Hydraulic Bike Report 2024

Noah Flannery

Nico Navarro

Kyle Prysmont

Maggie McDowell

Alexander Whitfield

Abstract

The goal of this National Fluid Power Association (NFPA) sponsored Fluid Power Vehicle Challenge was to create a vehicle that is human-powered and contains a fluid-powered component. This vehicle must complete the competition without any catastrophic failure. Also, as far as the design of the vehicle goes, the improvements that must be made include making the bike weigh less and increasing the top speed of the bike. This report covers the design process, component selection, frame fabrication, bike assembly, testing, and results from the 2023-2024 University of Cincinnati's Hydraulic Bike Team's participation in the Fluid Power Vehicle Challenge.

Problem Statement

The Fluid Power Vehicle Challenge has the aim to challenge students to design and build a hydraulic system that uses human input. This design project is a submission to the Fluid Power Vehicle Challenge, sponsored by the National Fluid Power Association (NFPA). Specifically, the University of Cincinnati is in the Norgren Competition, as opposed to the Danfoss Power Competition. This annual event invites universities nationwide to undertake the design, fabrication, and racing of hydraulic vehicles. The competition itself is comprised of four separate challenges/races including a sprint, endurance, efficiency and regeneration race.

- **Sprint Race -** This event will demonstrate the ability of the vehicle to move a distance where the weight of the vehicle is proportional to the human propulsion.

- **Endurance Race -** This event will demonstrate the reliability, safety, replicability, and durability of the fluid power system design and assembly.

- **Efficiency Challenge -** This event will demonstrate the ability of the vehicle to effectively store and most efficiently use the smallest amount of stored energy to propel the unassisted vehicle the greatest distance proportional to the vehicle's weight. The final winner will be based on an efficient formula.

- **Regeneration Race** - This event will demonstrate the potential of stored energy and the regenerative braking capabilities of the fluid power system design. The team is given a maximum distance allowed to build up charge till or until their vehicle makes its initial stop going down the hill. Then all this charge will be released into the accumulator drive and the team that can travel the furthest off accumulator charge wins.

Project Plan

<u>Objectives</u>

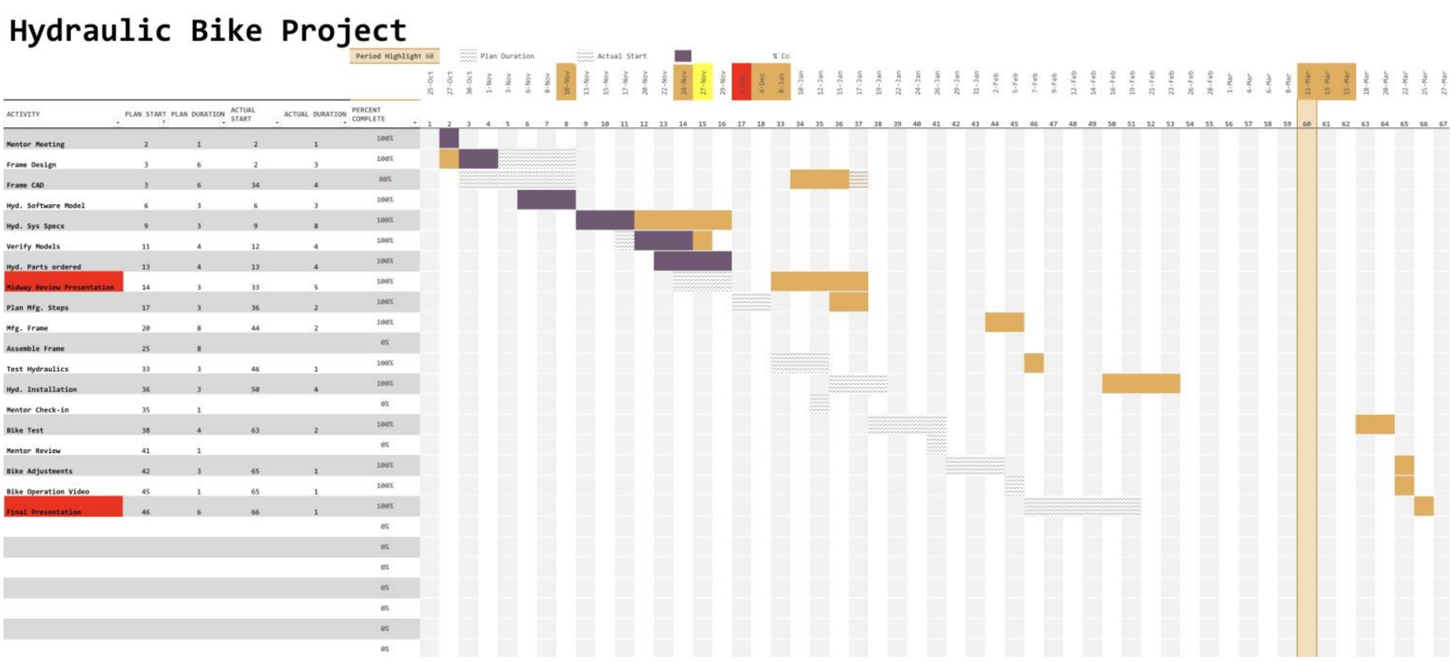
Our objectives for the bike were straightforward and aimed to build a strong foundation for the teams to follow. These objectives primarily stemmed from our limited communication with previous teams, lack of previous hydraulic experience, and known shortcomings of the 2022-2023 bike.

