performance data of the bicycle is another important objective. Another goal is to test the RLT when finished. To do so, a test rig will provide data on the power output, which will be able to give a good estimate of how much power is needed to ride uphill. The second objective is to include the new drivetrain in a bicycle frame that includes cargo-mounting stations that can be used for shopping errands and daily commuting in cities with hills. This bicycle design should fit in a standard shipping box with the dimensions of 26”x26”x10” when disassembled, to save on shipping costs.

4. Methodology

This project has several primary tasks that must be completed by the end of the semester. The HANSCycle must be in working order as well as tested so that its data may be compared to that of a traditional bicycle. Currently Team 8 is working on several integral components.

The first of which is newly designed crank arms. These crank arms are constructed with steel in order to increase strength over the prior design, which sheared under stress. This shear stress was caused from operation and can be attributed to an aluminum design paired with misalignment of the mounting holes. Only two of the four holes could be used, which caused additional stress on the two aluminum keys, causing them to fail and shear. The new crank arms were designed in Pro-Engineer by Team 8 in a way that pairs properly to the RLT. This new design has properly aligned holes which will increase robustness in unison with an all steel design. The steel used in fabrication was chosen by Team 8 to be Chromoly Steel or AISI4130. This steel is commonly used in bike construction due to its large increase in strength over a mild steel or aluminum. It is a steel alloy which implements two main impurities, chromium and molybdenum. This alloying procedure increases the strength but maintains its ability to be welded.

This is important since the crank arms will receive most of the force supplied by the rider. The material for the crank arms was ordered from a third party and the alloying process has already been done for Team 8. After acquiring the material and finalizing the design, the FAMU/FSU machine shop will be utilized. The machinist will use Team 8's CAD model to fabricate the crank arm bases in the CNC machine. After the team receives the crank arm bases, a section of square tube Chromoly will be welded to the base in order to reduce weight and machining time that would be required if a one piece crank arm was implemented. Then a drill press will be used to drill and tap the hole required to accept the pedals.

In addition to the crank arms, new needle bearings must be put into the RLT to regain functionality. The needle bearings previously used were sufficiently robust, however they failed due to improper alignment of the RLT shaft. The previous needle bearings were removed by hand because they were severely damaged. New needle bearings have been ordered to replace the previous ones and will be pressed into place using a press. Once in place they will allow for the shaft to spin in place with minimal internal friction.

Another key component that must be machined and implemented is a new shaft to go inside of the RLT. The previous RLT shaft was misaligned which caused extensive damage to the needle bearings and additional wear and tear on the ratchet and pawl design. Team 8 made a slight adjustment to the previous RLT output shaft in Pro-Engineer. The RLT design constrains the output shaft to the same dimensions within the system since that is all that will fit, however a more robust design was included for the locking mechanism. Previously, a locking bolt was screwed into the end of the shaft by drilling and tapping the end of the already narrow shaft. Team 8's new design uses a locking nut instead. This is done by extending the shaft slightly and using a die to thread the outside of the shaft at the end. This allows for a nut to be put on in order to lock the system together, while still allowing for removability and an increase in strength.

After all other components are sourced and machined, the prototype must be reassembled. Team 8 will accomplish this using common tools such as drills and the appropriate bits. The bolts will all be replaced with a much stronger Grade 8 bolt. This will be important for the longevity of the HANSCycle, since there are large amounts of concentrated forces on the system and many of the components are small due to size and weight restrictions. Previous bolts used by last year's Team 20 were sheared off or stripped out due to lower quality steel paired with the misalignment of holes and the shaft.

4.1 Finite Element Analysis (FEA)

Prior to having our new designs sent to the machine shop to be made finite element analysis was run on both the new crank arm design and the output shaft. The crank arm design had an applied load of 250 lbf at the point where one's foot would make contact with the pedal. Looking at the figure below one can see that the displacement is estimated at about 3.25 mm. While, this is good it is also relevant to note that the information is based on mild steel because Pro/Engineer does not have the properties of 4130 steel. The tensile strength of 4130 is almost double that of mild steel so the deflection would be lower than estimated.

The output shaft was also put under FEA. The output shaft was constrained in four locations like how it would be in the transmission. After apply the 250 lbf load to the point where the chain would pull on the shaft the displacement was negligible. With both the FEA run on the output shaft and the new crank arms it was deemed to be capable to withstand the necessary applications and work orders were submitted to the machine shop.

