SAE Mini Baja Drivetrain

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Team 02

Final Proposal

REPORT

Submitted towards partial fulfillment of the requirements for

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1. Introduction

The Baja Vehicle Design is a competition sponsored by the Society of Automotive Engineering (SAE) and hosted in different locations across the country. Teams of students from different universities will design and build a Baja vehicle to compete against each other. All teams will use the 10 hp OHV Intek provided by Briggs & Stratton Corporation. The teams will have to build the vehicle to fit that engine and maximize their designs to meet the design objectives and win the competition. For the capstone senior design project, the Baja vehicle was assigned to three teams each with a separate task. All teams must collaborate together to design the vehicle. The tasks assigned to the teams are the frame design, suspensions design, and drive-train design. In this report, drive-train first stage analysis is discussed where customer needs, product specifications, and project plan will be identified and explained.

2. Goal Statement and Objectives

2.1 Objectives

The main objective of this project is to design and build a Baja vehicle that meets the client and stakeholders requirements and needs. Our client is the Society of Automotive Engineering (SAE) and they are the sponsor of the competition who sets the rules and regulations. The stakeholder is Dr. John Tester who will oversee the project progress to make sure that our teams design will win the competition. To win the competition, the Baja vehicle will be run through a series of events to see if it finishes them successfully. These events include acceleration, traction, maneuverability, specialty, and endurance events. Our team will design and build a drive-train with all these objectives in mind to ensure winning the competition. Based on the information obtained from the stakeholder and provided by the SAE, specific objectives are set by our team to maximize the drive-train design. Objectives include choosing a transmission that can have reverse so that the Baja vehicle can succeed in the maneuverability event. Moreover, the gear ration has to be maximized so that the resulted torque will win the acceleration and traction events. Finally, the sprocket materials will have to be chosen carefully so that the drive-train will have better endurance. This will result in low maintenance to be needed and will successfully complete the endurance and specialty events.

2.2 Goal

2.2.1 Torque Goal

In the hill climb event, the Baja vehicle will be expected climb an incline of significant difficulty. The team assumed the incline to be approximately 40 degrees. Through the inspection of previous courses, as a group we felt this would be the maximum angle in any hill climb we might encounter. In order to complete the incline, the force on two wheels will need to be greater than the component force of gravity along the incline, which is G1 in the figure below:

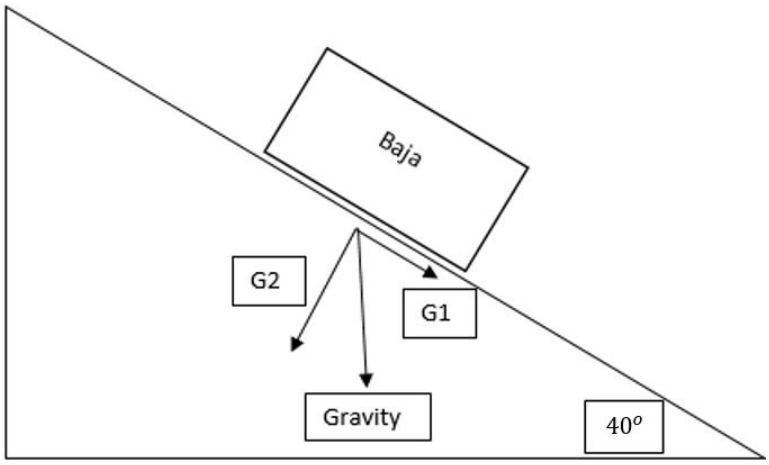

Figure1. Free Body Diagram of Baja for Hill Climb Event

G1 = G × sin ∂ = 600lb × sin 40 = 385.67 lb

Force per wheel = 192.83 lb

Torque per wheel = $192.83 \times \frac{D}{2} = 192.83 \times \frac{23}{2} \times \frac{1}{12} = 184.8\ lb - ft$

Total torque $(T_t) = Total\ torque\ on\ the\ wheel = 369.6\ lb - ft$

From the result above we know that the minimum torque that needs to be transferred to the final output shaft is 369.6 lb-ft. Based on the result, team has set 380 lb-ft as our goal for max torque that can be transferred to the final output shaft.

