SAE Baja - Drivetrain

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Team 11

Progress Report

Document

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1.0 Introduction

The Northern Arizona University Chapter of the Society of Automotive Engineers (SAE) has instructed our team to design and build a vehicle for the Baja SAE Series. This entails designing a single seat off-road vehicle capable of performing in the top 10 in the collegiate competition at Portland, Oregon from May 27-30, 2015. This competition is a challenge for colleges to design an off-road vehicle capable of exceptional performance and customer appeal. The performance aspect of the vehicle is measured from the accomplishments of the vehicle in 5 dynamic events: the Acceleration, Hill Climb, Maneuverability, Rock Crawl, and Endurance challenges.

The drive train team is responsible for the design of the of the engine through to the wheels. This will include the engine, transmission, differential, and any power transmitting shafts. The engine is a constraint in our design, as SAE requires the use of a Briggs & Stratton Model 20 engine. This specific model of engine proposes a challenge due to its maximum power output being 10 horsepower. Our particular engine, however, is only 8.5 horsepower, which was discovered through the use of a dynamometer.

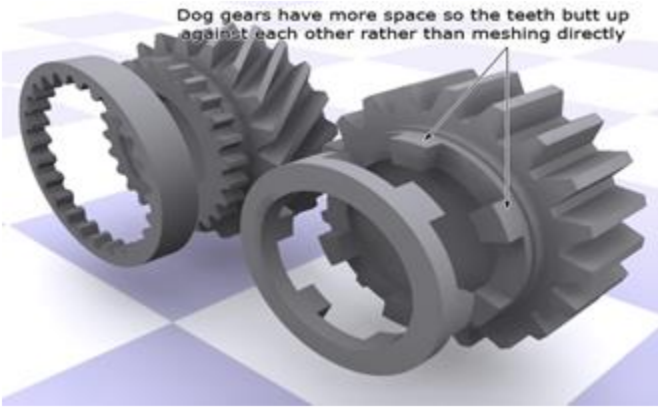
This year's drivetrain team has set a goal of placing in the top ten in two specific events: Acceleration, and Hill Climb. These events were chosen because the overall performance in these events depend greatly on the design and execution of the transmission design. The set performance goals to achieve this objective are to complete a 100 foot distance in 4 seconds from a complete stop, and for the vehicle to be able to drive up a hill of about 60 degrees. The contents below describe how the drivetrain team chose between six transmission concepts, to then analyze the sequential transmission, to implement into the NAU Baja for the May 2015 competition.

1.1 Project Goal

In last year’s competition the NAU Baja placed 58th in the acceleration test and 64th in the hill climb test. The goal the team has for this project is to design a drivetrain that will be competitive and place in the top 10 for the acceleration and hill climb tests against other competing universities.

2.0 Sequential Transmission

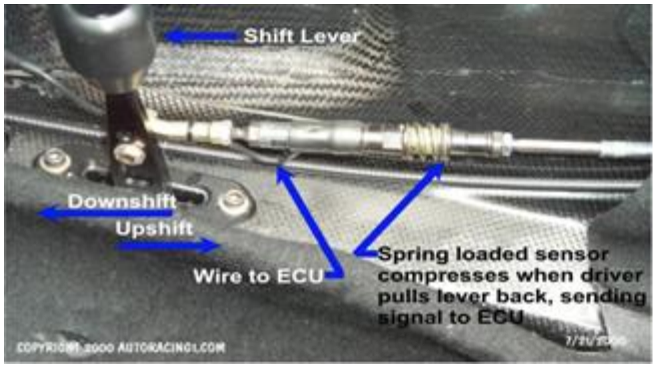
The next concept the team considered for a possible design solution is a sequential transmission. The sequential transmission is a derivative of the manual transmission with slight differences in the shifting mechanism. As seen in Figure 2.1, there is a difference in the geometry of the dog rings and the way which the gears and dog rings engage.



(Figure 2.1, Manual (left) Vs. Sequential (right) dog ring)

Because the sequential dog ring has a square geometry and more room to engage to the gear, it allows the gear and ring to engage at different speeds, as opposed to a manual gearbox which requires both the gear and ring to be spinning at the same 1:1 ratio in order to engage the two. This means the clutch does not have to be engaged each time the operator wants to shift from one gear ratio to the next.