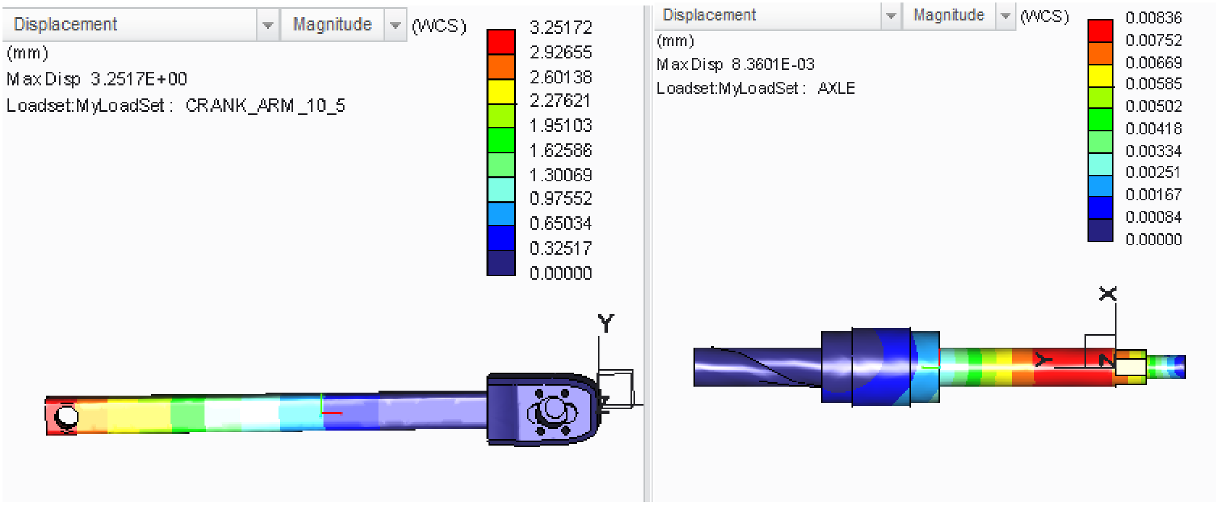

Figure 3: FEA of Crank Arms (left) and Output Shaft (right)

5. Progress Made

Team 8 inherited the Hans cycle last semester and was under the impression that the RLT was farther along and had less issues than anticipated. Therefore, we set our plans for the semester on testing and getting results to compare and analyze them against a traditional bike, since this was the main goal and request made by the project sponsor, Gordon Hansen. However, the team soon learned that everything was not working properly. Project plans quickly changed and the team decided to fix and replace old broken parts with new ones. With the new goal in mind, Team 8 was able to make considerably good progress. The old parts that were broken included the crank arms, multiple bolts, the ratchet and pawl, the output shaft, bearings and a few more pieces. The first focus was on the crank arms. The biggest issues with the old crank arms was that the holes didn't line up with the holes on the RLT and that the keys had also sheared.

The first step the team had taken to move towards the goal of getting data was to modify the crank arms in a way that would allow the RLT to work properly. Originally, Team 8 attempted to fix the various issues with the crank arms as well as tap holes in the crank arms at 12, 10.5, and 9 inches. Testing at these different lengths will allow the team to determine which produced the most power, was the most ergonomic (i.e. what length was the most comfortable), and didn't cause any collisions with the ground or bike wheels. After determining that the modified crank arms would no longer be an option, Team 8 decided to redesign and use alternative ideas for the crank arms. Using Pro-Engineer, the crank arms were redesigned to be made out of 4130 steel and utilized a more basic design which was done to speed up manufacturing. To make sure that crank arms were capable of withstanding the load, FEA was run with a 250 lbf load applied perpendicular to the pedal position. This can be seen in detail later in the analyze section. A CAD model as well as the multiple stages of the CNC process can be seen in figures 3 through 5 below.

Another component that had to be redesigned and fixed was the output shaft. The original output shaft was made by pressing a case hardened shaft into a mild steel outer component. However, in doing so the shaft had been put and welded off center, which caused the shaft to spin off axis. The new shaft that was designed incorporates a similar design because of the size constraints within the RLT. The difference is that the new shaft uses a cases hardened inner shaft and a 4130 steel outer shaft. The inner shaft also has been extended by 12mm to allow for threads on the outside instead of the inside like in the previous design. This allows for a smaller displacement when running FEA because there is no longer a small wall thickness between the output shaft and the chain ring.