2.2.2 Speed Goal

Table 1. Tennessee 2013 Acceleration Event

Rank	Car No	School	Team	Time Run 1	Time Run 2	Best Time	Acceleration Score (75)
1	1	Cornell Univ	Big Red Racing	3.870	3.861	3.861	75.00
2	52	Michigan Tech Univ	Blizzard Baja	3.950	3.872	3.872	74.70
3	6	Univ of Maryland - Baltimore County	UMBC Racing	3.902	3.957	3.902	73.86
4	78	Univ of Maryland - College Park	Terps Racing	3.906	3.974	3.906	73.75
5	73	LeTourneau Univ	Renegade Racing	3.935	3.916	3.916	73.48
6	3	Rochester Institute of Technology	RIOT Racing	3.999	3.924	3.924	73.26
7	44	Ohio Northern Univ	Polar Bear Racing	3.945	3.955	3.945	72.67
8	36	Universite de Sherbrooke	Sherbrooke Racing Team	4.011	3.992	3.992	71.37
9	57	Univ of Wisconsin - Madison	UW Baja	4.129	4.037	4.037	70.13
10	45	Univ of Arkansas - Fayetteville	Racing Razorbacks	4.043		4.043	69.96

(Source: sae.org)

From the table we can see the top team have an average time of 4 seconds to finish a 100 foot course. Assuming that the Baja keeps accelerating with the average acceleration during that time. We can calculate the maximum velocity

$$\text{Distance} = \text{Max Velocity} \times \text{time} \div 2$$

$$\text{Max velocity} = \text{Distance} \times 2 \div \text{time}$$

$$= 100 \times 2 \times 0.68 \div 4$$

$$= 34 \text{ mph}$$

Based on the result, 35 mph is the goal for max speed that the team has set out to obtain.

3. Old Design

The CVT has an initial high ratios of .45 and low ratio of 3.1. The gearbox has high ratio of 2.734 and low ratio of 5.682. This however was not ideal for the goals that have been established. Thus, the group had to consider a secondary reduction. For the volume provided to us by the frame team, which is approximately 6.3 cubic feet, our team put together this simple lay out of the reduction system as seen in Figure 2. In Figure 3 we depict how the engine, CVT and reduction system might sit with in the frame. As you can see because of the odd shape of the rear, to optimize the space, the engine should be mounted approximately 17 inches above the bottom of the frame. This can be visualized in Figure 4. This will allow for ample space to implement the reduction system and eventually our braking system.

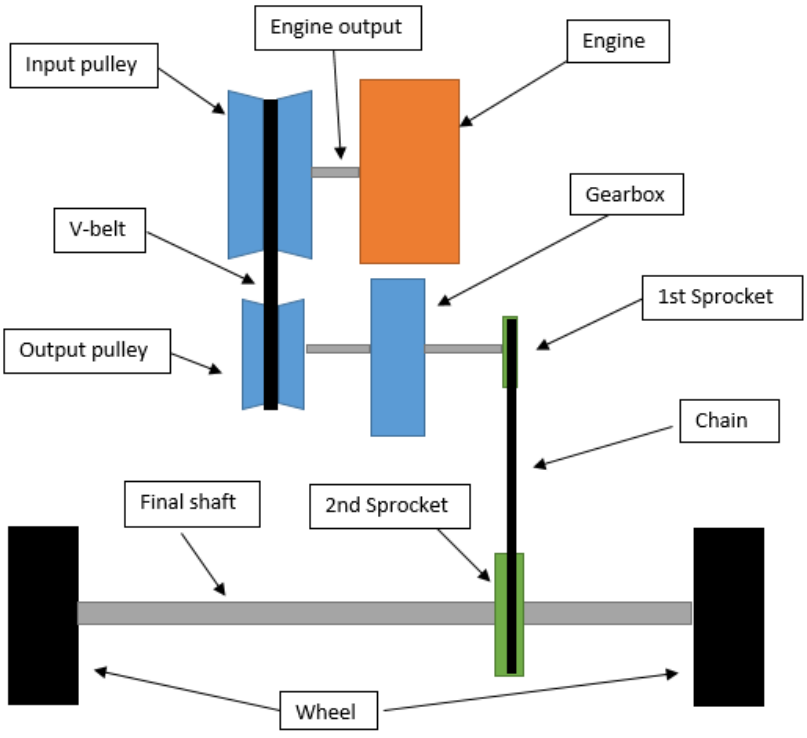

Figure2. Basic Concept of CVT Drivetrain System

The reduction contains 2 sprockets with different teeth: n1 = 36 and n2 =12, which give us a 3:1 reduction ratio.

