# Utility Terrain Vehicle (UTV)

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Cole Gatman

April 2021

Thesis Advisor:

Professor Amir Salehpour

## TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

# ABSTRACT

The Utility terrain vehicle (UTV) Is a widely saturated market with many differing styles of vehicle. The goal of this project was to create a relatively cheap and reliable alternative to commercially available UTVs. While lacking in some of the luxuries that are offered by modern UTVs, the group managed to deliver on this idea. Splitting into three areas (frame, body panels and brakes, and suspension and drivetrain) a simple design was created for the following year's seniors to fabricate. To accompany the design, part and assembly drawings were created to assist in the fabrication. Lastly, all purchased components were compiled into a document for reference.

# PROBLEM DEFINITION AND RESEARCH

### *PROBLEM STATEMENT*

For our senior design project, we will be completing the design, manufacturing prints, and creating a list of overall components required for assembly of the UTV. The aim is to improve upon and/or redesign the current braking system, drive train, and suspension in an affordable and maintainable way using CAD tools. The group will then pass on a full list of components along with manufacturing prints to next year's senior design group.

# RESEARCH

### *BACKGROUND AND SCOPE OF THE PROBLEM*

Many improvements can be made to the modern utility terrain vehicle. We chose to narrow our approach to three main components within the typical UTV: the braking, drive train, and suspension. More specifically, we would like to focus on maintenance and adjustability of each of the three components mentioned above. We aim to make an affordable and simplistic product, perhaps even allowing the operator to adjust "on the fly" without taking their UTV to a mechanic.

Anyone who owns or operates a UTV on a regular basis is impacted by this problem. Mainly, our target audience would be individual users with a more adventurous or on the go lifestyle which might require a quick change or adjustment of suspension or drivetrain parts. In addition, anyone with limited free time who would like to spend it using their UTV instead of taking hours to adjust for different terrain and conditions.

Anybody who has gone for a joyride in any vehicle knows that there is no problem worse than getting ready to go and having to fix an issue with your vehicle. This issue only gets worse when you find the perfect spot to ride your UTV and find out that you need to adjust your suspension for the terrain. This results in a ride back home and a whole lot of disappointment for the user.

Currently, the maintenance options for a UTV come primarily from the manufacturer or aftermarket products which can cost the consumer a pretty penny. The closest quick fixes are very expensive and still require a handful of tools specifically designed for a single purpose (2).

We have identified a few areas where the current solutions are inadequate:

1. Convenience: The ability to adjust the suspension travel and overall height of the chassis relative to the wheels is selectively available, however none of the solutions allow for adjustment without a separate tool. This is one feature which we hope to add to our UTV.

2. Speed: Many current methods of adjustment and maintenance require the consumer to set aside an entire day. We hope to make our maintenance as fast and accessible as possible.

## *CURRENT STATE OF THE ART*

The most common transmission around today is the Continuously Variable Transmission, or CVT for short. Unlike traditional automatic transmissions, continuously variable transmissions do not have a gearbox with a set number of gears, which means they do not have interlocking toothed wheels (6). The most popular system among CVTs uses a combination of pulleys which ride along cones to achieve a near infinite combination of gearing with no distinct "gears" like other types of transmissions. CVTs are used in modern cars with automatic transmissions to improve fuel economy and smooth the transition between gears when up or downshifting.

Continuously variable transmissions are not without their fair share of issues, however. There have been a few large class-action lawsuits against Nissan, Honda, and Suzuki. These lawsuits allege that the CVTs "shake, jerk, hesitate, lag, decelerate and finally fail, requiring expensive transmission replacements." (7)

The more classic transmission option is a planetary gear transmission. This system utilizes a group of planetary gears to adjust the output speed and torque of a shaft connected to the rear differential. Locking a single component of a planetary gearing system yields a unique output, but when combined in series, they allow for anywhere from a 3-speed to a 6-speed transmission (8). This system is heavy relative to the CVT and offers few advantages with respect to power.

### *END USER*

The ideal end user will be 20 to 60 years of age. They will have a medium income. Male or female and able bodied. Some minor mechanical knowledge will be required, but no more than the average individual who changes the oil on their car. The finished product will not accommodate any specific medical disabilities and will be ergonomically suited for a person in the specified age group.

## *CONCLUSIONS AND SUMMARY OF RESEARCH*

Transmission technologies are sophisticated enough that few improvements can be made. With that being said, the group decided to purchase a complete transmission and focus the majority our design efforts in other areas.

# QUALITY FUNCTION DEPLOYMENT

## *CUSTOMER FEATURES*

Between the 3 people working on this project, a total of 45 people were surveyed. The first survey question asked for the survey taker's perceived mechanical aptitude, allowing us to weigh responses of engineers and mechanics slightly higher. Following this question, they were asked if they had ever owned a UTV. These two questions allowed us to calculate our weighted score. We chose to weigh anyone who rated their mechanical aptitude higher than a 3 as 1.25, while responses below were weighed as 1. The rest of the survey asked the survey taker to rate the importance of customer features. After averaging the answers together and rounding to the nearest decimal, a table was created (see Table 1)

| Customer Features | Weighted Score |
|---|---|
| 1.) Maintenance | 4.1 |
| 2.) Safety | 4.3 |
| 3.) Braking | 3.5 |
| 4.) Cargo Capacity | 3.7 |
| 5.) Transmission | 3.6 |
| 6.) Steering | 3.1 |
| 7.) Suspension | 3.9 |
| 8.) Investment Cost | 4.3 |

