The Development of the HANSCycle RLT

Design for Manufacturing/Reliability/Economic Report

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Abstract

Team 8 is dedicated to developing a working HANSCycle, which implements the Reciprocating Lever Transmission (RLT) designed by Gordon Hansen. The goal of the RLT is to improve upon a few aspects of the traditional bicycle. These include two ‘dead spots’ at the top and bottom of a normal pedal rotation, as well as alleviating joint damage to the user from the ‘dead spots’. If successful, the HANSCycle will be both efficient and ergonomically comfortable for the user. Once a working prototype was developed, the team tested it and compared values such as torque, cadence, work, and speed, with values of a traditional bicycle. Initial testing has been promising, as the data suggests favorable power transfer from the user to the road. However, the current size constraints of the initial prototype have led to premature failures. This has been primarily due to the high levels of torque transferred through the RLT, which has caused several components to shear, including most recently, the output shaft. The torque produced by the RLT is greater than a traditional bicycle because of the increased crank-arm length. This project strives to prove that the Reciprocating Lever Transmission can perform as well as or even better than a traditional bicycle, while also causing less stress and damage to the rider’s joints.

Intro

While traditional bicycles have been redesigned and stream-lined, their overall function and design has not been altered much. This project aimed to change that. The Reciprocating Lever Transmission (RLT) aimed to improve the function of the traditional bicycle. Traditional bicycles are known to have two ‘dead spots’ at the top and bottom of a full pedal rotation, which causes stress and joint damage to the ride, specifically when traveling uphill. The RLT design uses dependent motion to ease stress on joints, while increasing power and torque. Using clipped-in shoes, a rider is able to create power on both the upstroke and downstroke, maximizing energy and efficiency. This report aims at breaking down various design aspects, and further explaining the thought process and goals throughout each aspect.

Design for manufacturing

When designing a product, its ability to be manufactured easily and efficiently is a very important parameter. This requires the design, no matter how intricate, to be rather simple to machine, as well as be made of accessible materials, realistic processes, and adaptability to market demands. With this said, the HANSCycle was designed with these aspects in mind.

One would likely begin the manufacturing of the HANSCycle by starting with the frame. The frame tubes must be measured, cut and notched individually, before being welded together. After the frame is assembled the components that need to be fabricated must come next. The fabricated components of the RLT include the crank arms, the chainring adapter, and the output shaft. The crank arms require CNC machining, cutting and notching, tapping and finally welding. The chainring adapter is first cut using the water jet, followed by milling to proper dimensions to allow for the sprocket to mate and finally the hexagonal broach is pressed to create the hexagon mating surface. The last fabricated component is the output shaft which is first turned to the proper dimensions on the lathe. Next it is heat treated to the desired case hardening specs and finally the drivers checked to make sure proper fitment exists after the change in size of the shaft due to heat treating. Next is the RLT itself, consisting of bevel gears, inner/outer housing, output shaft, and bearings. A large bevel gear should be assembled into the outer housing, and be secure. The five small bevel gears have exact holes in which to assemble each with a bearing. Once these have been assembled, the crank arm should be next. The crank arms will have brass oil-embedded bushings pressed into them. This is in what the output shaft will be held by and rotate within. The output shaft will also need the drivers for the ratchet and pawl to be welded and installed in opposite directions. This is necessary in order to allow for the RLT movement in the appropriate direction. Then the large bevel gear and housing can be slid onto the output shaft, and the output shaft can move through the crank arm bushings. The other side of the outer housing, containing the five smaller bevel gears should be placed on top of the crank arm set up, ensuring that the seams are flush. Then the other crank arm can be attached to the shaft through its bushing and secured with the grade 8 cap head screws. The chain ring adapter should then be put onto the shaft so that the hexagon pattern lines up properly. After which the grade 8 locking flange nut should be properly tightened to ensure it will not come loose.

When the frame and RLT have been assembled, the RLT must then be secured to the frame. There are three mounting tabs in double shear that are welded to the bike frame. This is to ensure that the RLT is lined up properly and secured. The RLT can then be bolted to the frame. The remaining off-the-shelf components, including the gears, brakes, handlebars, and seat, can be installed.