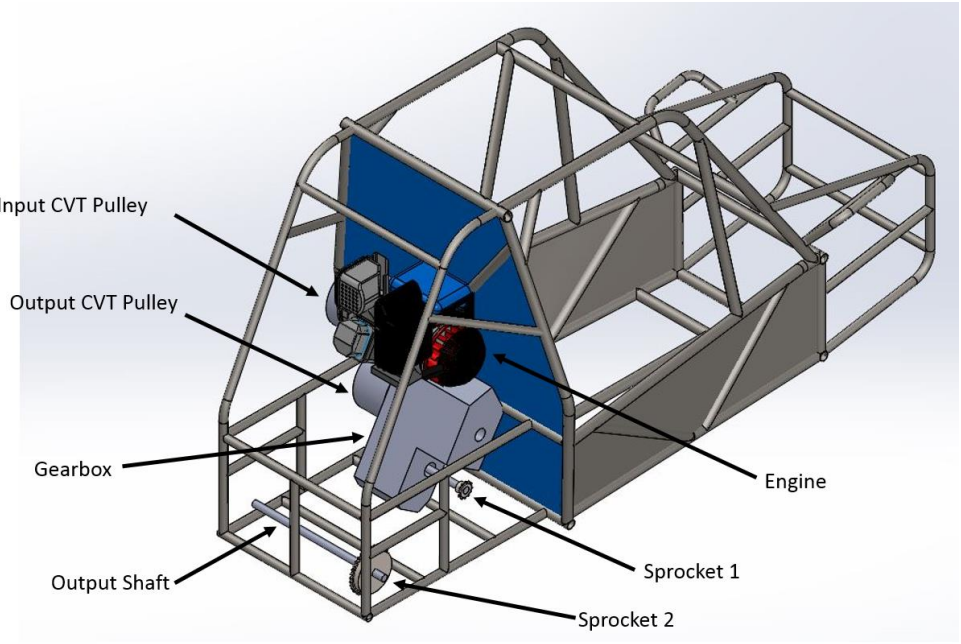

Figure3. 3-D Drawing of CVT Drivetrain System

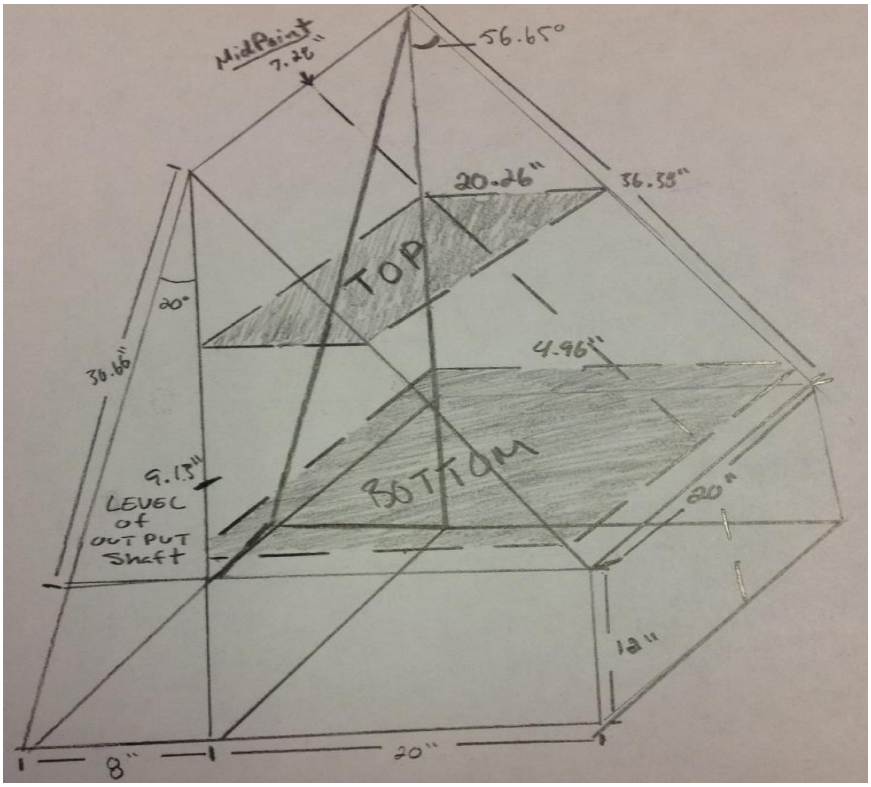

Figure4. Simple depiction of the lay out of the rear of the frame and the prospected optimal placement of the engine

4. New Design

4.1 Description

Over the course of winter break the 2014 Baja drive-train system has change significantly but for the better. The new system will be drastically lighter with the replacement of the gear box for a single differential/transmission combination. The Baja will still operate using the Briggs and Stratton ten horse power engine in connection with CVTech-AAB's CVT. The CVT will still have a low ratio of 0.43:1 and a high ratio of 3:1. Following this assembly is where the system has been altered. The gearbox was swapped out for a Dana Spicer H-12 FNR differential that provides the cart with a