University of Illinois at Urbana-Champaign

Parker Hannifin 2014/2015 Chainless Challenge

Project Summary

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The University of Illinois has competed in the Parker Hannifin sponsored Chainless Challenge competition consecutively for the last three years. This year continued that tradition with a newly designed and built hydraulically-driven bicycle. The goal of the Chainless Challenge competition was to design a vehicle that ran on a human propelled hydraulic or pneumatic system rather than the traditional chain driven bicycle. A bicycle with a chain present anywhere in the system was heavily penalized and could not place higher than third in the Challenge. The vehicle was required to move with power input directly by a single rider or with energy stored by the rider via accumulators. In addition, the bicycle was also required to weigh less than 225 pounds (without hydraulic fluid) and be safe to ride.

The abilities of the vehicle were tested in three different racing competitions. Before each competition, the team was allowed 10 minutes to store as much energy in the hydraulic system as possible. The first competition was the sprint race in which the rider pedaled the bicycle, with or without the assistance of stored power, for 200m. The goal of this race was simply to have the fastest time. The second competition was the efficiency challenge in which the rider ran the bicycle off the stored energy in the hydraulic system. The goal of this race was to travel as far as possible without pedaling and the race ends once the bicycle stops. The winner of the race was calculated using a scoring matrix that accounts for the weight of the rider, the distance traveled, and the gas pre-charge pressure and volume of the accumulators. The final competition was the time trial which was a 6.2 mile course with a slalom section. The goal was to be the team to finish in the least amount of time. These three races were designed to test different aspects of the bicycle: the sprint race tested the vehicle's acceleration and maximum speed, the efficiency challenge tested the bicycle's efficiency in converting stored hydraulic energy into kinetic energy, and the time trial tested the ability of the bicycle to be used for a prolonged period of time and the maneuverability of the vehicle in a slalom section.

In order to facilitate the building of the vehicle, the team defined several objectives to guide development, namely – use no chain, keep the vehicle under the 225 lb weight limit, institute an electronic control system with a default direct drive path, integrate a regenerative braking system, and make the vehicle easy to pedal with a cruising speed of approximately 13 mph. These goals were achieved by dividing the team into three subcategories. This allowed the team to work in conjunction on developing different parts of the vehicle. The three systems that made up the vehicle – called the FL.E.E.T. (Fluid Efficient Energy Transport) – were the power transmission system, the hydraulic system, and the electronic control system.

The power transmission team worked on developing both the front and rear gear trains which helped to transmit power from the pedals to the pump and the motor to the drive wheel, respectively. Additionally, the power transmission team was in charge of making sure that the frame would be able to withstand the forces and moments that would be introduced in the system. The front gear train was

composed of 5 gears that connected the pedals, an internal gear hub, and the pump. This gear train, with the integrated 8-speed gear hub, could produce gear ratios from 4.22-12.92. These different gear ratios were useful for each of the different functions of the vehicle, such as charging the accumulators and directly pedaling the vehicle. The rear gear train had a fixed gear ratio of 4:1 and used three gears to relay torque from the motor shaft to the drive wheel of the vehicle.

The hydraulic system was composed of a pump, a motor, two accumulators, a reservoir, various hose and fittings, and a manifold. The manifold acted as a hydraulic switchboard, and using a series of valves it controlled flow into different aspects of the hydraulic system. When the vehicle was in direct drive, the manifold directed fluid flow from the pump into the motor, thus driving the rear wheel. The coasting path of the vehicle was passive. This meant that every time the rider stopped pedaling, the manifold would automatically pull fluid from the reservoir into the motor and keep cavitation from occurring in the system. When the vehicle was in accumulator charging or discharging mode, the manifold directed fluid into or out of the accumulators. The accumulator charging process stored energy via fluid power. The accumulators had a nitrogen bladder that compressed and increased in pressure thus storing the energy. The final hydraulic circuit was the regenerative braking path, which used the inertia of the slowing vehicle to drive the motor as a pump and push fluid into the accumulators, storing energy.

The electronic control system was composed of two parts – the controller which was a custom built microcontroller subsystem mounted on the rear of the vehicle and the user interface which was mounted on the handlebars. The purpose of the controller was to correctly actuate each valve when the command was given at the user interface. The user interface allowed the rider of the vehicle to select the desired function of the hydraulic circuit and the preferred accumulator using several toggle buttons. It also gave live feedback on the pressures in the accumulators and what mode the vehicle was in.

These three systems when working together composed a fully functioning hydraulic vehicle that could be pedaled like a normal bicycle and store energy through fluid power. The team at the University of Illinois was given 8 months to design and build this vehicle for competition in the 2014/2015 Chainless Challenge competition in Irvine, California on April 8-10, 2015. The team is happy to report that participation in the Chainless Challenge was completed successfully. The team performed well in the competition: placing second overall and in the top three in 10 of the 11 categories.