DRIVETRAIN

The 2019 drivetrain design chosen is a rear wheel drive system that employs a Gaged Engineering Continuously Variable Transmission (CVT), custom gearbox, and CV axles from a Polaris Ranger. When designing and selecting components for the drivetrain system, reliability, weight, and cost were the most important aspects assessed.

CVT - For the 2019 competition year, the drivetrain team chose a Gaged GX9 CVT drive and driven pulley to transmit power from the engine to gearbox. A CVT was chosen as the transmission as it supplies power continuously from the engine to the wheels. The different terrain conditions and events in the competition require different gear ratios, which are changed best by the CVT as it doesn't pause power delivery. Specifically, the Gaged GX9 CVT was chosen because of its high tunability and low weight of both the drive and driven pulleys. Additionally, the 3.9 to 0.9 starting and ending ratios of the Gaged CVT system allowed for a reasonable gearbox ratio given expected drivetrain loading conditions.

The design phase of the CVT consisted of tuning and data acquisition. The Olav Aaen's Clutch Tuning Handbook was referenced in learning the tuning process. The primary goal for tuning was set to achieve an engagement RPM that matches the engine torque peak RPM. This peak RPM was obtained from the engine specifications, and was found to be around 2700. This RPM is to be achieved by generating a MATLAB code and identifying the spring that would produce such a RPM. The code calculated the force applied by the initial compression of the drive spring found using estimates of the spring constant and compression distance. This force was equated to the flyweight centripetal force and the flyweight velocity was found. The flyweight angular velocity when the forces are balanced is the engagement RPM. Using this method, the theoretical engagement RPM was found. The process was reversed to find the appropriate spring constant for an engagement RPM equal to torque peak RPM.

The secondary goal was fine tune the shift out RPM. Shift out RPM is desired to be equal to engine horsepower peak RPM, which was discovered to be 3800 from the engine specs. First, the centripetal force by the flyweights at that RPM was calculated. Then, the force applied by the driven spring was calculated. Finally, these two forces were summed and equated to the side force from the driven clutch. The balance was used to find the ideal driven spring constant for the power peak RPM.

The ideal springs are to purchased and tested. Testing includes using a tachometer built using an arduino and hall-effect sensors on each pulley. The data is recorded onto an SD card, providing the ability to graph vehicle speed vs RPM. The graph can be used to estimate the experimental engagement RPM and shift out RPM. The testing will serve as a verification of the generated Matlab program.

GEARBOX - For the 2019 competition year, the drivetrain team decided to design and manufacture a custom gearbox. There were multiple factors that guided the team's decision: reducing the weight of the drivetrain system, not having to mix and match parts from various manufacturers, having a custom gear ratio, and to further develop the custom gearbox design from last year. The drivetrain team decided to design the gearbox with an 10:1 reduction, spur gearing, forward capabilities, and no differential. Spur gears were chosen over helical gears because they do not produce any axial thrust, allowing for a simpler and lighter case design. The reverse capability and limited slip differential were removed from this year's gearbox design because of our improved steering design and to decrease the complexity of the gearbox design

When designing the gearbox internals, basic stress analysis and the AGMA equations were used for the shafts and gears, respectively. The components were assumed to experience the worst-case scenario loading: maximum torque and power at maximum engine speed for the desired lifetime of the gearbox. The failure modes considered for the gears were contact and tooth bending whereas the failure modes for the shafts were torsion and bending. Failure due to static loading and fatigue for the gearbox internals were verified using Solidworks FEA testing. The team opted to use custom cut gears and shafts supplied from Gear Enterprises to ensure the interfaces of the internals would match correctly. The case was designed to be manufactured out of billet aluminum using a 5-axis CNC mill. This manufacturing method was chosen since this is a low volume production run and high precision was needed for the shaft spacing. Alternative manufacturing methods for the gearbox case such as casting were considered but were not chosen based on the increased cost, increased lead time, and finish machining complications.

CV AXLES - The axles that we chose to run this year were the 2011-2014 Polaris Ranger 4x4 CV axles based on their size, the rated horsepower of the axles, and the ease with which technical information about the axles could be obtained. The rated horsepower of the Ranger CV axles is 68 HP which is almost seven times the power output of the Briggs and Stratton engine (10 HP). Even though the axles are rated for a much higher power output making them extremely robust for Baja applications, their relative small size and weight allow the axles to be easily integrated into the drivetrain design. The CV joint design of the axles allow for maximum a operating angle of 30 degrees that will be critical to this year's suspension and steering design. Acquiring design information regarding the axle spline pattern, CV joint size, and maximum joint articulation angle was easy thanks to Polaris's partnership with the Baja program which aided our design process. The overall feasibility and durability of the axles proved to be a great addition once more to our drivetrain design.

The mounting points for the drivetrain system were set up horizontally instead of vertically in an effort to save chassis weight and allow for easier drivetrain installation in the chassis. A net weight of 5 lbs was saved from the chassis by removing members solely dedicated to mounting drivetrain components.

BRAKE SYSTEM - The design for the 2019 braking system maintains many of the fundamental design points from previous years, while also adding improvements and modifications. The goal for the year was to bring in completely new parts and designs to replace the previous design, and ensure that the car could stop effectively and achieve wheel lock.

The system contains two master cylinder setups, with one handling the two front brakes and the other devoted to the rear brake. In contrast to last year's ¾'' diameter, each master cylinder now has a bore diameter of ⅝'', which results in increased pressure on the line and therefore an increase in forces applied to the brake. The three calipers (two front and one rear) are Wilwood DH4 floating calipers with 1.5'' diameters, which allow for compact placements without sacrificing effectiveness. A balance between front and rear set at 80/20 was implemented with a bias bar while easily allowing for change. Force calculations were made based on the 80/20 bias as an over design assuming that most of the braking force comes from the front brakes. In practical use, the bias bar will be set closer to 65/35 but for the calculations a larger bias was considered in the case of one of the brakes failing. The rear brake is also designed to be capable of applying as much force as the front two, even though this is much more than necessary. These design provisions were made to ensure that the other two brakes will be able to recover in the case of a brake failure.

Steel brake lines were also added to replace the worn braided cables, increasing the durability and strength of the lines under stress and protecting them from external debris. The rotors sport a new design, with a 6'' diameter, ⅛'' thickness, and a greater focus on heat dissipation. The rotors are now made from 1018 steel, an alloy that is strong and easy to machine, to further improve heat dissipation. The pedal box consists of two 4130 steel plates mounted directly to the front chassis bars. A center plate made of 1018 steel meets between the two. The master cylinders and bias bar are housed on this center plate. The design is small and lightweight to prevent hindrance to the drive and unnecessary weight to the vehicle. The pedal levers were modified to increase the pedal ratio from 5:1 to 8:1. This change was instrumental in decreasing the required amount of pressure applied to the pedal from 150 to 60 pounds while still achieving wheel lock.