forward ration of 13.25:1 and a reverse ratio of 14.36:1. This improved system will provide a direct connection from the power source to the output shafts reducing the loss of efficiency. These alterations have also made the system more compact and easily removable in the case of swapping broken parts. Though the system suffered significant changes, they have optimized the drive-train in as many ways as possible.

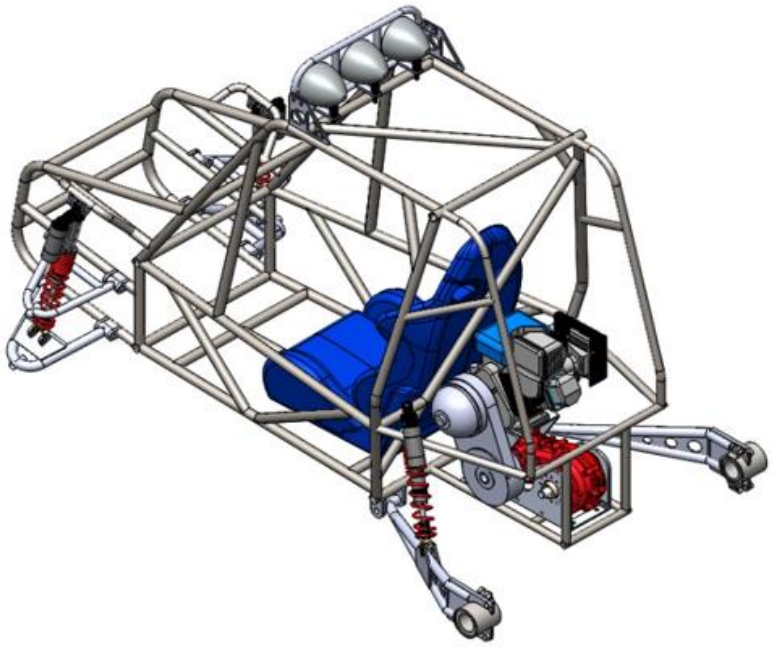

Figure 5. New design

4.2 Engine Mount Design

4.2.1 Description

To make the maintenance of drive-train system easier, the team designed an engine mount during winter break, which will encompass the engine, differential and CVT. If the team needs to remove

the drive-train system for maintenance or testing, the whole system can be taken out because the engine mount secures all individuals pieces together.