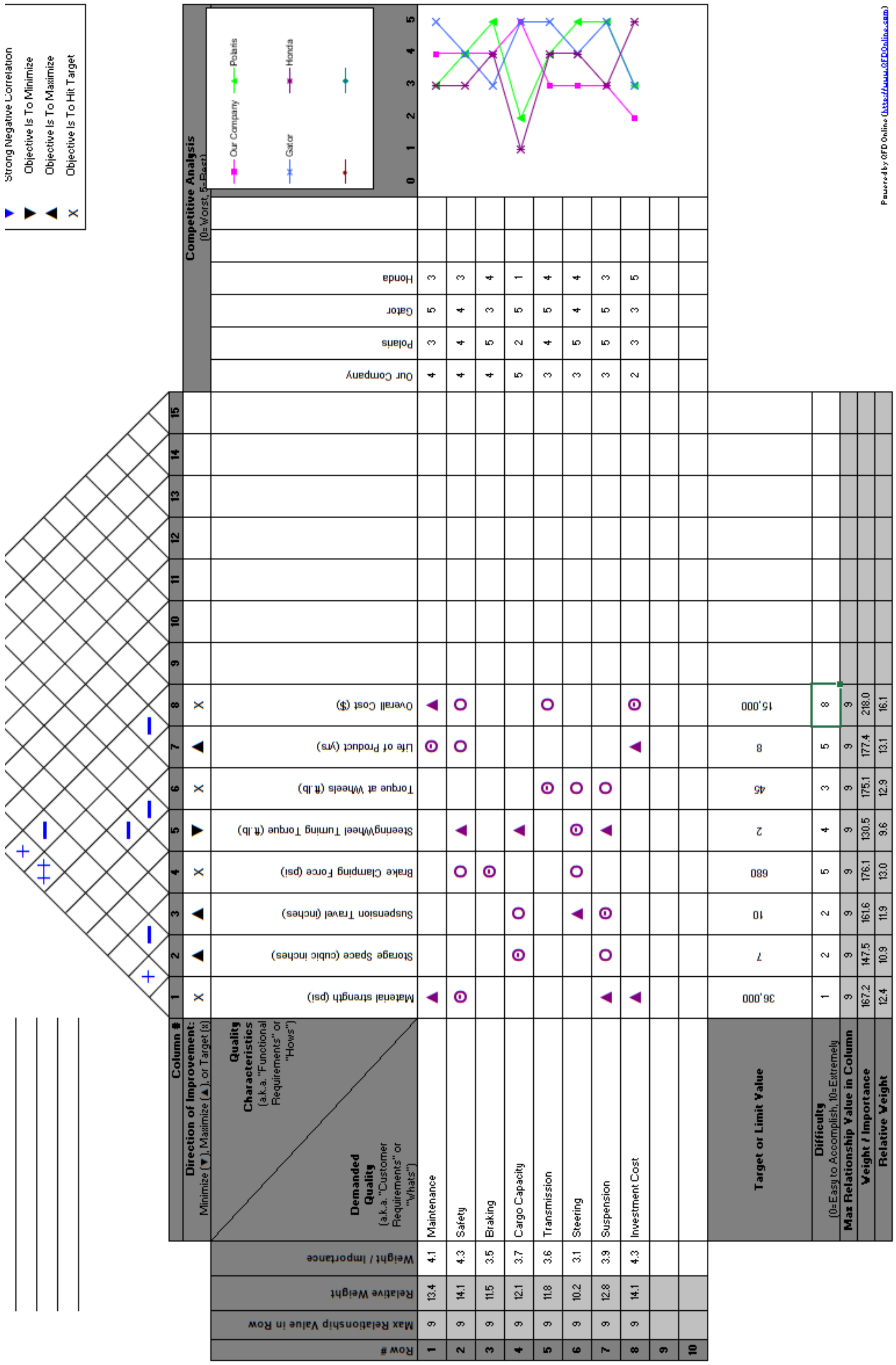
*Table 1*

## *ENGINEERING CHARACTERISTICS*

Through further discussion and after a review of our survey responses, the group had to narrow down exactly how to describe the customer features in terms of measurable benchmarks, and units to describe these benchmarks. This led to the following list of engineering characteristics.

1.) Material Strength (psi)
2.) Storage Space (cubic inches)
3.) Suspension Travel (inches)
4.) Brake Clamping Force (psi)
5.) Steering Wheel Turning Torque (ft.lb)
6.) Torque at Wheels (ft.lb)
7.) Life of product (yrs)
8.) Overall Cost ($)