Overall the design of the RLT is more complicated than a traditional bicycle. However, due to the complexity of the reciprocating motion and the size constraints on the design there are very few ways to simplify the device. Due to the complexity of the RLT and its components, some of the manufacturing took a long time and several different tools needed to be bought or made. Since this is the case, if and when this design moves towards production, a large amount would need to be made to keep costs low and to justify the many one off components.

Design for reliability

Bicycles can, and often do offer years of service. They are fairly low maintenance mechanisms that are designed to last. In order for the HANScycle to be a feasible replacement for the traditional commerter style bicycle it must be designed and manufactured in a robust manner. This mean that there should be sufficient factors of safety, and good design practices throughout. The HANScycle was designed to be an everyday commuter with the ability to produce more torque than is produced in traditional bicycle. Fundamental engineering practices and modern computer aided design software allowed Team 8 to produce robust components that should last for years.

Crank Arms

The crank arms on the HANSCycle went several iterations before the final set used in the prototype was decided upon. Unlike the previous design, they are constructed of 1018 and 4130 steel which is much stronger than the aluminum used before. The crank arms were designed to be more visually appealing, cheaper, and less likely to fail then the original crank arms. The new crank arms being made of steel lowered the cost substantially while retaining the required strength. The new crank arms use a 1018 steel block that was cut using a CNC to match the required mating features of the RLT.

A piece of ¾ in. 4130 square tubing was then cut to the desired length and welded into a slot within the steel block. Lasly a notch was cut to house the shaft which was tapped to allow for the pedals to thread in. The new crank arms can be seen in the picture on the right in the figure above. When simulated in pro-engineer, a reasonable load would only cause a deflection of 3.2517 mm with no chance of failure. The keys and holes in the steel version also proved necessary, as the aluminum versions failed prematurely due to the stress applied by the riders. The strength of the steel keys and holes held up well to the task of powering the HANSCycle at full speed.