There is also a different manner in which the sequential transmission selects each gear ratio. The shifting mechanism and selector work by only allowing the operator to shift either up or down a single step in gear ratio. If the operator desires to select fourth gear from second gear, he/she must engage third gear from second gear, and then fourth gear from third in sequence. The gear selection can be achieved by use of a shift lever as seen in Figure 2.2:



(Figure 2.2, Sequential Shift Lever)

There are many advantages when using a sequential transmission. First there is little loss of power because the clutch does not need to be engaged in between each shift. This means there will be a minimal amount of time that there is no power being transmitted to the wheels, which, in effect, means an increase in performance when accelerating. Also, sequential transmissions are generally smaller and more compact, which also means that the gearbox will be lighter as well. The sequential transmission is also easy to operate because the clutch needs to be used only when starting from a stop. Each gear shift after is completed by pulling or pushing a lever which will engage the gear ratio below or above the current gear. Finally, the sequential transmission is more reliable and stronger than a standard manual transmission. A countershaft is generally used to transmit power to the gear ratios, which means that the gears in a sequential transmission will experience about half the force of a normal manual transmission.

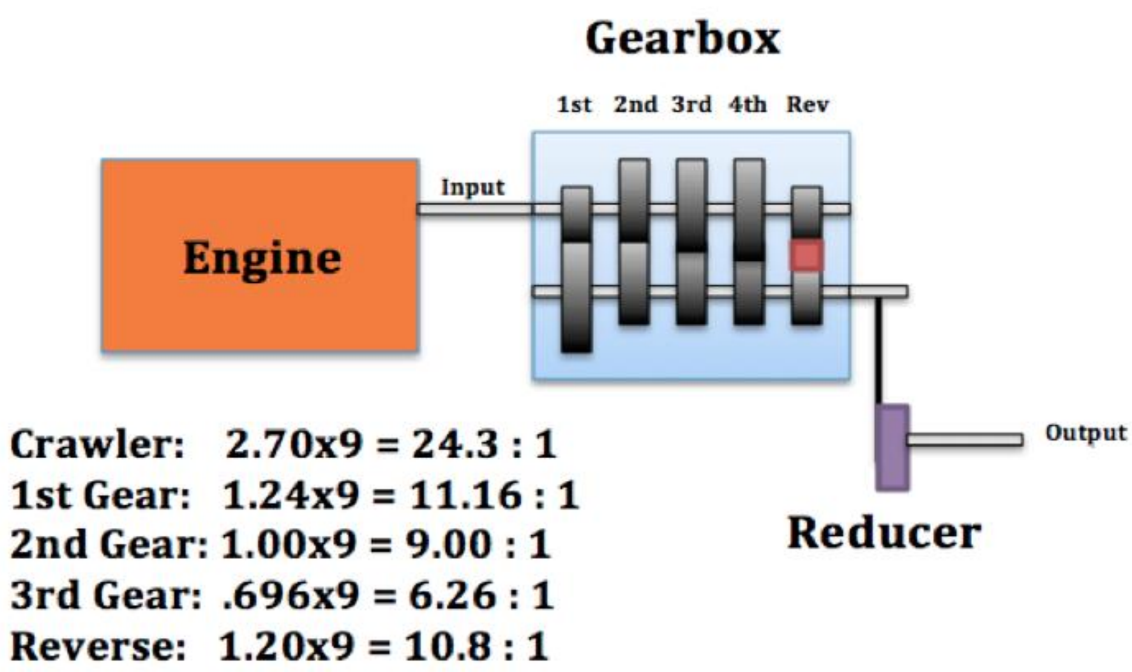
There are a few disadvantages of using a sequential transmission as well. Most sequential transmissions do not have a reverse integrated into the design of the gearbox, as they are generally used on motorcycles and off-road applications where reverse is not needed. It will be a difficult task to integrate a reverse into a pre-existing design. Also, if the team decides to integrate a reverse into an existing transmission, it will be an added expense to the production.