# *HOUSE OF QUALITY*

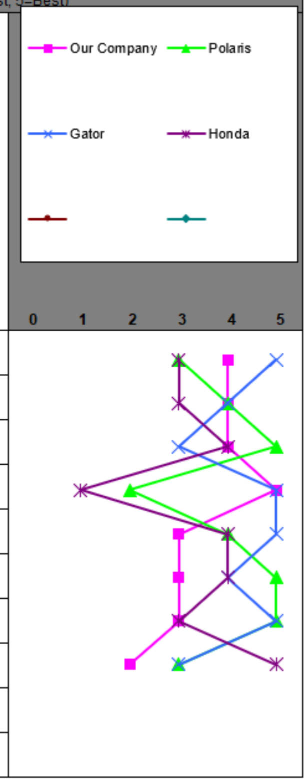


| Row # | Max Relationship Value in Row | Relative Weight | Weight / Importance | Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats") | Material strength (psi) | Storage Space (cubic inches) | Suspension Travel (inches) | Brake Clamping Force (psi) | SteeringWheel Turning Torque (ft.lb) | Torque at Wheels (ft.lb) | Life of Product (yrs) | Overall Cost ($) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Column # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | | | Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x) | x | ▲ | ▲ | x | ▼ | x | ▲ | x |
| 1 | 9 | 13.4 | 4.1 | Maintenance | ▲ | | | | | | ⊙ | ▲ |
| 2 | 9 | 14.1 | 4.3 | Safety | ⊙ | | | O | ▲ | | O | O |
| 3 | 9 | 11.5 | 3.5 | Braking | | | | ⊙ | | | | |
| 4 | 9 | 12.1 | 3.7 | Cargo Capacity | | ⊙ | O | | ▲ | | | |
| 5 | 9 | 11.8 | 3.6 | Transmission | | | | | | ⊙ | | O |
| 6 | 9 | 10.2 | 3.1 | Steering | | | ▲ | O | ⊙ | O | | |
| 7 | 9 | 12.8 | 3.9 | Suspension | ▲ | O | ⊙ | | ▲ | O | | |
| 8 | 9 | 14.1 | 4.3 | Investment Cost | ▲ | | | | | | ▲ | ⊙ |
| 9 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| **Target or Limit Value** | 36,000 | 7 | 10 | 680 | 2 | 45 | 8 | 15,000 |
| **Difficulty** (0=Easy to Accomplish, 10=Extremely Difficult) | 1 | 2 | 2 | 5 | 4 | 3 | 5 | 8 |
| **Max Relationship Value in Column** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **Weight / Importance** | 167.2 | 147.5 | 161.6 | 176.1 | 130.5 | 175.1 | 177.4 | 218.0 |
| **Relative Weight** | 12.4 | 10.9 | 11.9 | 13.0 | 9.6 | 12.9 | 13.1 | 16.1 |

**Competitive Analysis**
(0=Worst, 5=Best)

| Our Company | Polaris | Gator | Honda | | |
|---|---|---|---|---|---|
| 4 | 3 | 5 | 3 | | |
| 4 | 4 | 4 | 3 | | |
| 4 | 5 | 3 | 4 | | |
| 5 | 2 | 5 | 1 | | |
| 3 | 4 | 5 | 4 | | |
| 3 | 5 | 4 | 4 | | |
| 3 | 5 | 5 | 3 | | |
| 2 | 3 | 3 | 5 | | |
| | | | | | |
| | | | | | |




## *PRODUCT OBJECTIVES*

Based on our House of Quality the engineering characteristics are listed below in order of importance, with the first on the list being most important

1.) Overall Cost (16.1%)
2.) Life of Product (13.1%)
3.) Brake Clamping Force (13.0%)
4.) Torque at Wheels (12.9%)
5.) Material Strength (12.4%)
6.) Suspension Travel (11.9%)
7.) Storage Space (10.9%)
8.) Steering Wheel Turning Torque (9.6%)

Our group has certainly set some ambitious goals, but there is no doubt in our mind that we will be able to at the very least achieve these goals, with the target being to exceed them in the design of our UTV.

# DESIGN

## *DESIGN ALTERNATIVES AND SELECTION*

The first concept began with a step file of manual transmission gearing. This design is based off the manual transmissions used in cars like the Toyota Supra and later the Nissan Skyline. All the gears and bearings are converted from step files allowing for a nice assembly and rendering which can be seen below. It is extremely uncommon for a UTV to have a manual transmission, but those that do offer a more performance and sporty option. While a manual transmission may suffice in your car, we felt that this would not be the ideal design for our UTV. An example can be seen in Figure 1.

*Figure 1*

The next concept is based on an Allison 1000 automatic transmission. These are used in medium duty applications, most notably on the Ford F-650 trucks. This alone made it a very good candidate for our UTV. The medium duty transmission would allow for plenty of load in terms of storage without having the weight of a heavy-duty transmission. This would normally make it our selection for the transmission design, but to make an easily maintainable UTV, we felt that the following option would be the best fit. An example can be seen in Figure 2.

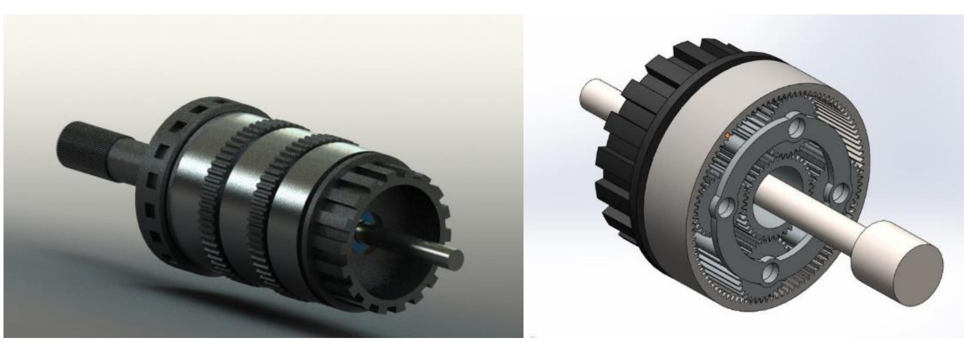


*Figure 2*

The last design is the Continuously variable transmission (CVT). The belt system on the CVT allows for a near infinite amount of gearing options, meaning the UTV will be suitable for on and off-road conditions. The relatively simplistic design allows anyone with mechanical experience to maintain it, as most of the controls are in terms of electrical signals. Lastly, the CVT is the lightest and smallest option available, allowing for easy install and operation. An example can be seen in Figure 3.