4.2.2 3D model

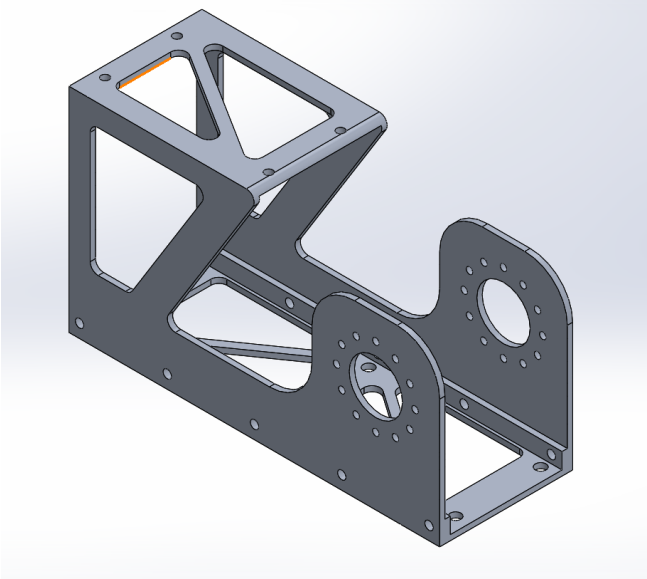

Figure 6. Mount Solidwork

4.2.3 Finite Element Analysis

When the team designed the engine mount, a FEA test has been done to make sure the mount can hold the stress that will be added on the mount. 200 lbf load has been added on the top of the mount, and 80 lbf load has been added on each threaded hole on both two sides of the mount. The test showed that the maximum deflection will be on the bar at the top of the mount, and the stress will be 0.288mm. The safety factor of this mount is 10.97 maximum.