Weight – The frame from last year was challenging to maneuver and was close to the competition limits. There was an opportunity to increase efficiency, improve maneuverability, and reduce excess material.

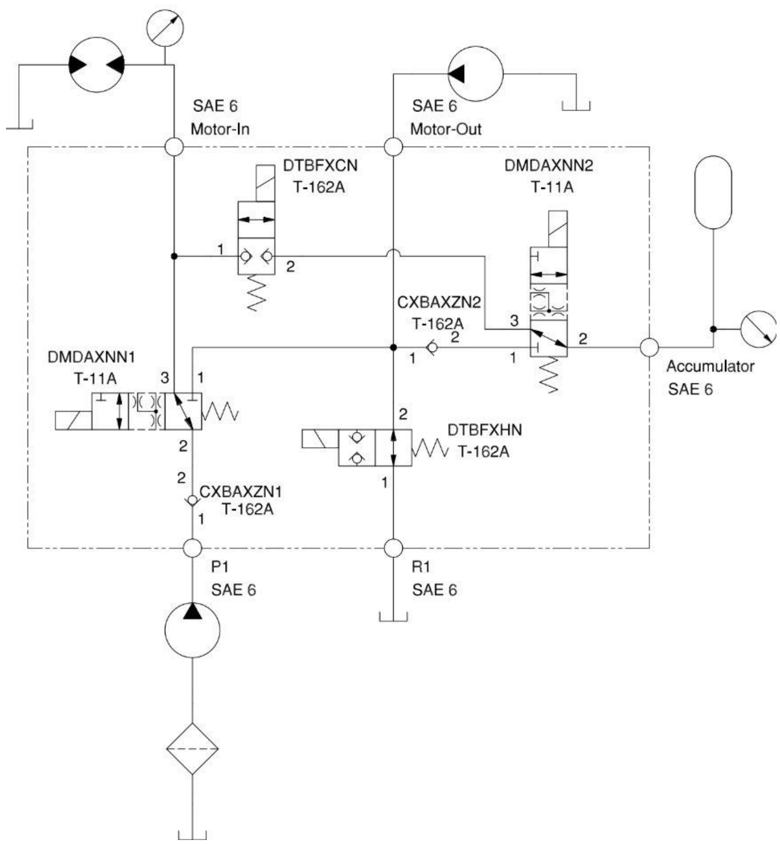
Speed – Videos watched from last year's bike showed a need to prioritize simplifying the drive system to reduce friction, and other mechanical losses. The principle being that less resistance meant enabling higher gear ratio later on, which in turn meant a faster bike.