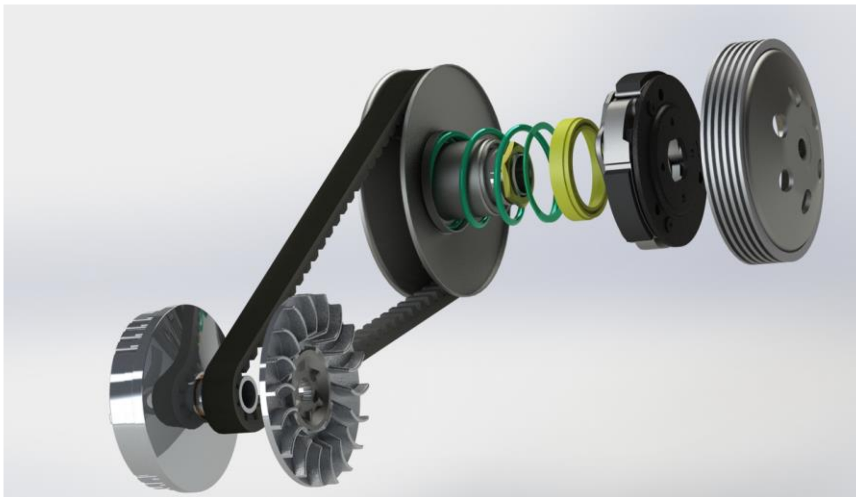


*Figure 3*

## ENGINEERING CALCULATIONS

$$Wheel\ circumference: 20\ in * pi = 62.83\ inches\ or\ 5.25\ feet$$

$$5.25\ feet = 1\ revolution\ of\ the\ wheel$$

$$Revolutions\ per\ mile = \frac{5{,}280\ feet}{5.25\ feet} = 1{,}006\ revolutions/mile$$

$$Wheel\ Speed = \frac{miles}{minute} * \frac{revs}{mile} = \frac{35\ miles}{hr} * \frac{1\ hr}{60\ minutes} * \frac{1{,}006\ revs}{mile}$$

$$Wheel\ Speed = 587\ rpm$$

$$Max\ Engine\ rpm: 3750$$

$$Desired\ Output\ rpm: 587$$

$$Reduction = \frac{587\ rpm}{3{,}750\ rpm} = 1: 0.156\ \approx 6.5: 1$$

## BUILD AND TEST

The group concluded early in the semester that the group would not be able to complete the fabrication of this UTV. Instead, we would do 3 things as a substitute; we would complete the design of the entire UTV, create process prints for next year's group, and complete a parts list for purchased components. The group, along with our advisor, felt that this would be plenty of work, and would set next year's group up nicely to complete the fabrication.

### *TEST PROCEDURE AND CRITERIA*

Due to the pandemic, the group was unable to test the engine. Instead, the engine behavior was approximated using existing documentation for a 10Hp engine. The only official Briggs and Stratton documentation that existed was for a 10Hp 3600RPM engine. To get the values for the 8Hp engine, the data needed to be normalized and scaled Using a Python script, data points from the 10Hp graph were used to create a rough curve based on our point inputs. Utilizing the same program, the data was interpolated, to give a continuous curve for the 10Hp data. From this point, the data was scaled down to the 8Hp engine, and a curve was developed using a 7th order polynomial which passed through all the points within an acceptable margin of error.

### *TEST RESULTS AND FINDINGS*

The peak torque output was chosen from our new curve. This was found to be 17.649Nm and occurred at 2496.667 RPM. The torque converter had a 1:3 ratio prior to reaching max speed, which gave a torque value of 52.948Nm. This value would drive the remainder of the drivetrain calculations.

## *FINAL DESIGN AND ENGINEERING CALCULATIONS*

The final solution included a combination spur gear reduction and chain drive. The following slides cover calculations which were done to ensure that this design would work in practice. As a quick run through, here were the steps taken for our gear calculations, the calculations themselves can be seen in Figures 4-7.

"Solve for the module given some initial guesses on ratio and center distance"

$a := 106.25 \cdot mm$ "Center Distance Guess"

$Z1 := 18$ "Initial Value for Pinion"

$SpeedRatio := 3.88$ "desired Speed Ratio"

$Z2 := Z1 \cdot SpeedRatio = 69.84$ "Calculated number of teeth"

$Z2 := 70$ "Actual number of teeth available from catalog"

$module := \frac{2 \cdot a}{(Z1 + Z2)} = 2.415\ mm$ "Calculated Module"

$module := 2.5 \cdot mm$

$Ratio := \frac{Z2}{Z1} = 3.889$

$\alpha := 20 \cdot deg$

$Zmin := \frac{2}{(\sin(\alpha))^2} = 17.097$

$d1 := module \cdot Z1 = 45\ mm$

$d01 := d1 + 2 \cdot module = 50\ mm$ "Outside diameter Gear 1"

$db1 := d1 \cdot \cos(\alpha) = 42.286\ mm$

$d2 := module \cdot Z2 = 175\ mm$

$d02 := d2 + 2 \cdot module = 180\ mm$

$db2 := d2 \cdot \cos(\alpha) = 164.446\ mm$

$a := \frac{(Z1 + Z2) \cdot module}{2} = 110\ mm$ "Center Distance"

*Figure 4*

$$\varepsilon := \frac{\sqrt{\left(\frac{d01}{2}\right)^2 - \left(\frac{db1}{2}\right)^2} + \sqrt{\left(\frac{d02}{2}\right)^2 - \left(\frac{db2}{2}\right)^2} - a \cdot \sin(\alpha)}{\pi \cdot module \cdot \cos(\alpha)} = 1.669$$