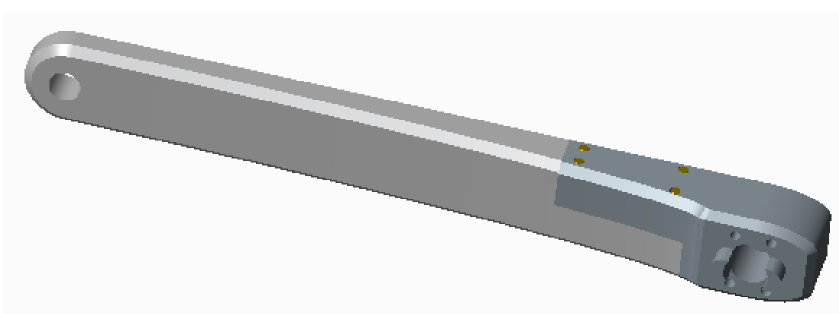

Figure 4. Crank arm design 1

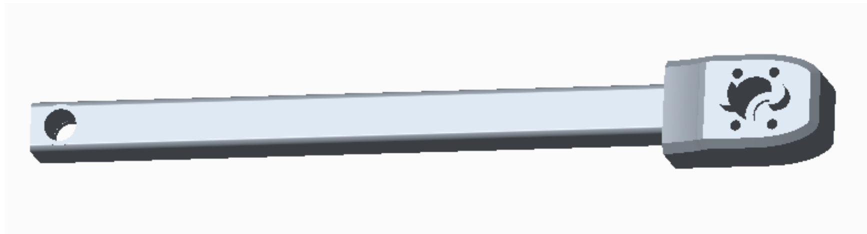

Figure 5. Crank arm design 2

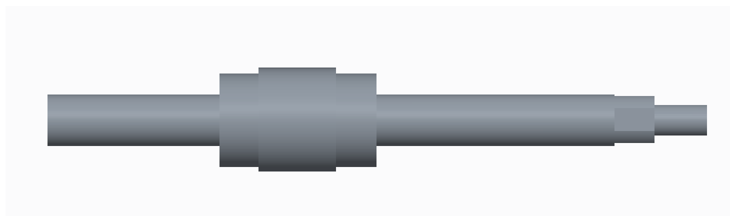

Figure 6. New shaft design

After redesigning, a few of the broken parts. The materials were ordered so that the machining of the parts can begin. Although Team 8 was not able to reach the goal of building and testing the new crank arms by the end of the fall semester, the new materials were ordered using some of the 2,000 budget. Below is a chart displaying the purchased materials and budget.

#	Part	Material	Vendor	Cost	Quantity	Subtotal
1	One-way Bearing	steel	VXB bearings.com	$24.95	1	$24.95
2	rachet and pawl	plastic/steel	Trilton cycles (UK)	$90.00	2	$180.00
3	square tube (5ft)	steel	speedy metals	$5.95	1	$5.95
4	round bar (shaft)	8620 steel	speedy metals	$6.89	1	$6.89
5	steel plate	A-36 steel	speedy metals	$29.53	1	$29.53
6	square bar	A-36 steel	speedy metals	$21.16	1	$21.16
7	socket screws	steel	Mcmaster.com	$9.82	1	$9.82
					Total	$278.3
					Remaining Budget	**$1,721.7**

Table 1. Procurement of materials ordered

6. Challenges and Constraints

Team 8 plans for the fall semester were met with a few major challenges. For one, in addition to the parts that were already broken, new parts began to break. Socket head screws, needle bearing, and locknuts were the parts that began to break. Almost every crucial component of the RLT has broken in some fashion. Due to the breaking of numerous parts, Team 8 was not able to test the HANSCycle. Even when initial testing took place, more pieces broke so the testing was inconclusive. It caused a setback, testing could not take place because of the broken pieces. Team 8 had to purchase even more new parts to replace the broken ones. Attending to the broken parts, pushed back the scheduling and in consequence we were not able to test the HANSCycle at its highest efficiency. This put the team behind in the schedule to have the new crank arms built by the end of the fall semester.