3.0 Gearbox Specifications

After all the calculations, all the ratios will be as follows:

Engine to gearbox ratio:	1:1
Crawler:	2.70:1
First gear:	1.24:1
Second gear:	1:1
Third gear:	0.696:1
Reverse gear:	1.20:1
Reducer ratio:	9:1

Figure 3.1 shows a basic concept representation of our drivetrain layout:



(Figure 3.1, Gear Selection)

3.1 Gear Specifications

After more calculations, Team Drivetrain has decided to go with 7075-T6 aluminum for the gear material, and found the following tooth sizes for each gear. The minimum factor of safety out of all the gears came out to be 6.2.

Crawler:	Pinion: 15	Gear: 41	
First Gear:	Pinion: 25	Gear: 31	
Second Gear:	Pinion: 28	Gear: 28	
Third Gear:	Pinion: 33	Gear: 23	
Reverse:	Pinion: 15	Gear: 15	Gear 2: 18
Reducer:	Pinion: 10	Gear: 90	

3.2 Shafts

Using the DE-Goodman equation and the calculated torque and moment values (shown below), the Drivetrain Team decided upon 4340 Normalized Steel as the shaft material with a diameter of 0.5 inches. From all this, the factors of safety come out to be 2.94 and 2.00 for the input and output shafts, respectively.

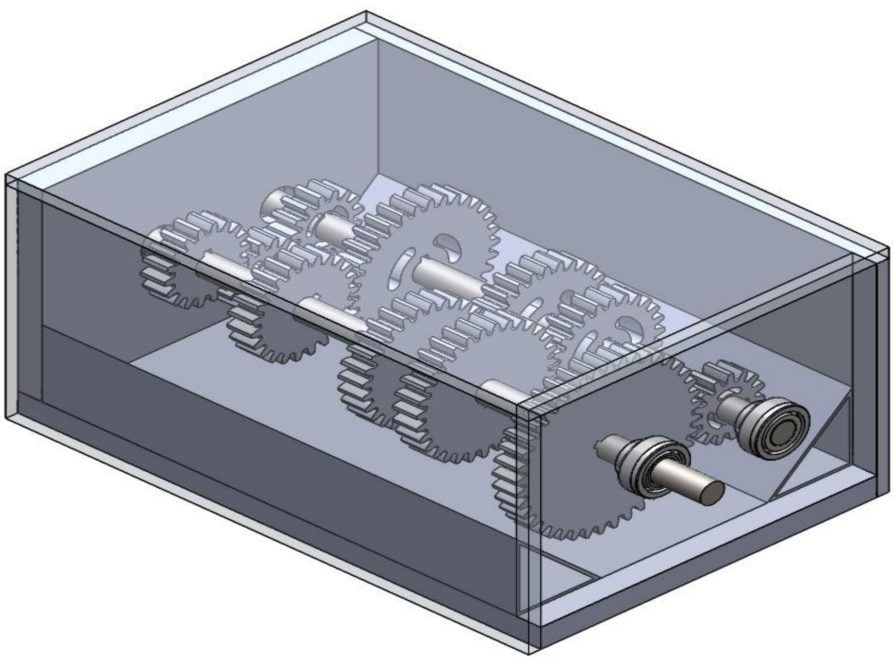
3.3 Bearings

After doing more calculations, Team Drivetrain has decided on purchasing Open Steel Ball Bearing from the McMaster-Carr website. The specifications work for a shaft diameter of 0.5 inches, and the bearings have an outside diameter of 1.125 inches, a width of 0.375 inches, and a dynamic load capacity of 600 pounds. This leads to a factor of safety of 2.3 for our purposes. Figure 3.2 shows an example of a bearing being ordered.