$b_h := 25 \cdot mm$

$Y_f := 2.5$

$Y_\varepsilon := \frac{1}{\varepsilon}$

$\beta_0 := 0$

$Y_\beta := 1 - \frac{\beta_0}{120}$

$K_L := 1$

$K_{fx} := 1$

$K_v := 1.3$

$K_0 := 1.75$

$S_f := 1.2$

$Torque := 52.158 \cdot N \cdot m$ "Input Torque"

$F_t := \frac{Torque}{\left(\frac{d1}{2}\right)} = \left(2.318 \cdot 10^3\right) N$

$$\sigma_f := F_t \cdot \left( \left( \frac{Y_f \cdot Y_\varepsilon \cdot Y_\beta}{m \cdot b_h} \right) \cdot \left( \frac{K_v \cdot K_0}{K_L \cdot K_{fx}} \right) \cdot S_f \right) = 0.039 \frac{kgf}{mm^2}$$

*Figure 5*

$H_b := 220$ "Brinell Hardness"

$i := \frac{d2}{d1} = 3.889$

$\sigma_{hlim} := 131 \cdot \frac{kgf}{mm^2}$

$K_{hl} := 1$

$Z_h := 2.5$

$Z_L := 1$

$R_{max1} := 0.003$ $R_{max2} := 0.003$

$$R_{max} := \frac{R_{max1} + R_{max2}}{2} \cdot \sqrt[3]{\frac{100}{\left(\frac{a}{1 \cdot mm}\right)}} = 0.003$$

$Z_r := 1.1$

$Z_v := 0.98$

$Z_w := 1.2 - \frac{H_b - 130}{1700} = 1.147$

$K_{hx} := 1$

$K_{h\beta} := 1.15$

$S_h := 1.15$

*Figure 6*

$$E_1 := 21000 \cdot \frac{kgf}{mm^2} \qquad \upsilon_1 := 0.3$$

$$E_2 := 21000 \cdot \frac{kgf}{mm^2} \qquad \upsilon_2 := 0.3$$

$$Z_m := \sqrt{\frac{1}{\pi \cdot \left( \frac{1-\upsilon_1^2}{E_1} + \frac{1-\upsilon_2^2}{E_2} \right)}} = 60.604 \left( \frac{kgf}{mm^2} \right)^{\frac{1}{2}}$$

$$Z_\varepsilon := 1$$

$$Z_\beta := 1$$

$$F_{hertzian} := \sigma_{hlim}^2 \cdot d1 \cdot b_h \cdot \left( \frac{i}{i+1} \right) \cdot \left( \frac{K_{hl} \cdot Z_L \cdot Z_r \cdot Z_v \cdot Z_w \cdot K_{hx}}{Z_h \cdot Z_m \cdot Z_\varepsilon \cdot Z_\beta} \right)^2 \cdot \frac{1}{K_{h\beta} \cdot K_v \cdot K_0} \cdot \frac{1}{S_h^2}$$

$$F_{hertzian} = \left(2.899 \cdot 10^3\right) N$$

$$F_t := \frac{Torque}{\left( \frac{d1}{2} \right)} = \left(2.318 \cdot 10^3\right) N$$

*Figure 7*

1. First, an approximate center distance was chosen as well as a tooth number for the pinion.
2. Next the desired speed ratio was selected, giving the number of teeth on the larger gear.
3. Then, the gear module was calculated and rounded to the nearest available.
4. The outside diameters of the gears were calculated, and a new center distance was calculated based on the module.
5. The contact ratio was then calculated, and factors were chosen based on the expected usage that the geartrain would receive.
6. Tangential force at the pitch diameter was then calculated along with required strength at the dedendum. The value sigma f would help us choose our gears for the next step.
7. Next, a gear was selected as a test and the allowable tangential force at the pitch diameter. A few gears were chosen, and the process was repeated until a suitable gear was found.
8. An allowable tangential force based on the allowable hertzian stress of the selected gear was found, which for this gearset was larger than the tangential force calculated.

Center distance for the chain drive was calculated and a length of chain was also found. Double strand #35 chain was used since it allowed the required horsepower to be carried to the differential with ease. Center distance calculations can be seen in Figure 8.

Formulas obtained from
Mechanical Design Handbook
Second Edition

$$P_{chain} := 12.7$$

$$N_1 := 20$$

$$N_2 := 30$$

$$C' := 125 \quad \text{"Desired Center Distance"}$$

$$\frac{N_1 \cdot P_{chain}}{\pi} = 80.851$$

$$\frac{N_2 \cdot P_{chain}}{\pi} = 121.276$$

**Calculation**

$$\alpha_1 := \frac{180}{N_1}$$

$$\alpha_2 := \frac{180}{N_2}$$

$$\varepsilon := \operatorname{asin}\left(\frac{\frac{1}{\sin(\alpha_2)} - \frac{1}{\sin(\alpha_1)}}{2 \cdot C'}\right) = -0.024$$

$$L' := 2 \cdot C' \cdot \cos(\varepsilon) + \frac{(N_1 + N_2)}{2} + \left(\frac{(N_1 + N_2) \cdot \varepsilon}{\pi}\right) = 274.546 \quad \text{"Exact Chain Length"}$$

$$N_{links} := \frac{L'}{P_{chain}} = 21.618 \quad \text{"Round links to the nearest whole number"}$$

$$N_{links} := 22$$

$$L' := N_{links} \cdot P_{chain} = 279.4 \quad \text{"Recalculate L'"}$$

$$e := L' - \frac{(N_1 + N_2)}{2}$$

$$S := \left(\frac{(N_1 + N_2)}{2 \cdot \pi}\right)^2$$

$$C' := \frac{e}{4} + \sqrt{\left(\frac{e}{4}\right)^2 - \frac{S}{2}} = 126.951$$

$$C' := C' \cdot 0.99 = 125.681 \quad \text{"Reduce center distance 1\% to provide slack on the non-drive side"}$$

*Figure 8*

Now that the drive components were chosen, the rest of the drivetrain could be designed. Figure 9 shows a sketch of the drivetrain speed and torques can be seen at each stage, from the forward-reverse gearbox in the bottom left, to the rear differential in the top right.