Another major issue was the procurement of our materials. After ordering the metal for the new crank arms, Team 8 was waiting on the metal come in. Unfortunately, the metal was delivered to the school but Team 8 was never notified. It was not until 3 weeks later that one of the team members stumbled upon the metal that was ordered. Prior to this mishap team 8 was on schedule to get the new designed crank arms machined. Due to this 3 week mishap it was not possible to machine and build the new crank arms at the end of the fall semester as planned.

In addition to the metal being lost, one of the vendors carrying a very important part, the replacement ratchet and pawl, was not accepting the payments from the school. The P-card that was used for last years and this year's team was rejected this time. Different types of purchases was attempted but none went through. As a consequence the ratchet and pawl has not been ordered although it is still needed. This is yet another issue to cause a big setback on the building of the working HANSCycle prototype. Possible solutions include finding an alternative, to the ratchet and pawl system or asking the sponsor to purchase the ratchet and pawl then reimburse him. All in all this is another setback for team 8.

In conclusion Team 8 has experienced some unusual setbacks dealing with the broken parts as well as procurement issues. Therefore Team 8 was unable to fulfill fall semesters goals of building new cranks arms as well as building and testing the new prototype. However, in the spring semester Team 8 does not expect any delays or procurement issues to cause a setback in scheduling or reaching the goals. If no other parts break and procurement runs smoothly, team 8 will undoubtedly reach all of its semester goals.

7. Deliverables and Schedule

Team 8 has been working on the HANSCycle and RLT since the project was assigned. All deliverables have been turned in punctually, and critiques have been taken into account, in an effort to improve various aspects of the project itself as well as the deliverables. When the semester is over, in May, Team 8 hopes to have successfully completed and fulfilled all goals for the HANSCycle project. Firstly, a working prototype is expected to be completed by mid-February. The team has been slightly behind the original schedule because of issues with procurement of parts and materials. Once a prototype is completed, testing will be done to compare various crank arm lengths, in order to determine the most efficient length and arc. Once a length has been chosen, the HANSCycle will be tested on the Kinetic Road Machine, to obtain values for torque, power, cadence and speed. These values will then be compared with a traditional bicycle, also tested on the Kinetic Road Machine, to see the differences.

Using the comparison of test values, the team will decide what next steps to be taken. If the HANSCycle values are close to, or greater than, the traditional bicycle's, the team will focus on ergonomics of the bicycle. This would include changing the user's position on the bike by possibly moving the seat, handle bars, or even the RLT itself, without having a large impact on the test values. However, if the HANSCycle values are much lower than the traditional bicycle's, the team will have to reevaluate its design and approach. This could include changing the crank arm length or design, altering the RLT gears and inner components, or trying different materials. Various parts of the HANSCycle would then have to be reconstructed, and testing would have to be repeated, in order to attempt to improve the overall function and test values of the HANSCycle.

When the semester has ended, the team hopes to have a successful HANSCycle, functioning as efficiently as a traditional bicycle. The team will also leave the sponsor, Gordon Hansen, with all of the testing values, failure analysis, reports, and component information, along with possible steps and ideas for the HANSCycle, moving forward.

