SAE Baja - Drivetrain

By

Ricardo Inzunza, Brandon Janca, Ryan Worden

Team 11A

Concept Generation and Selection

Document

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Department of Mechanical Engineering

Northern Arizona University

Flagstaff, AZ 86011

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1.0 Introduction

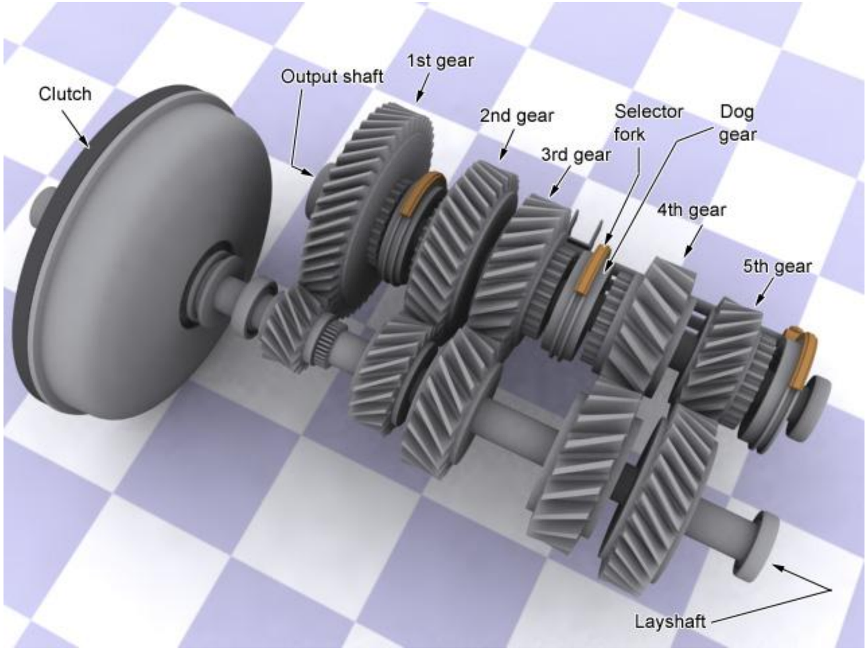
The Northern Arizona University Chapter of the Society of Automotive Engineers (SAE) has instructed our team to design a single seated off road vehicle capable of performing in the top 10 in a collegiate competition at Portland, Oregon from May 27-30, 2015. This competition is a challenge for colleges to design an off road vehicle capable of off road performance and customer desirability. The performance aspect of the vehicle is measured from the performance results of the vehicle in five challenging dynamic events: Acceleration, Hill Climb, Maneuverability, Rock Crawl, and Endurance.

The drive train team is responsible for the design of the vehicle from the engine to the wheels. This will include the engine, transmission, differential, and any power transmitting shafts. The engine is a constraint in our design; SAE requires the use of a Briggs and Stratton Model 20 engine. This specific model of engine proposes a challenge due to its max performance being 10 horsepower.

This year's 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 performances in these events depend greatly on the design and execution of the transmission design. The set performance goals to reach this goal are to complete a 100 ft distance in 4 seconds from a dead start, and for the vehicle to be able to drive up a large grade hill. The contents below describe the six concepts for transmission design that the team is considering to achieve the performance goals.

2.0 Concept 1: Manual

The manual transmission is the team's first concept generated for the drivetrain portion of the baja. As seen below in Figure 2.1, the manual transmission works by connecting multiple sets of gears, each of which has a different gear ratio.



(Manual Gearbox, Figure 2.1)

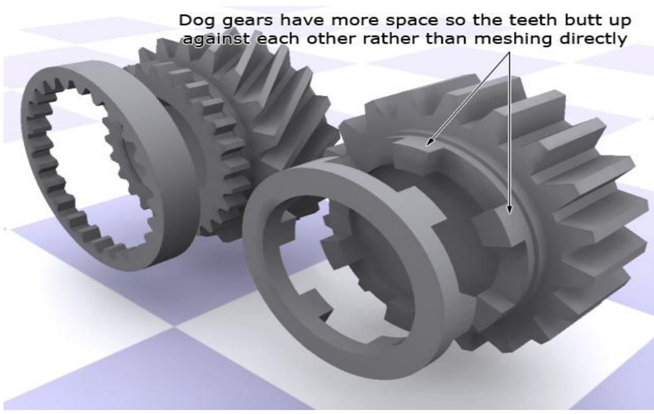
The gear sets are driven by an input shaft that is connected to a clutch. The clutch acts as a means of transmitting power by engaging a spring or hydraulic lever that will connect or disengage the input shaft to the set of gears. In order to shift from one ratio to the next, a shift fork is used to choose each gear. The shift fork is connected to a lever that the operator may use to select any gear he/she wishes. The gears are engaged by the use of a dog ring that is connected to one of the shift forks. In a manual transmission, the dog ring and gear must match up in a 1:1 ratio in order to shift into each gear. In order to do this the clutch must be engaged each time the operator wants to shift into another gear.