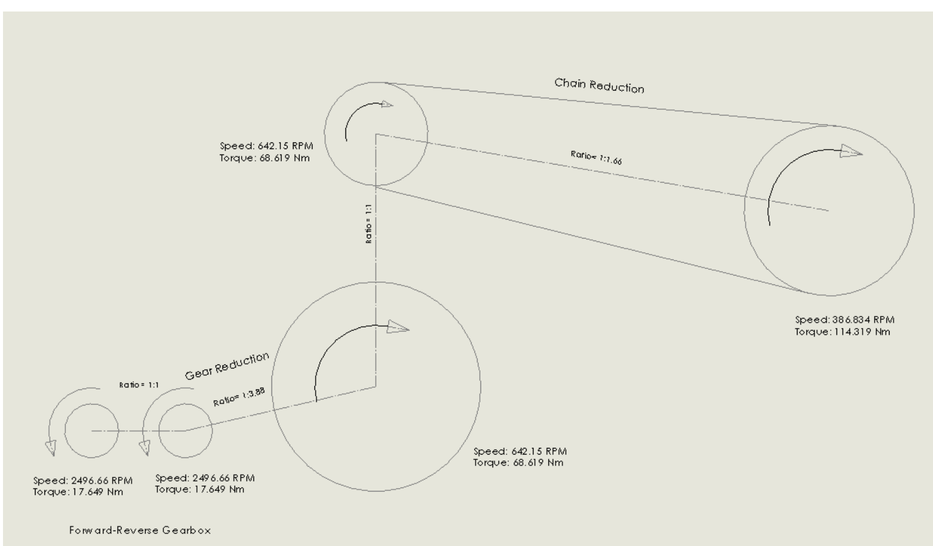



*Figure 9*

The suspension utilizes a hub design in combination with a four bar to allow vertical travel as well as heim joints at the pins to allow travel from side-to-side on rough terrain. The final design of the drivetrain and suspension can be seen in Figure 10 and 11.