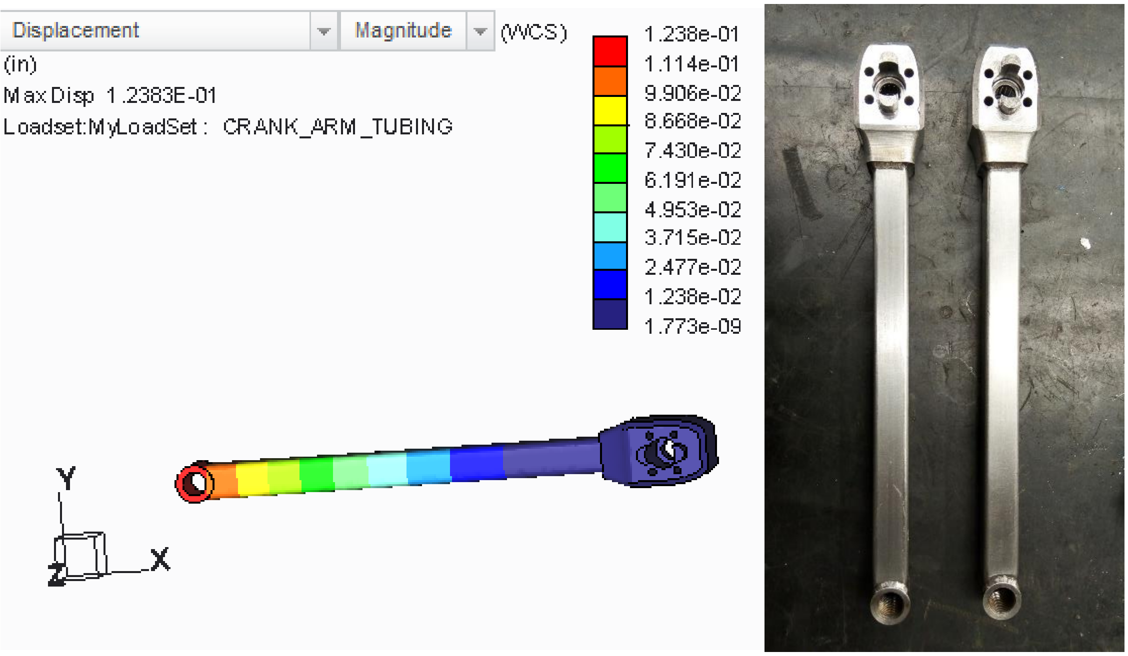

Figure 1: Crank arm Failure Analysis and finalized crank arms

Output Shaft

Another highly stressed component is the output shaft which is the core of the RLT. This shaft provides the link between input force into crank arms and the chain ring adapter which powers the chain ring, chain, thus back wheel of the HANSCycle. This component has failed before due to the size constraints of the RLT. The most recent iteration is an all steel design which will be 14mm in diameter rather than the 10mm shaft used before. This additional size will allow the will allow for a more robust design. The new output shaft has also been made out of 8620 alloy steel and has been case hardened. The heat treatment process will allow the steel to have a hard outer layer and a softer middle. This is necessary to ensure that the shaft will twist many times before failure but allows for the outside to spin freely in the bushings. The hardened surface also allows for the mating point of the shaft and the chainring adapter to remain constant and lowers the chance of any rounding on the hexagon points.

Figure 2: Original shaft vs new shaft (left), before and after heat treatment (middle), before and after the heat treated shaft was cleaned up (right).

In the first picture of the figures above one can see the size difference between the original output shaft and the new larger and more robust one. The middle picture shows the output shaft before being heat treated on the left and after on the right. The 8620 alloy steel was heated to 830°C and then water quenched. After the shaft was quenched it was put into the furnace again at 200°C to be tempered for 2 hours. The output shaft on the right in the second picture shows how the surface finish looked after this process. The picture on the right shows the difference in surface finish after the surface had been cleaned.

Figure 3: On the left is the furnace that was used and on the right is the power supply with the temperatures of each zone and the furnace.

Bicycle Frame

The frame of the HANScycle is constructed of 4130 alloy steel tubing. This strong steel is both light and tough and welds well. The completed design merely weighs 6 pounds and has a factor of safety of about 1.9 when a load of 250 pounds were on the HANScycle and it were to drop 3 feet. This was done as a worst case scenario where the rider was 250 pounds and the bicycle experience a sudden fall from 3 feet which is not recommended or very likely. Based on the FEA, the frame should last the rider a lifetime of enjoyment when properly cared for.

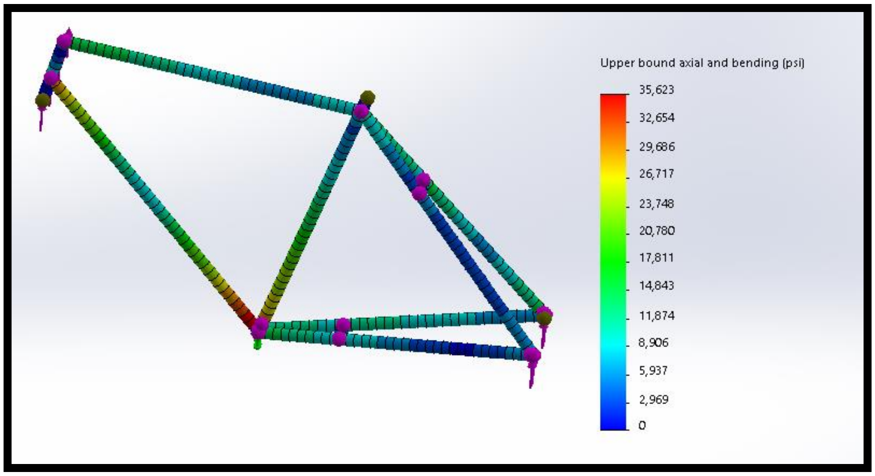

Figure 4: Bicycle Frame FEA

Design for economy

The total cost of the HANScycle prototype can be seen below in Table ####. The final cost for the components used in the final prototype are only $### which is well below the $2,000.00 budget allocated to Team 8. It should also be noted that the cost of both the components and the ram materials would significantly decrease if this bicycle were manufactured at a larger scale and manufacturing time would dramatically decrease which would help save money on production costs of a finalized production model.

The typical cost of commuter style bicycle is about

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