With the manual transmission comes a mix of both pros and cons. An advantage of the manual transmission is that it is reverse capable. Our customer, Dr. John Tester, required that we have a reverse gear integrated into our drivetrain. Because almost every manual gearbox is designed with a reverse gear, it will be very easy for the team to take an existing manual gearbox with reverse-capabilities, or to design a manual gearbox that can have a reverse gear integrated into it. Also, manual gearboxes have been tested for many years now and are a reliable means of transmitting power with multiple gear ratios. It is also a fairly cost effective design because most of the parts, such as gears and bearings, for this transmission are mass produced.

There are however a few disadvantages of running a manual transmission. First, they are in nature a bit heavier because of the need for a clutch and reverse gear. This also makes the gearbox larger because of the needed clutch and reverse shaft. A manual transmission also causes a loss of power that will occur in between each shift. When engaging and disengaging each gear ratio, the clutch must be used. Between each shift there is a brief period where there is no power being transmitted to the wheels. This can negatively impact the teams overall performance in both the Hill Climb and Acceleration tests, since there will be wasted time engaging and disengaging the clutch between each shift.

3.0 Concept 2: Sequential

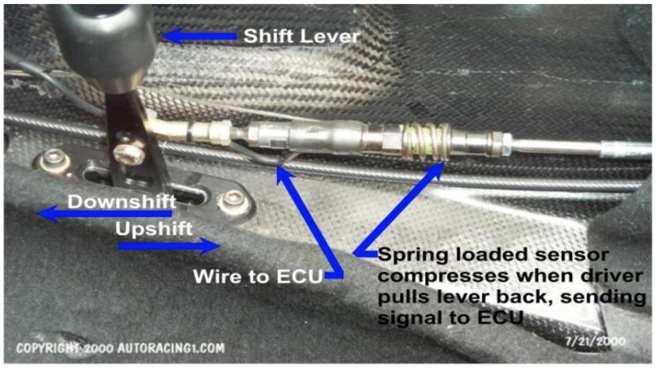
The next concept the team considered for a possible design solution is a sequential transmission. The sequential transmission is a derivative of the manual transmission with slight differences in the shifting mechanism. As seen in Figure 3.1, there is a difference in the geometry of the dog rings and the way which the gears and dog rings engage.



(Sequential (front) Vs. Manual (back) dog ring, Figure 3.1)

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 4th gear from 2nd gear, he/she must engage 3rd gear from 2nd gear, and then 4th gear from 3rd in sequence. The gear selection can be achieved by use of a shift lever as seen in Figure 3.2.



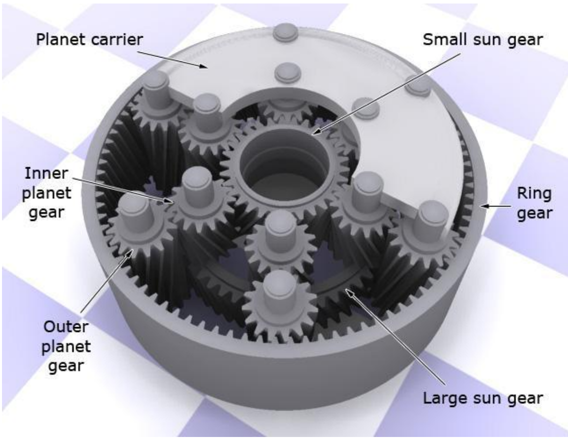
(Sequential Shift Lever, Figure 3.2)

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.

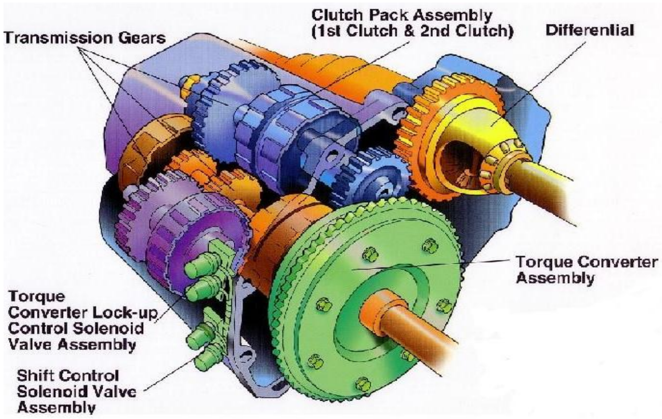
4.0 Concept 3: Automatic

The third concept the Drive Train team came up with was to design an automatic transmission. The automatic transmission has great attributes - it will shift gears on its own via the compound planetary gear system shown in Figure 4.1, which is connected to a torque converter by the small sun gear. The planet carrier then turns the ring gear by trying to spin the opposite direction of the torque converter, but due to a one-directional clutch system, the ring gear instead turns and becomes the output power. The compound planetary gear set allows for four forward gear ratios, and one reverse.