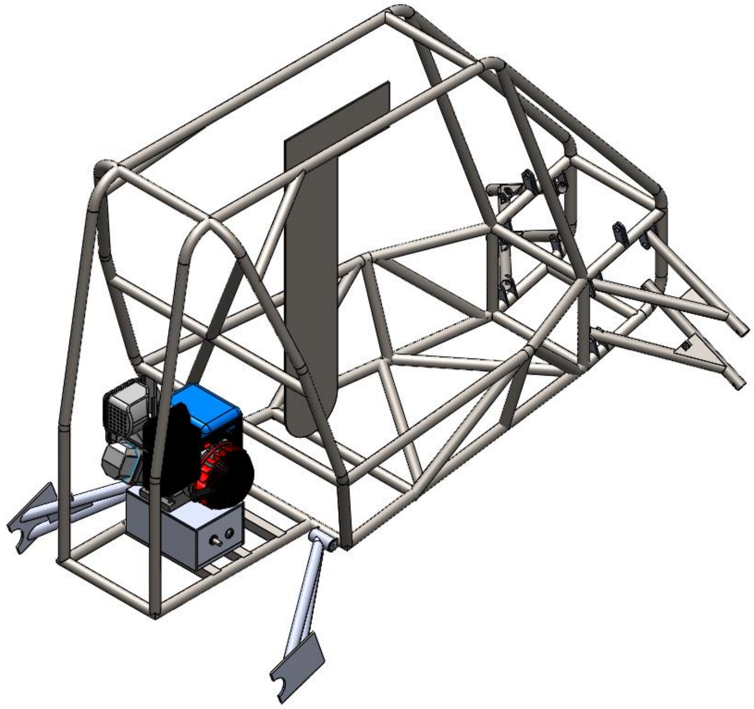
(Figure 3.2, Open Steel Ball Bearing)

3.4 Final Assembly

In Figures 3.3 and 3.4 are preliminary CAD Assemblies of the drive train transmission and engine combination. It is currently sitting at 11 in x 7.5 in x 10.5 in and weighs 15.7 pounds. This design is very optimal, as it is compact, lightweight, and efficient. 6.6 and 6.7 portray where the gearbox will sit on the most current frame design.



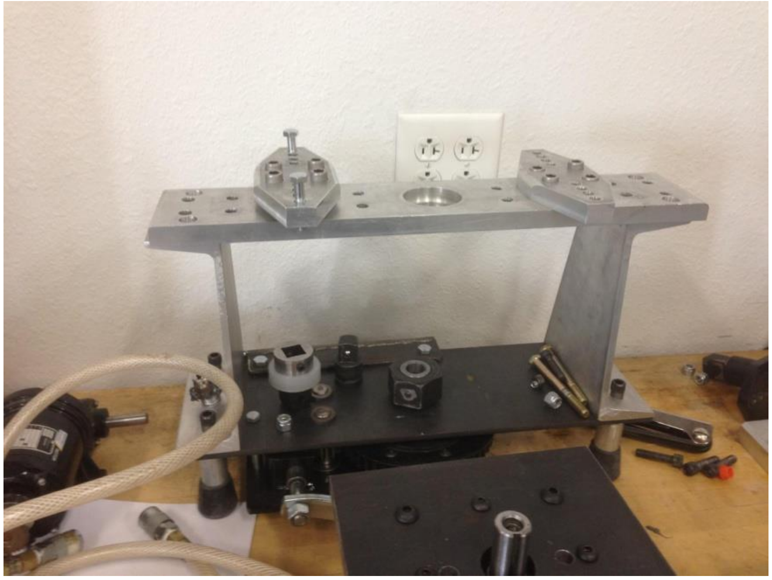
(Figure 3.3, Internal Gearbox Assembly)



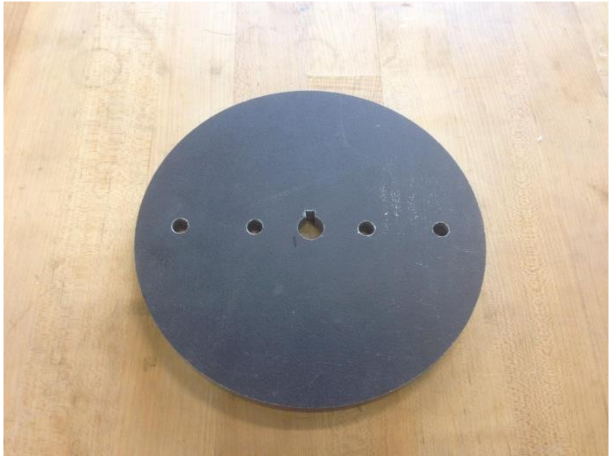
(Figure 3.4, Overall Assembly)

4.0 Testing

For testing the gears, the team has devised an apparatus that will test the aluminum gears strength and contact stresses that maybe experienced under actual operation. As seen below in figure 4.1 and 4.2, this is the testing device that the gears will connect to.