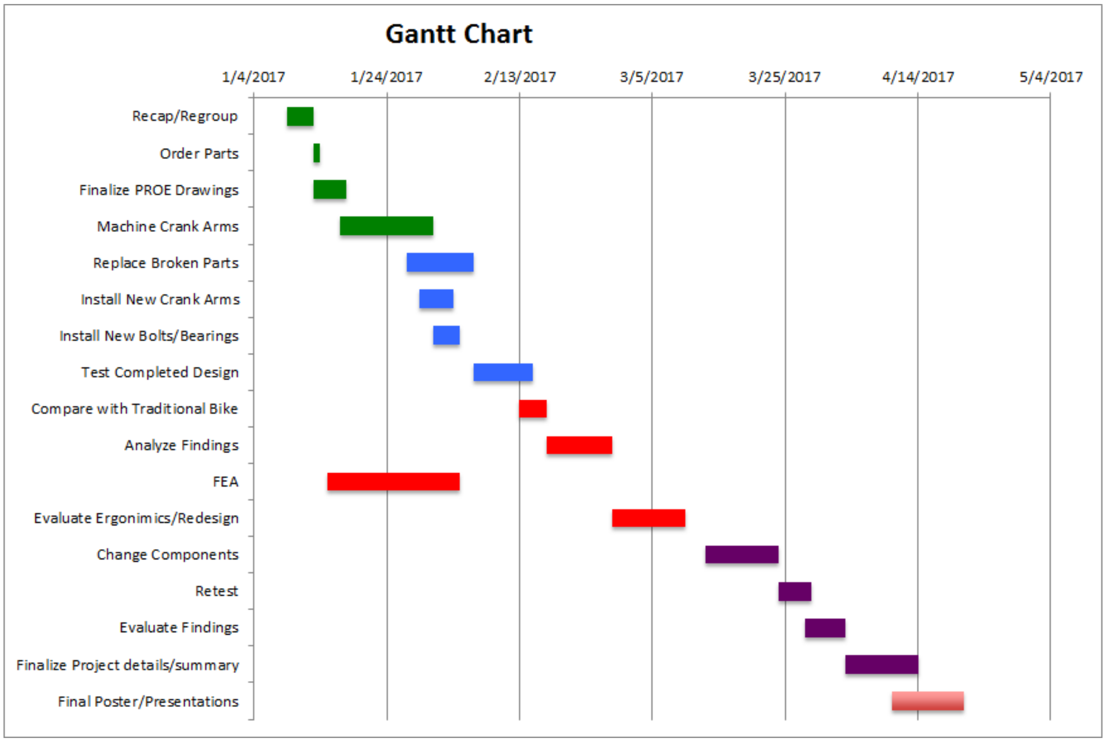

Figure 7: Gantt Chart

As can be seen in the Gantt Chart above in Figure 6, the team has set up a schedule and time limits for the rest of the semester. The schedule has some flexibility up until Evaluating Findings. The findings, testing, and design must all be completed by April 3, so as to be prepared and able to complete final details and finalize a project summary. This must be done in order to properly prepare a Final Poster and Presentation for the set dates between April 10 and April 21. This will be the culmination of Team 8's HANSCycle project, and will hopefully be a successful endeavor.

8. Summary

The HANSCycle and Reciprocating Lever Transmission aim to improve bicycle riding by redesigning the pedal motion to avoid dead spots and joint harm to the user. After inheriting last year's project, team 8 has experienced various problems with the HANSCycle prototype. Multiple parts on the prototype were found to be broken and needed to be fixed or replaced. After sourcing some new parts, designing new parts, and performing failure analysis, the prototype is now on track to be completed and working. Team 8 has made a new schedule which they hope to stick to, given no further problems arise. Once all of the parts are machined and received, Team 8 plans to assemble the prototype and begin testing. Testing will include the various crank arm lengths, as well as comparing values with a Traditional bicycle. Once testing has been completed, the findings will be analyzed and Team 8 will have various next steps, including possible adjustments of the RLT system or altering the rider's position. Team 8 plans to work hard for the remainder of the project semester, in order to have a successful HANSCycle project.