(Compound Planetary Gear System, Figure 4.1)

The automatic transmission has many advantages: 1) there is no power loss in shifting gears, 2) it has a high gear ratio range to allow for various speeds and terrains, 3) it is very reliable, and 4) the transmission has a reverse gear capability. However, there are many disadvantages for this type of transmission: the cost tends to be higher than most other kinds of transmissions, since it can shift gears by itself, and thus has more components, also resulting in a larger size. An example of an automatic transmission is shown in Figure 4.2.



(Automatic Transmission, Figure 4.2)

5.0 Concept 4: Direct Drive

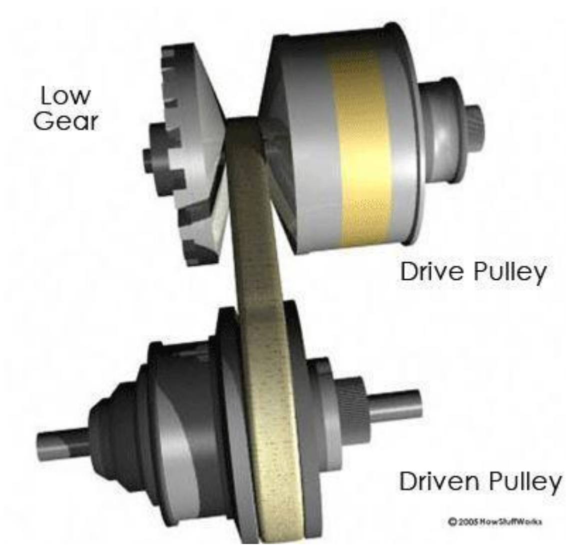
The fourth concept the Drive Train team came up with was a direct drive transmission, which is essentially a manual transmission with just one gear on the input shaft, and another on the output shaft, i.e. a single gear ratio, which is shown in Fig. 5.1.

(Direct Drive, Figure 5.1)

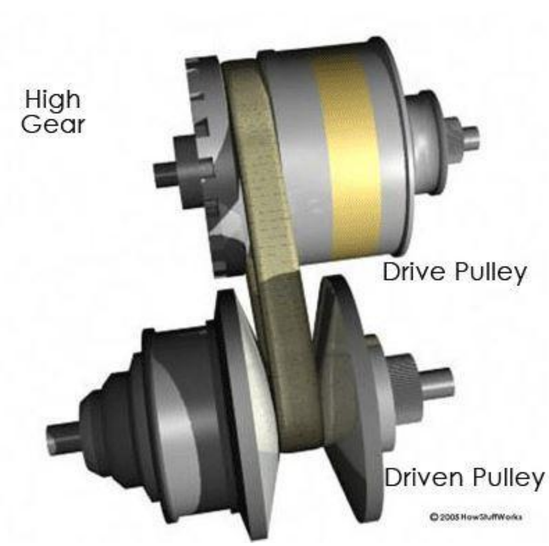
This system has many advantages: the cost is extremely low, the set up is very simple, small, and light, as the transmission only requires two gears; the one-to-one ratio also calls for a highly efficient system, as there aren't many losses due to friction if the gearbox is designed correctly. However, for the design of the Mini Baja, a Direct Drive Transmission will not be effective in events (such as the Hill Climb due to a static gear ratio), and will lose points in the design category, as the system does not allow for a reverse gear.

6.0 Concept 5: CVT Belt

The CVT (Continuously Variable Transmission) is the next concept being considered. The first type of CVT being considered is belt driven. A CVT has a desirable attribute of being able to change its overall gear ration without the need of shifting gears, thus saving time in acceleration; CVTs are also relatively light for the gear ratio ranges they offer. This is due to the capability of a CVT to change its pulleys' diameters via rotational force. A simple way of looking at a CVT is that it is a pulley system where the pulleys can change size to optimize the output power as shown in Figures 6.1 and 6.2 below. The CVT changes the pulleys' diameters by linearly shifting allowing the belt to slip down into the larger gap causing the relative pulley size to shrink, as in Figure 6.1 with the drive pulley, or grow if the gap has shrunk, as in Figure 6.2.