Ease of Use – The bike's operation to the rider should be simple and reliable. It should not be possible to enter an invalid mode of operation, and in the event of error, the bike should fall into a safe state.

Project Timeline



Hydraulic Circuit Design



Frame Design

This year's frame design was different from the previous year's designs. We wanted to use a 3-wheel bicycle, but we also wanted a smaller and lighter weight design from last year's recumbent design. We chose to use a prefabricated bicycle design to retrofit the hydraulic circuit onto. For this, we chose a 3-wheel bicycle that is standard sitting up style as well as having a 3-speed hub gearbox that we can use for multiple speeds.

From this base frame, the pump mount was made first, this was made with 1/8th inch steel plate. The top plate the pump mounts to was made with slot mounting holes to allow the pump to move positions and act as its own chain tensioner. The bottom plate has a slot cut into it to allow the pump to outflow the fluid without interfering with the bicycle frame. For the chain, we chose to use the standard bicycle chain to power the pump since it only needs to be strong enough for the power of the human input.

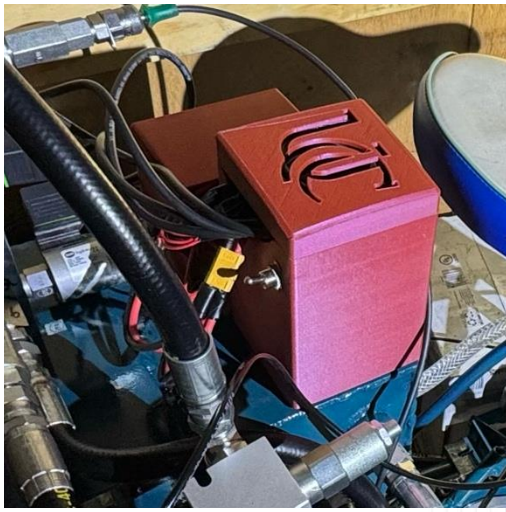
Next our accumulator holder and reservoir were made, this was made as one unit to minimize space usage. This was made to slip onto and bolt onto the bicycle frame for easier access for repairs. This was also made out of 1/8th inch thick steel plate for the accumulator holder as well as for the tank. The tank uses a breather on the top that also serves as a fill port. The tank has 2 return ports, a drain port as well as a supply port for the fluid system. The accumulator bracket has a slot cut into the top and bottom with a small plate of steel to bolt in and hold it. But it allows the accumulator to slide in and out of the bracket.

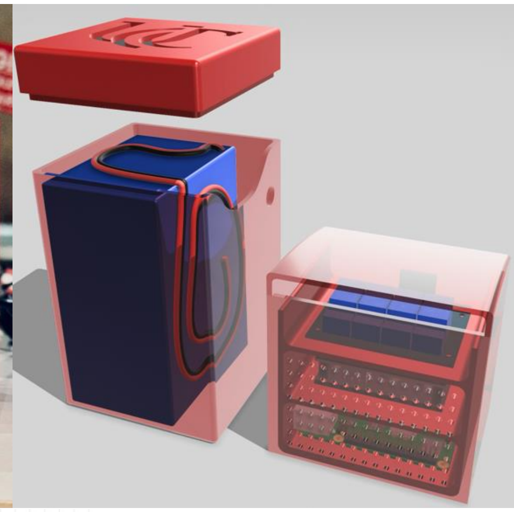
From this, the gearbox had to be modified to fit the new system. Due to using 41r chain and the chain width being too tight to fit on the original gearbox sprockets. Two 22 tooth sprockets were fitted onto the gearbox. One of the sprockets was to fit over the gearbox housing and then welded onto the drive shaft portion of the gearbox and the other one was welded to the other side of the gearbox housing.