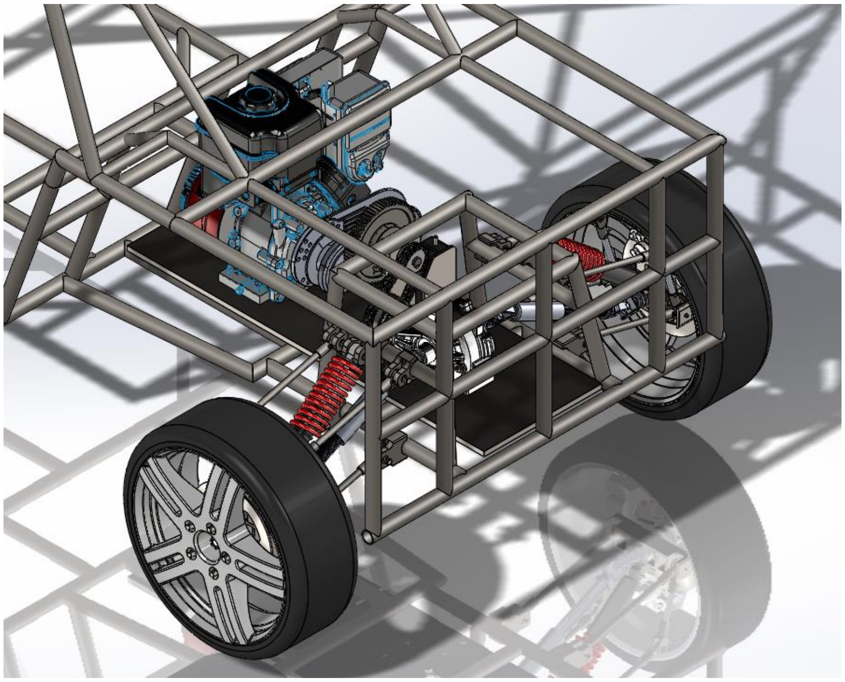


*Figure 10*

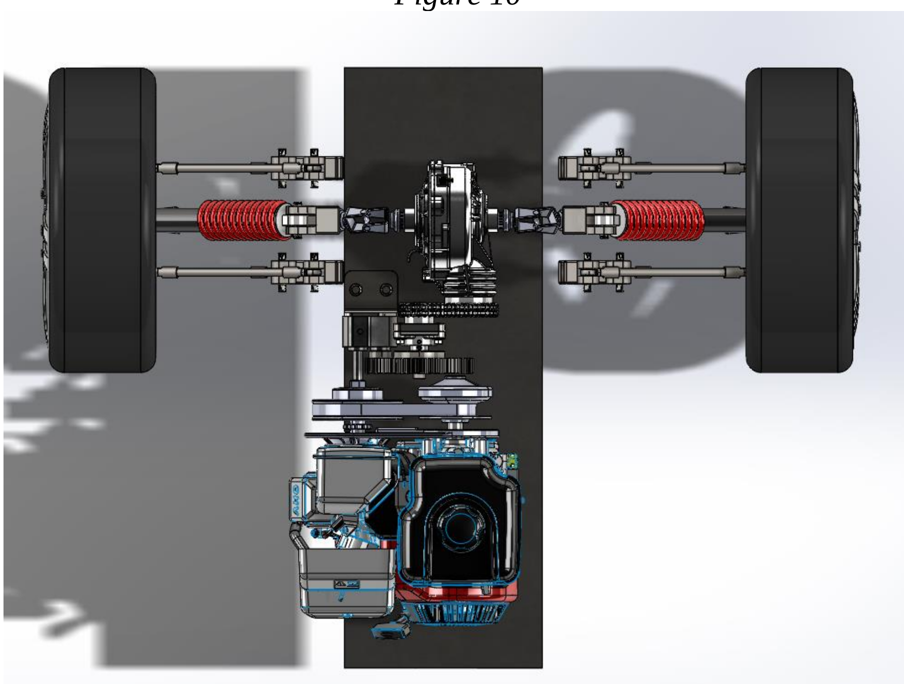


*Figure 11*

With the design complete, assembly drawings and parts lists were created. Figures 12, 13, and 14 show the first few pages of the drawing with a manufactured parts list, which corresponds directly to the individual parts drawings. For the drivetrain, plenty of exploded views were used to show fine details, like the wheel bearings in the hub, as well as the overall assembly broken down into manageable chunks for next year's group.