(CVT Belt, Figure 6.1)



(CVT Belt, Figure 6.2)

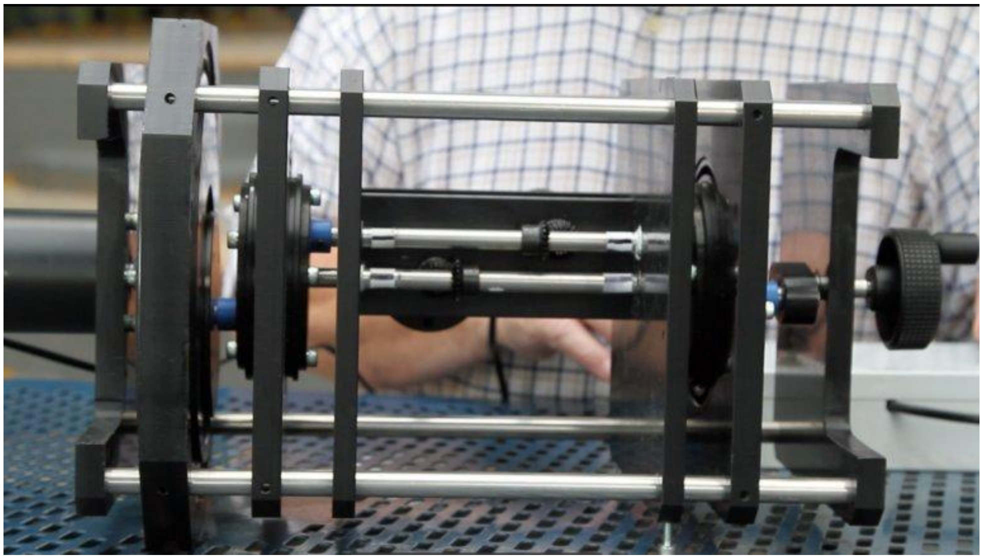
This is all great reason to use a CVT for fast acceleration and easy optimization of engine power. The disadvantages of a CVT though are also high in importance when considering overall performance in an off road vehicle. These include being limited in max power a CVT can handle due to the fact that the system is dependent on the belt's friction on the pulley to transmit power and this fact also results in relatively low efficiency compared to other designs.

7.0 Concept 6: CVT Gear

For these reasons the final consideration is a gear type CVT. The benefit of this design is that is keeps the changing gear ration of a normal CVT without the need of relying on the friction of a belt to transmit the power. This in conjunction with all the other benefits of a belt type CVT is very desirable for overall performance.

A CVT Gear setup works by transmitting power trough a double planetary gear system. The sun gear in both gear sets are connected to each other by a single shaft, ratio shaft, that is rotated by an external electric motor. This external motor actually sets the gear ratio by adjusting how fast the planet gear has to spin in order to keep up with how fast the ring gear is spinning. In the first gear set the planet gear is the input from the drive engine, and the ring gear is attached to a shaft that also attaches to the second ring gear. In the second gear set the planet gear is the output that goes to the drive shafts to the wheels. The technology for this variable capability is accomplished by rotating the ratio shaft at different speeds from the drive shaft to allow the gear sets to force each other to change how fast and which direction the output shaft is turning. As implied the CVT Gear setup does have the capability of reverse without additional weight.

The disadvantage of a gear type CVT is that is a very new technology. This proposes the issue of figuring out if we have the time and facilities to develop this type of CVT. Another disadvantage is as you can see in Figure 7.1 that it is relatively large and complicated with the number of moving parts and the number of gears.



(CVT Gear, Figure 7.1)

With these considerations, if we are capable of getting assistance from the inventor, Stephen Durnin, we may be able to design and manufacture this type of transmission for our specific application.