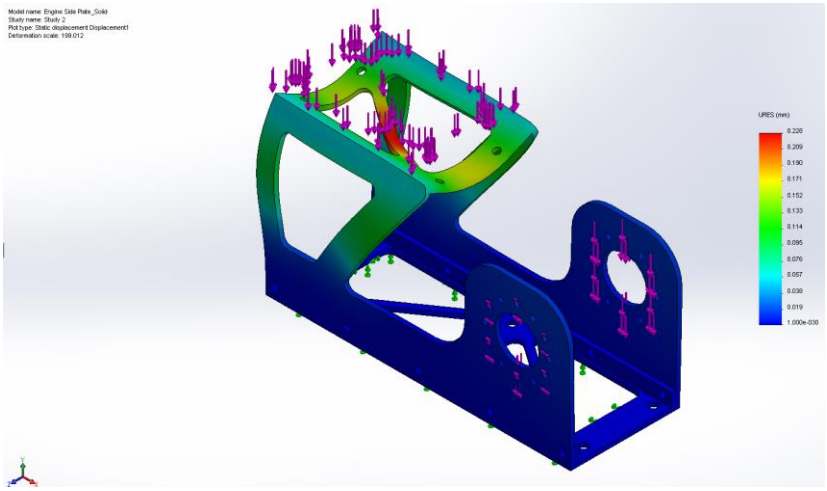

Figure 7. Deflection test

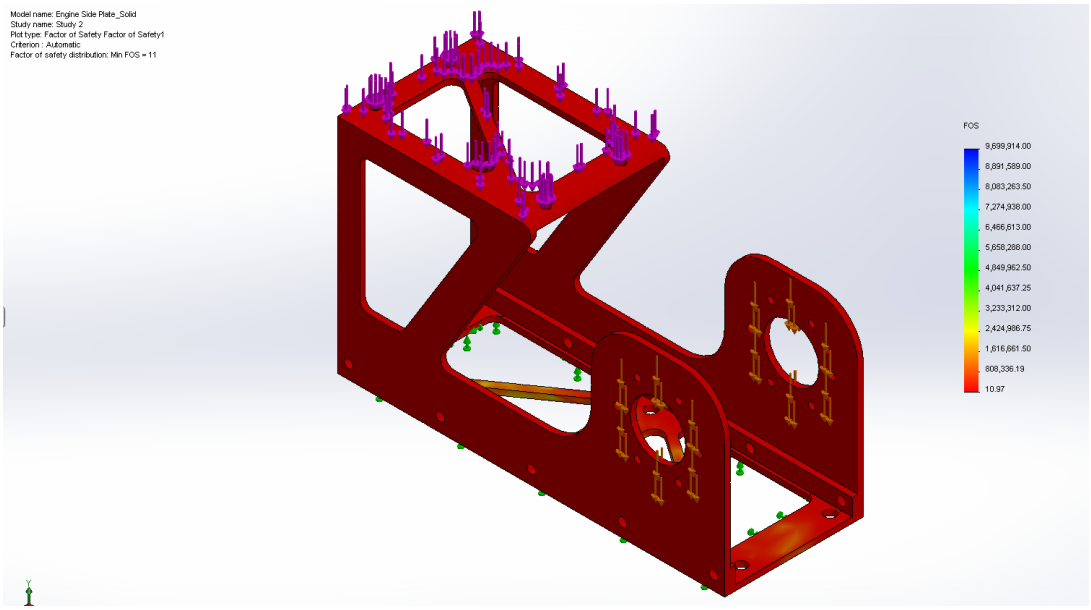

Figure 8. Safety Factor test

4.3 Drip Pan Design

4.3.1 Description

Following the SAE mini Baja rules, a drip pan will be necessary for every team to prevent the gas leak. The drip pan the team designed will be on the top of the gas tank with a drip pan drain. The gas that spill out of the gas tank when refilling will be lead to the ground through the drip pan drain.

4.3.2 3D model

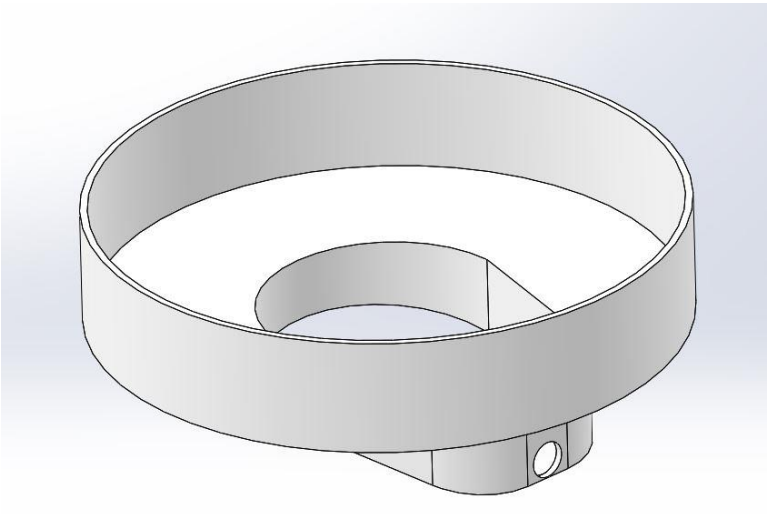

Figure 9. Drip Pan solidwork

5. Old Parts List

- Chosen CVT: *PULLEY SERIES 0600 AND DRIVEN PULLEY SERIES 5600* from CVTech-AAB Inc.

  High speed ratio (r_{cvt-h}) : 0.45 Low speed ratio (r_{cvt-l}) : 3.1

- Chosen Gearbox: *ATV/UTV Gearbox T03* from GaoKin Inc.

  High speed ratio (r_{gb-h}): 2.734 Low speed ratio (r_{gb-l}): 5.682

- Second reduction ratio (Sprockets) (r_r): 3

6. New Parts

6.1 New Parts List

- Chosen CVT: PULLEY SERIES 0600-0021 AND DRIVEN PULLEY SERIES 5600-0171 from CVTech-AAB Inc.

  High speed ratio: 0.43:1 Low speed ratio : 3:1

- Chosen Differential : Dana Spicer, H-12 FNR

  Forward ratio: 13.25 Reverse ratio :14.36

6.2 Parts order status

Table 2. Parts order status

Ordered Parts	Quantity	Status
Engine	1	Arrived
Differential	1	Arrived
CVT	1	In transit
Shaft	2	Not ordered
Key	4	Not ordered

7. New Speed and Torque Calculation

With the equation we presented in the previous report, we made a new tables below showing how speed and total torque vary with the increase of engine rpm.