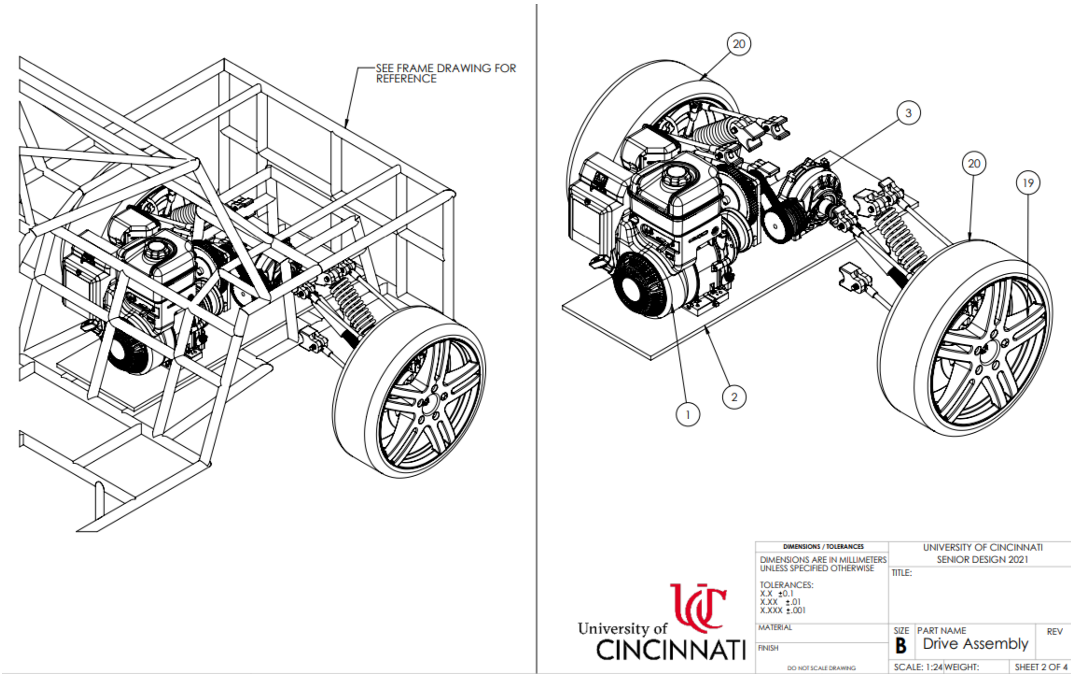



*Figure 12*

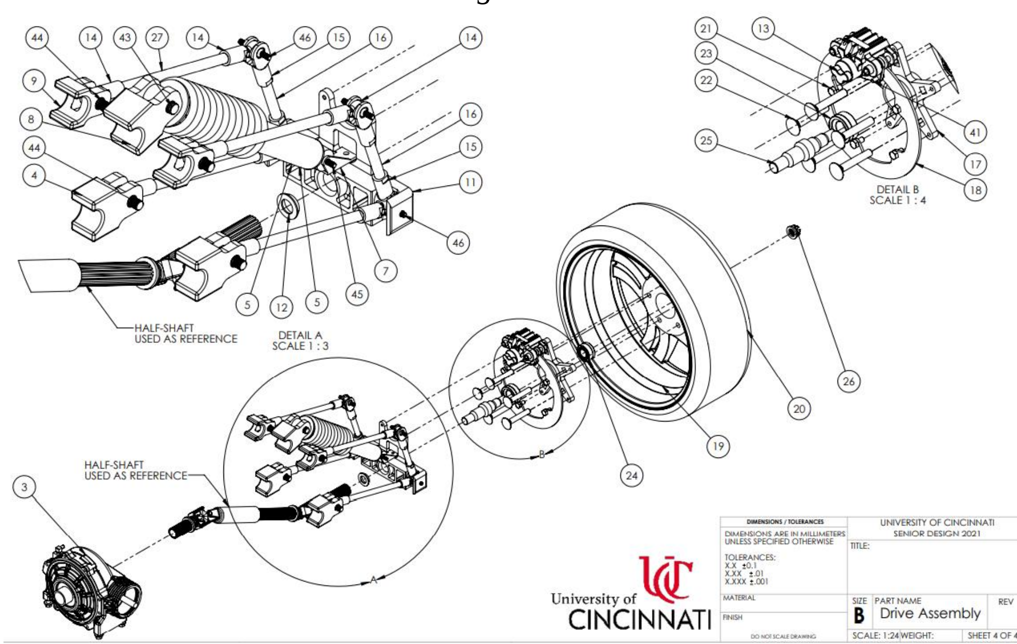



*Figure 13*

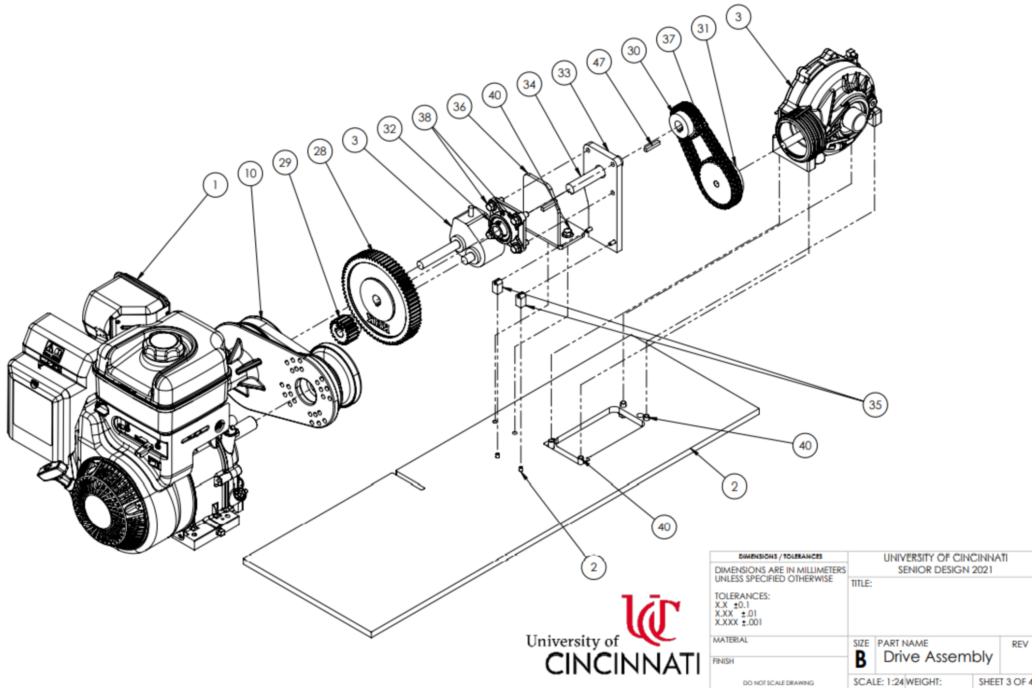

DIMENSIONS / TOLERANCES
DIMENSIONS ARE IN MILLIMETERS UNLESS SPECIFIED OTHERWISE
TOLERANCES:
X.X ±0.1
X.XX ±.01
X.XXX ±.001
MATERIAL
FINISH
DO NOT SCALE DRAWING
UNIVERSITY OF CINCINNATI
SENIOR DESIGN 2021
TITLE:
SIZE
B
PART NAME
Drive Assembly
REV
SCALE: 1:24
WEIGHT:
SHEET 3 OF 4
University of
CINCINNATI

*Figure 14*

# PROJECT MANAGEMENT

## *BUDGET AND SCHEDULE, PROPOSED/ACTUAL*

The proposed budget was ten thousand dollars, however with the current design, the group believes this is an overestimate. A new proposed budget would be around five thousand dollars, but this depends on how next year's group sources the parts.

The schedule changed from the fall semester since the overall scope of the project changed. The group met expectations for the schedule as discussed with our advisor.

# CONCLUSIONS

Given the circumstances, the group performed well, achieving all objectives after the scope change. The group that will be taking on the project next year has been given a well-crafted roadmap to the construction of the UTV and, given appropriate planning, should be able to complete the fabrication and assembly for the future owner. The group worked well designing around the existing components, only changing them where needed.

## WORKS CITED


1. Gator Utility Vehicles. John Deere. [Online] John Deere. [Cited: 4 September 2020]. https://www.deere.com/en/gator-utility-vehicles/.

2. Institute of Affordable Transportation. [Online] January 2010. [Cited: 4 September 2020]. www.drivebuv.org/buv-design.

3. Polaris Off-Road Vehicles (ORV): SxS, UTVs, ATVs, & 4-wheelers. [Online], [Cited 4 September 2020]. https://offroad.polaris.com/en-us/

4. SAWYERS, Harry, 2018, ATV vs. UTV: What Vehicle to Use When. *Popular Mechanics.* [Online]. 15 February 2018. [Cited: 4 September 2020]. https://www.popularmechanics.com/cars/motorcycles/a6457/atv-vs-utv-vehicle-guide/

5. GRABIANOWSKI, Ed, 2009, How Off-Road ATVs Work. *HowStuffWorks* [Online]. 5 October 2009. [Cited: 4 September 2020]. https://adventure.howstuffworks.com/outdoor-activities/off-roading/off-road-atvs.htm

6. HARRIS, William, 2005, How CVTs Work. *HowStuffWorks* [online]. 27 April 2005. [Cited18 September 2020]. https://auto.howstuffworks.com/cvt1.htm

7. WOOD, David A., 2018, Nissan Sentra Automatic Transmission Problems Cause Lawsuit. *CarComplaints.com* [online]. 8 March 2018. [Cited: 18 September 2020]. https://www.carcomplaints.com/news/2018/nissan-sentra-automatic-transmission-problems-lawsuit.shtml

8. PU5EPX, Elvis Pfützenreuter, [no date], Automatic transmission and planetary gears. *EPx* [online]. [Cited18 September 2020]. https://epxx.co/artigos/autogear.html