8.0 Concept Selection

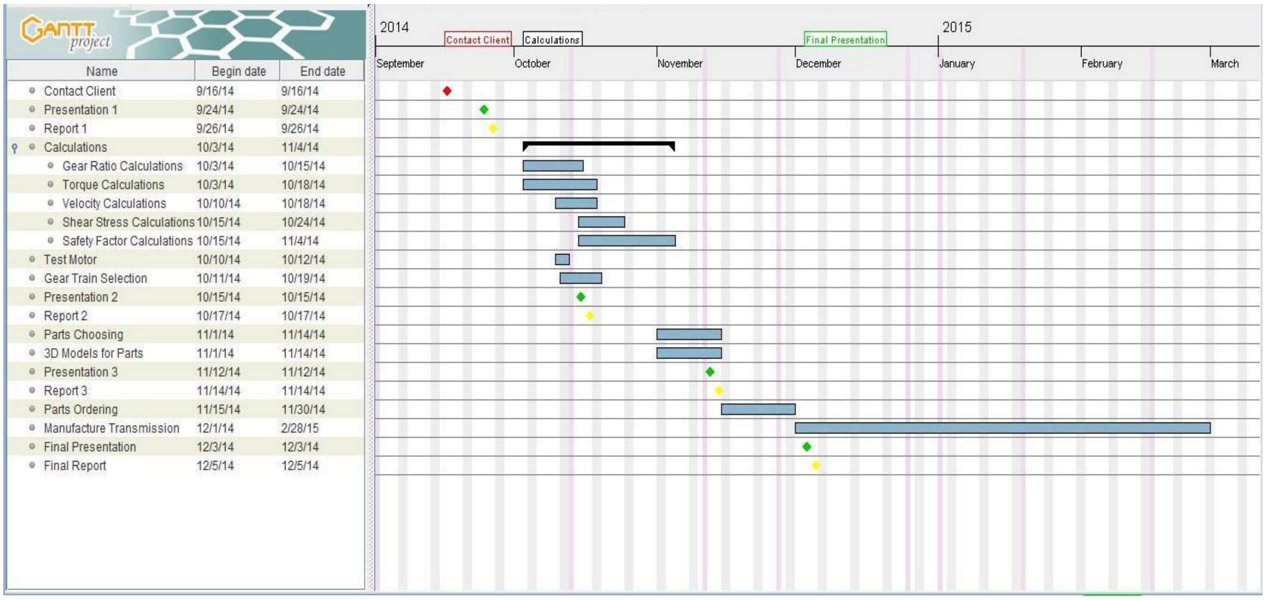
Using Dr. John Tester's requirements, as well as other necessary criteria, the Drive Train team came up with eight different criteria in which to rank each of the six ideas, as well as weights for each criterion, shown the decision matrix in Table 8.1. The criteria generated (cost, gear ratio range, efficiency, weight, simplicity of design, reliability, size, and capable of a reverse gear) were then ranked for type of transmission on a scale of one to five, five being the best for the vehicle, and one being the worst. Totals were then calculated by summing the products of the rank and weight of each criterion for each transmission. This led to two top choices: the Sequential and CVT Gear transmissions, with a manual transmission in third place. The team will now be analyzing all three gearboxes, as instructed by Dr. Srinivas Kosaraju, because of the complexity of the CVT Gear box. From our calculations we will then decide which concept to implement into the Mini Baja vehicle.

(Decision Matrix, Table 8.1)

Scale 1-5 5 = Best, 1 = Worst	Cost	Gear Ratio Range	Efficiency (Loss of Power)	Weight	Simplicity of Design	Reliability	Size / Volume	Reverse Gear Capable	Total
Sequential	3	5	5	4	3	4	4	3	3.95
Manual	3	5	4	3	4	4	3	4	3.85
CVT Belt	2	3	2	3	5	2	5	1	2.35
CVT Gear	2	5	4	3	3	4	3	5	3.85
Automatic	2	4	3	3	2	4	2	4	3.2
Straight (One Gear Ratio)	5	2	5	5	5	5	5	1	3.75
Customer Weighting	15%	15%	20%	10%	5%	10%	5%	20%	

9.0 Project Plan

The Drive Train team has been progressing through the project's plan as according to the team's Gantt Chart, shown in Fig. 9.1. The team actually has gotten ahead of schedule in testing the motor, which was done on October 10, 2014, five days before the originally planned date of October 15, 2014. The Drive Train team also acquired the help of Industrial Metal Supply Co., also on October 10, 2014, in Phoenix, AZ, who has helped supply parts and materials for various aspects of the baja vehicle. The team still hopes to have the calculations done by the beginning of November and its parts ordered by the end of November.



(Gantt Chart, Fig. 9.1)

10.0 Conclusion

In conclusion, the team has established constraints and objectives that must be considered when generating and deciding on which concepts to select for the drivetrain portion of the Mini Baja vehicle. The Drive Train team has also confirmed from the Gantt Chart that all deadlines and milestones are being met thus far in the project.

Six concepts were generated for the drivetrain of the baja that the team considered. In order to pick two final concepts from the initial six, a decision matrix was formed. The team came up with criteria in which each concept would be evaluated and weighted accordingly. The final two designs the team chose, was the sequential transmission, and the CVT gear. The team will now move to the next step of analysis for both concepts in order to be sure the two designs will meet the team's requirements and constraints.

11.0 References

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