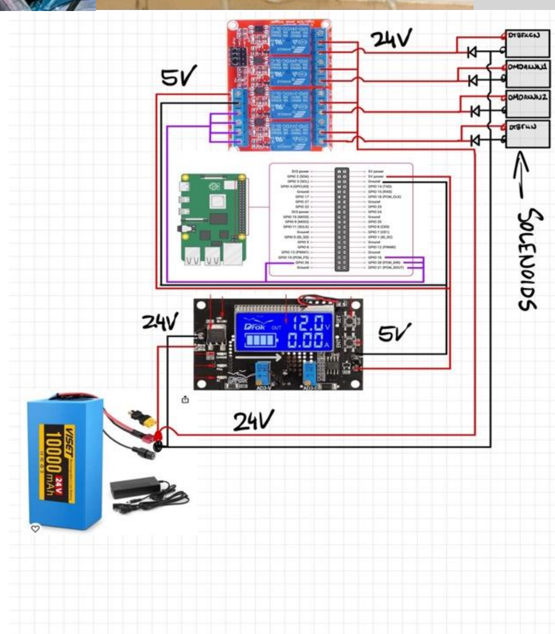
One problem we encountered was due to the gearbox having a neutral function when the wheels are spinning without the pedals, there was no ability for the motor to function as a regenerative source for the accumulator, so it was necessary to add an additional pump for the regenerative charging. This motor is driven directly by the axle shaft and under normal function it sends the fluid directly back to the reservoir until it's in regen mode. The accumulator and reservoir are fitted over the extra pump.

For the rear brake setup, a steel 1 inch tube was used to build a brake bracket over the drive wheel and perform the same as the front brake.

Electrical Components







A software controlled, electronic solution was implemented to actuate the manifold solenoids and switch modes of operation. The system consisted of the following components:

Component	Description
Battery	24 Volt, 10 Ah, Lithium. BMS Integrated
Buck Converter	Variable DC, with current limiter
Raspberry Pi 4	A convenient computer that can be powered with only 5V and has the interface to control the solenoids.
5V 4 Channel Relay	5V supply, high trigger relays
4 * Solenoids	24 Volt 0.6 to 0.8W

The Raspberry Pi hosted a Wi-Fi service to which any phone could pair and control the bike. A web interface, consisting of four large buttons (one for each corresponding mode) would be displayed in normal operation of the bike. Once a mode is selected, the button changes color to indicate the bike has responded to the request. The process takes a fraction of a second and is perceived to be instant. The Raspberry Pi directly controls the solenoids via a relay. Activating only the solenoids that are valid for the requested mode, the software makes it impossible to select a combination that is not valid or could cause harm to the bike or rider. Further, by using a wireless system, significantly fewer cables are needed from the rear of the bike running to the front.

Lesson Learned

Throughout the duration this project, the lessons we've learned and would like next year's team to take into consideration for the bike include incorporating the reservoir into the bike frame to save space and refine the design, using the accumulator to keep the system pressurized to decrease lag between pedaling and the bike moving, and using a variable displacement pump to allow for a more adaptable system.

Conclusions

In most of the competitions, our bike demonstrated satisfactory performance but faced challenges during the endurance race. Pedaling the bike, while in direct drive, proved to be strenuous on flat terrain and virtually unfeasible on inclines, a limitation attributed to the positioning of filtration components and the gearing ratio. However, a notable triumph was achieved as our bike Secured first place in the Regain race, marking a significant accomplishment. Notably, we also successfully achieved nearly all of our design objectives, including reaching the finish line without encountering failures, optimizing the cost-effectiveness of the bike, and surpassing the speed of previous iterations developed by previous year's team.

References

https://nfpafoundation.org/wp-content/uploads/2023/08/2024-FPVC-Overview-Rules-and-Awards-v.2.pdf