Table 3. Torque and speed

Engine rpm	Torque output (lb-ft)	CVT ratio	Total ratio	Torque on wheel (lb-ft)	Speed (mph)
1800	13.20	2.082	24.278	320.467	5.06
2000	13.70	1.899	22.137	303.282	6.17
2200	14.10	1.715	19.997	281.956	7.51
2400	14.30	1.531	17.856	255.347	9.17
2600	14.45	1.348	15.716	227.096	11.29
2800	14.52	1.164	13.576	197.117	14.08
3000	14.50	0.981	11.435	165.809	17.90
3200	14.40	0.797	9.295	133.843	23.49
3400	14.20	0.614	7.154	101.590	32.43
3600	13.80	0.430	5.014	69.190	49.00

From the table above we can see that the max speed of our Baja on the flat ground is 49 mph. This is an ideal speed which is so hard to reach in real life. What usually happen in the competition is that, the engine rpm cannot always increase to its max value because of the complicated situation of the course. The table tells us that at about 3400 rpm, the speed will be about 32 mph, which is what we want in the competition.

The table 3 shows the max torque we can get on the wheel is 320 lb-ft, which meets our goal.

8. Cost Analysis

For the SAE Mini Baja competition as a competing team we are required to create and present a Sales Presentation to a hypothetical manufacturing company. This imaginary company is prospecting to produce a Mini Baja at four thousand units per year. Thus, this will set the base criteria for our calculations and tables. Our team also assumed that out of 365 days this company would only be producing units for approximately 261 days of the year. With these two criteria established we were able to; create a Bill of Materials, estimate the manufacturing costs, cost of man power, and the total cost of production.

Since the final presentation in December of 2013 there have been a few changes made to the SAE Baja drive-train system. This had some effects on the cost analysis of the project, some positive and some negative. Below in Table 7 you will notice that because the system now incorporates a differential, the manufacturing hours required per day were reduced by more than thirteen hours. This equates to approximate savings of $350 per day jus in labor. Fallowing this, the budget for the system was hardly reduced. Because the new system uses a Dana differential, the price rose significantly. Luckily this product was donated to the SAE team, thus or budget rose but the system was actually more cost effective. A similar rise in cost can be seen in the systems bill of materials. Since the system has become more compact and efficient, you can see the cost increase for these

desirable attributes. Though there were slight increases in these two areas, the decrease in cost in all other areas still outweighs the increase in parts cost. Thus, our system has not only become more efficient and simplistic, but is cost effective as well.

Table 4. Manufacturing Hours

Part	Half Shaft	Keys	Short Shaft	Drive Shaft	Hours per Unit	Hours per Day
Individual	.65 Hours	.25 Hours	.35 Hours	.50 Hours		
Drive Shaft	1.3 Hours	.75 Hours	.35 Hours	.50 Hours	2.9 Hours	43.5 Hours

Table 5. Recalculated Manufacturing Hours

Part	Half Shaft	Keys	Hours per Unit	Hours per Day
Individual	.65 Hours	.25 Hours		
Drive Shaft	1.3 Hours	.75 Hours	2.05 Hours	30.75 Hours

Table 6. Old Budget for Drivetrain

Part	Price($)	Quantity	Comments	Total
Engine	200	1	Ship fee	200
Gearbox	400	1	GaoKin	400
CVT	580	1	CV-Tech	580
Shaft	29	1	Metals Depot	29
Bearing	15	2	Polaris	30
Key	5	4	Metals Depot	20
Sprocket	16	4	G & G	64
Chain	15	1	G & G	15
Half-shaft	260	2	Polaris	520
Shipping	200			200
Total Price(include tax)				2058

Table 7. Recalculated Budget for Drivetrain

	Price($)	Quantity	Comments	Total
Engine	200	1	Ship fee	200
Differential	1000	1	Dana	1000
CVT	250	1	CV-Tech	100
Key	5	4		20
Half-shaft	260	2	Polaris	520
Shipping	200		Fed Ex	200
Total Price (include tax)				2040

Table 8. Bill of Materials

12 tooth sprockets	36 tooth sprockets	Half shafts	2 feet 1040 Steel Shaft	Engine	CVT	Gearbox	Chain	Total
10,120	30,360	526,000	5,700	979,980	1,160,000	800,000	5836	3,511,996

Table 9. Recalculated Bill of Materials

Half shafts	Engine	CVT	Differential	Key Material	Total
1,040,000	979,980	500,000	2,000,000	5836	4,525,816