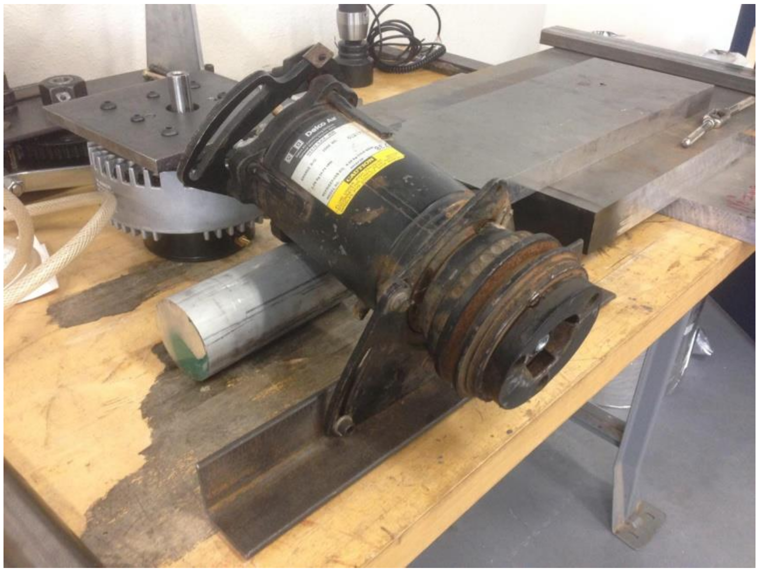
(Figure 4.1, Testing Stand)



(Figure 4.2, Testing Disc)

This test will show how much torque can be applied to the aluminum gear before it shears and fails. To test for contact stresses the aluminum gears will experience, the team has devised a test procedure using two electric motors. These two electric motors will mesh the gears together, and rotate the aluminum gears at an rpm comparable to what they will actually experience. The two electric motors that will be used can be seen in figures 4.3 and 4.4.

(Figure 4.3, Electric Motor)



(Figure 4.4, Electric Compressor)

5.0 Machining and Assembly

As stated previously, the Drivetrain Team will be building the gears and housing out of aluminum. The gears will be cut on the new FADEC CNC Mill machine, donated by Dave DeCausin, and the housing will be cut on the Tormach CNC Mill. The FADEC CNC Mill are shown below in Figure 5.1:

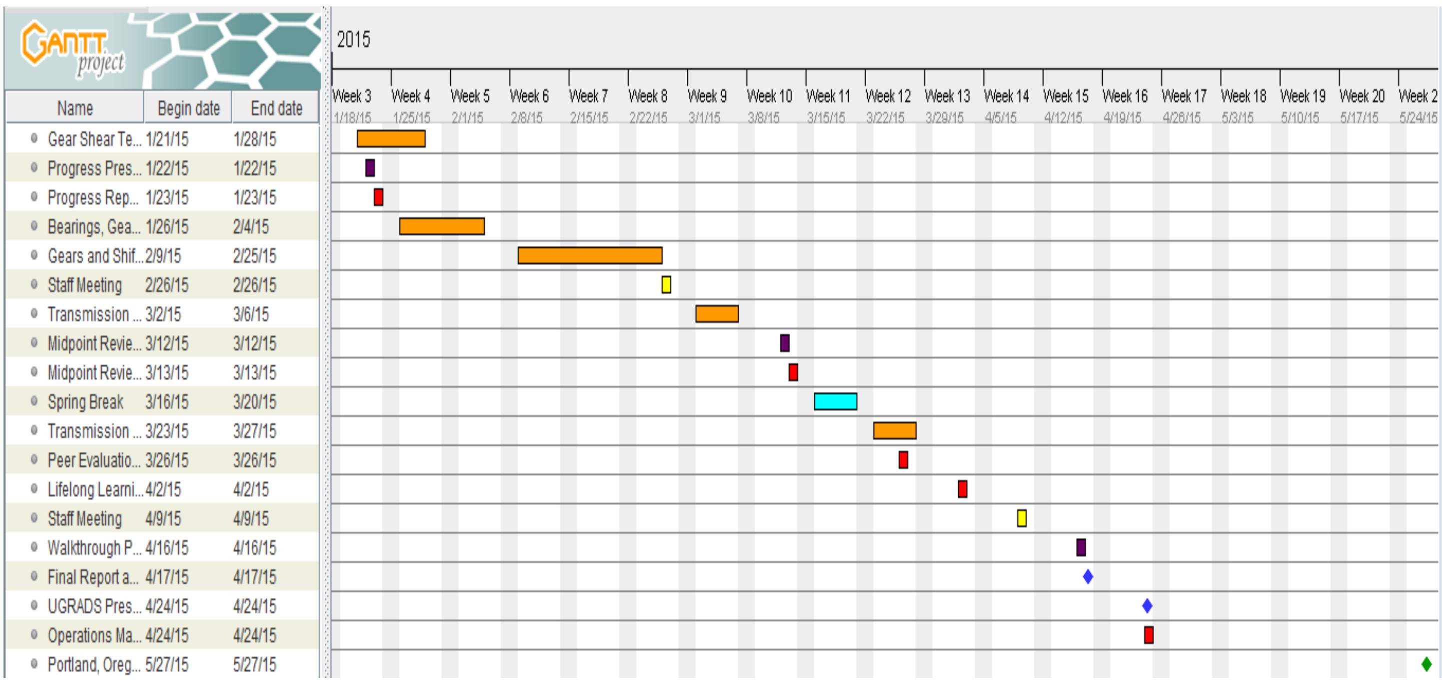
(Figure 5.1, FADEC Picture)

6.0 Bill of Materials

Materials	Quantity	Cost for One Unit of Material	Overall Cost of Each Material	Free/Donated
7075 T6 Aluminum (4" diameter, 2' bars)	1	$307.44	$307.44	x
7075 T6 Aluminum (3" diameter, 5' bars)	1	$298.87	$298.87	x
7075 T6 Aluminum (2" diameter, 4' bars)	1	$87.24	$87.24	x
6061 T6 Aluminum (0.5" thick, 1'x3' plates)	1	$164.92	$164.92	x
6061 T6 Aluminum (0.25" thick, 1'x3' plates)	1	$76.69	$76.69	x
4340 Normalized Steel (5/8" inch diameter, 5' bar)	2	$95.64	$191.28	x
Bearings	6	$7.36	$44.16	
Clutch	1	$300.00	$300.00	
Differential	1	$400.00	$400.00	x
80 tooth sprocket	1	$25.00	$25.00	
10 tooth sprocket	1	$10.00	$10.00	
		Total	$1,905.60	
		Total, subtracting free/donated	**$379.16**	

7.0 Project Plan

Below, in Figure 7.1, is the Gantt chart planning the Drivetrain Team's schedule for the Spring 2015 semester. As shown, the chart is color coded – orange shows time for gear/transmission testing and building, purple signifies dates of presentations, red is for deliverables, yellow shows staff meetings, light blue defines spring break, blue portrays the final report and UGRADS presentation, and green shows our competition in Portland, Oregon.



(Figure 7.1, Gantt chart)

8.0 Conclusion

In conclusion, the Drive Train Team chose to use and analyze the design of the sequential transmission for the Baja vehicle, due to its superiority over the manual transmission, for the Baja Team’s purposes. After selecting which transmission to implement into the vehicle, the team calculated the forces against the vehicle in the Hill Climb Challenge. Using this data, the Drive Train Team then calculated the gear ratios needed to climb up the hill in a reasonable amount of time. From there, the team assumed moving 100 feet in around 4 seconds for the Acceleration Test, letting the vehicle’s top speed hit around 35 miles per hour; gear ratios again were calculated to take these values into account. Afterwards, Team Drivetrain compared the gear ratios needed for the Hill Climb and Acceleration Tests, respectfully, which led to the final gearbox assembly.

9.0 References

1. Fadec Picture: https://www.facebook.com/FadecEng/photos/pb.179225548878310.-2207520000.1421962948./286764138124450/?type=3&theater