9. References

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10. Abstract

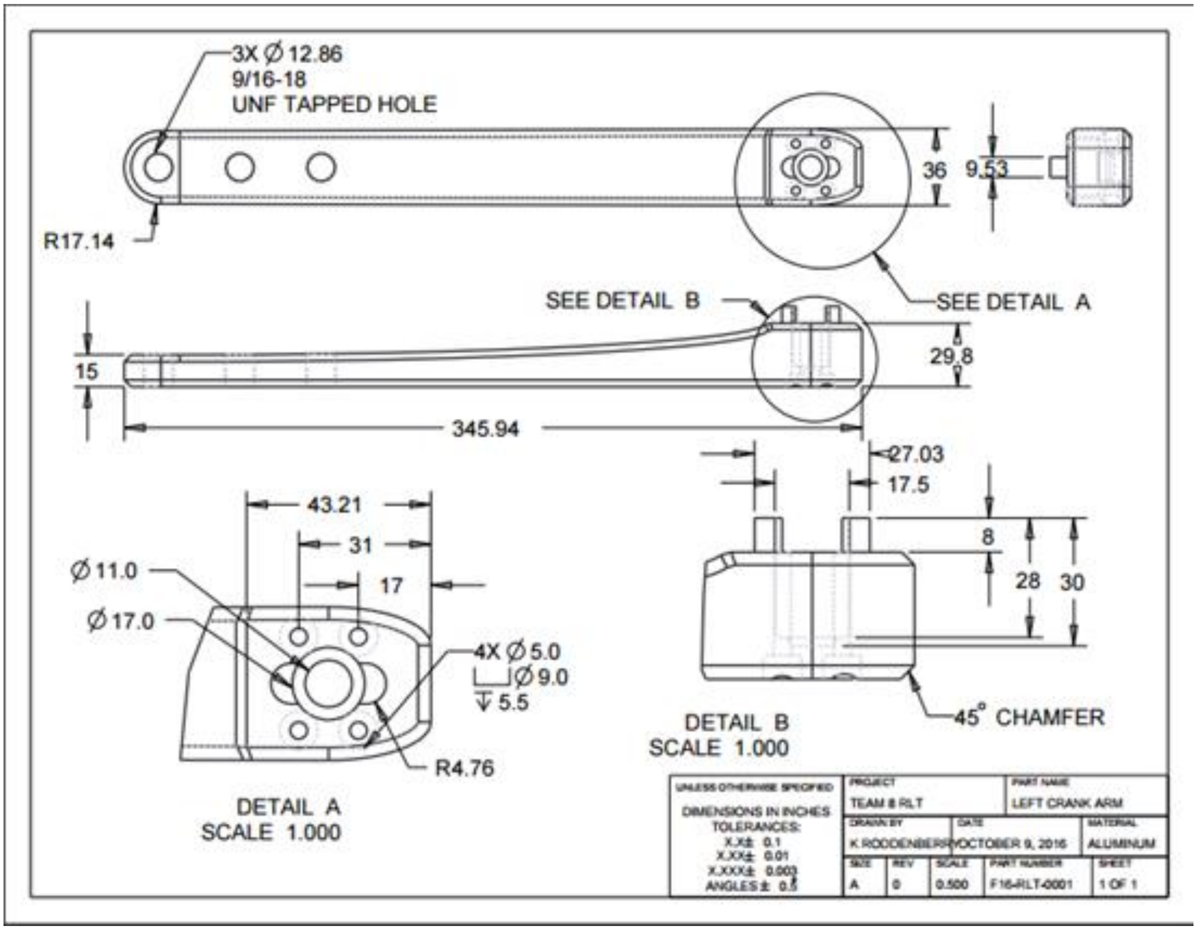

Figure 8. Detailed drawing of the revised crank arms.