Table 10. Total Estimated Man Hours

Total work units	Complete units per day	Total work hours per person	Number of labors	Work hours per person per day	Hourly Wage($)	Total cost of labors($)
4000	15	2086	10	8	26	542,286

Table 11. Recalculated Total Estimated Man Hours

Total work units	Complete units per day	Total work hours per person	Number of labors	Work hours per person per day	Hourly Wage($)	Total cost of labors($)
4000	15	2086	8	8	26	433,888

9. Project Plan

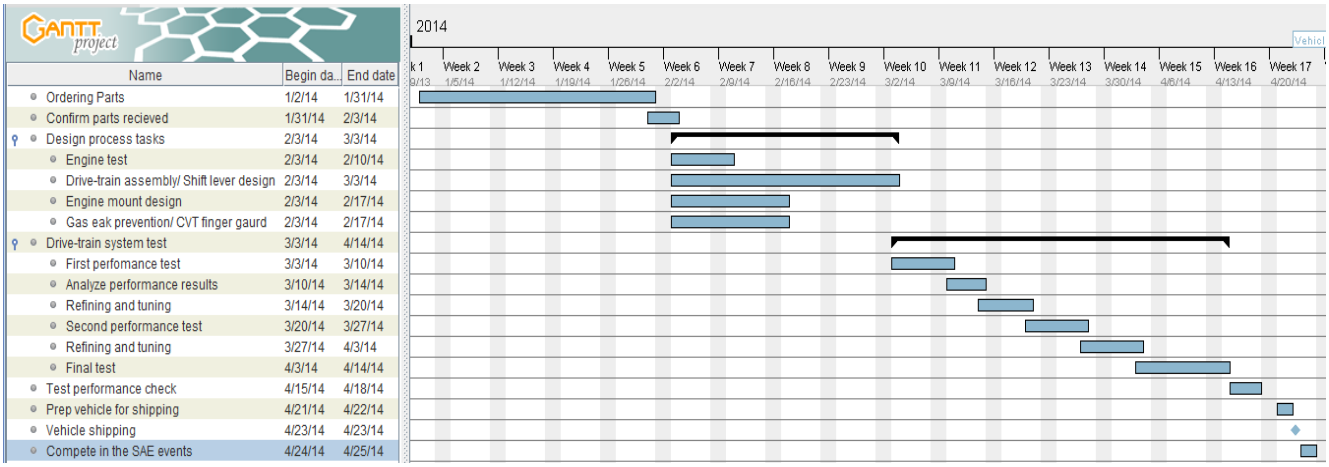

Figure 10. Gantt Chart

Based on the Gantt chart, the first step is to finish ordering all main the parts which is very essential to move this project forward. This should be done at 1/31/14. From 1/31/14 to 2/3/14, our team will confirm that all these parts have been received.

During the period, 2/3/14 to 3/3/14, our team will start working on the tasks assigned per drive-train tasks list. The tasks are supposed to be worked on at the same time to account for any delay and be able to finish all of the tasks at the assigned date. Drive-train assembly and shift lever design will take a month to finish. Therefore, it will be the team priority to make sure we are not falling behind on this task as it is the most essential step before the system testing.

After we finish the drive-train assembly, our team will start testing the whole system performance. Testing will be performed three times and tuning will be done after each test. This process will take from 3/3/14 to 4/14/14. After that, full performance test check will be done to confirm everything works perfectly and as expected. From 4/21/14 to 4/23/14, the vehicle will be prepared for shipping and shipped on the 23rd. the last task on this Gantt chart is to participate in the competition from 4/24/14 to 4/25/14.

10. Conclusion

Our team along with the frame team worked throughout the winter and has come up with a different design where the gear box and secondary reduction system are replaced by a differential. This idea was better because it will make our design lighter while it still achieve our intended goals for this

design. As a result, new parts needed to be ordered and a different plan account for the new changes. All the new parts have been ordered and most of them have already arrived. Testing of the parts will be performed when possible before assembly. After that, our team will start building and after that testing the system. According to our new plan, we will still be able to finish this project on time to participate in the SAE competition event.

11. References

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