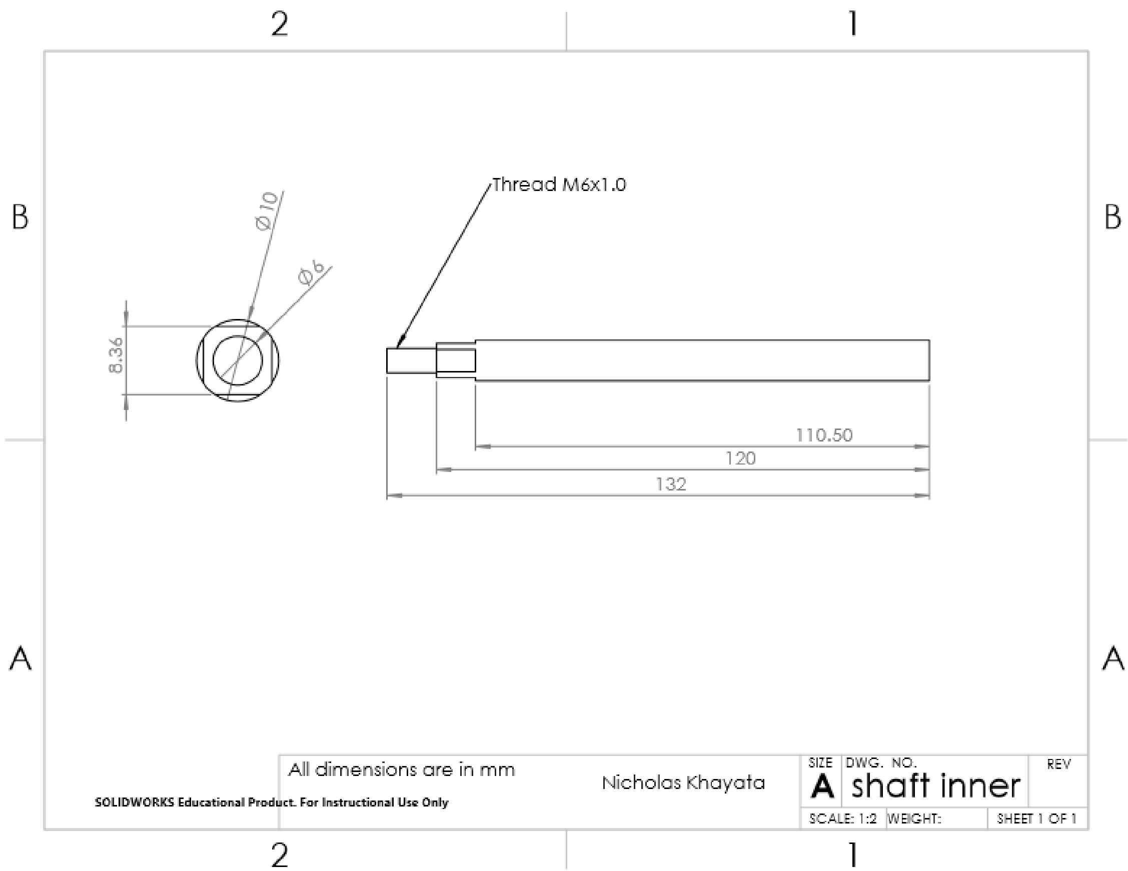

Figure 9: Drawing of inner shaft

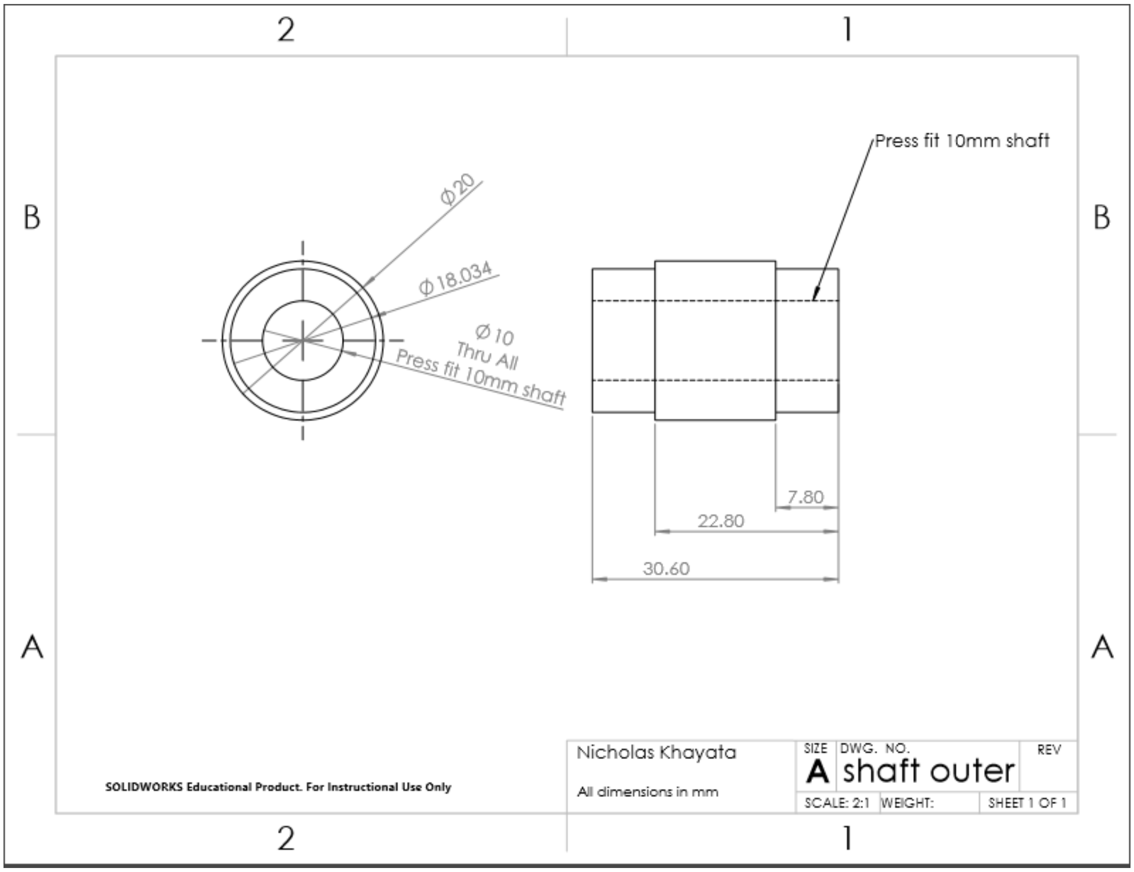

Figure 10: Drawing of outer shaft

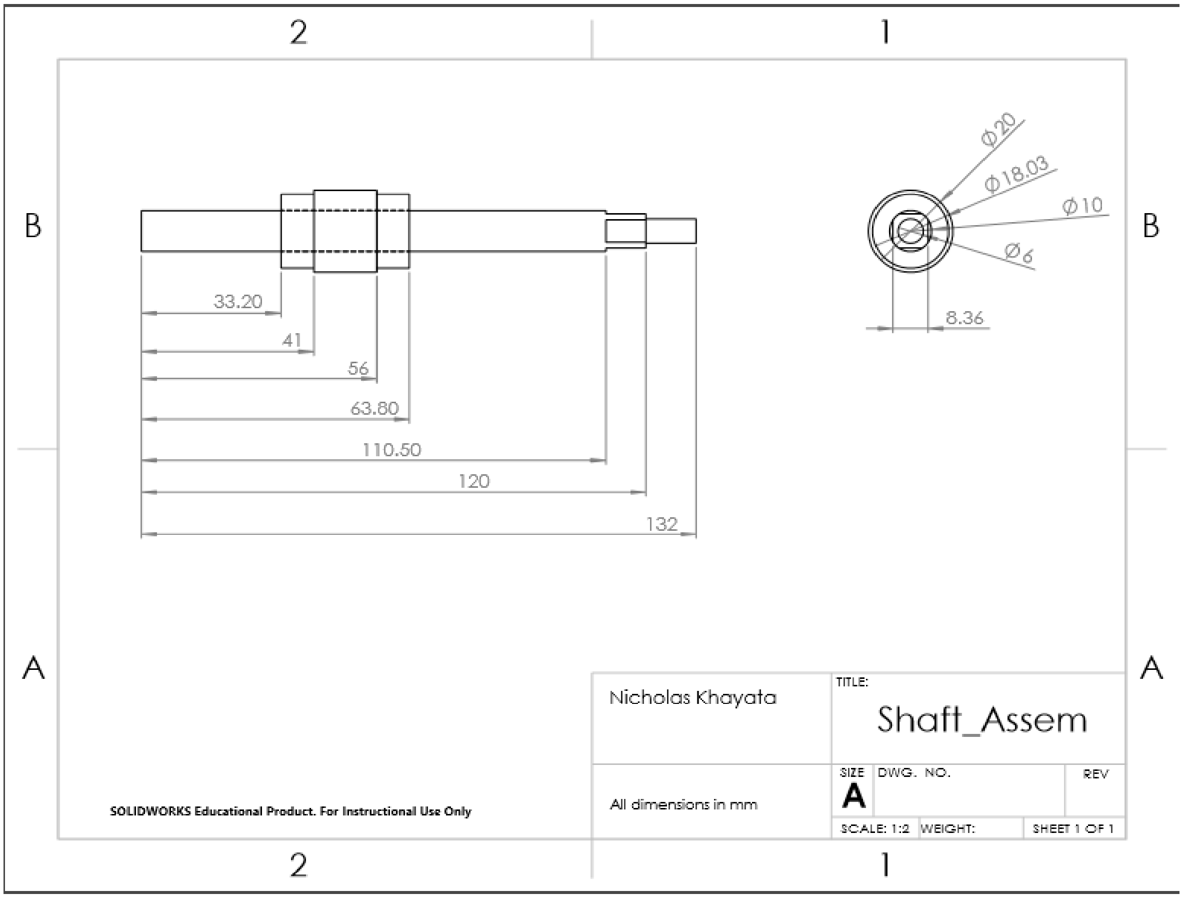

Figure 11: Drawing of shaft assembly