SAE Baja Design
Engineering Analysis Presentation
Team Drivetrain

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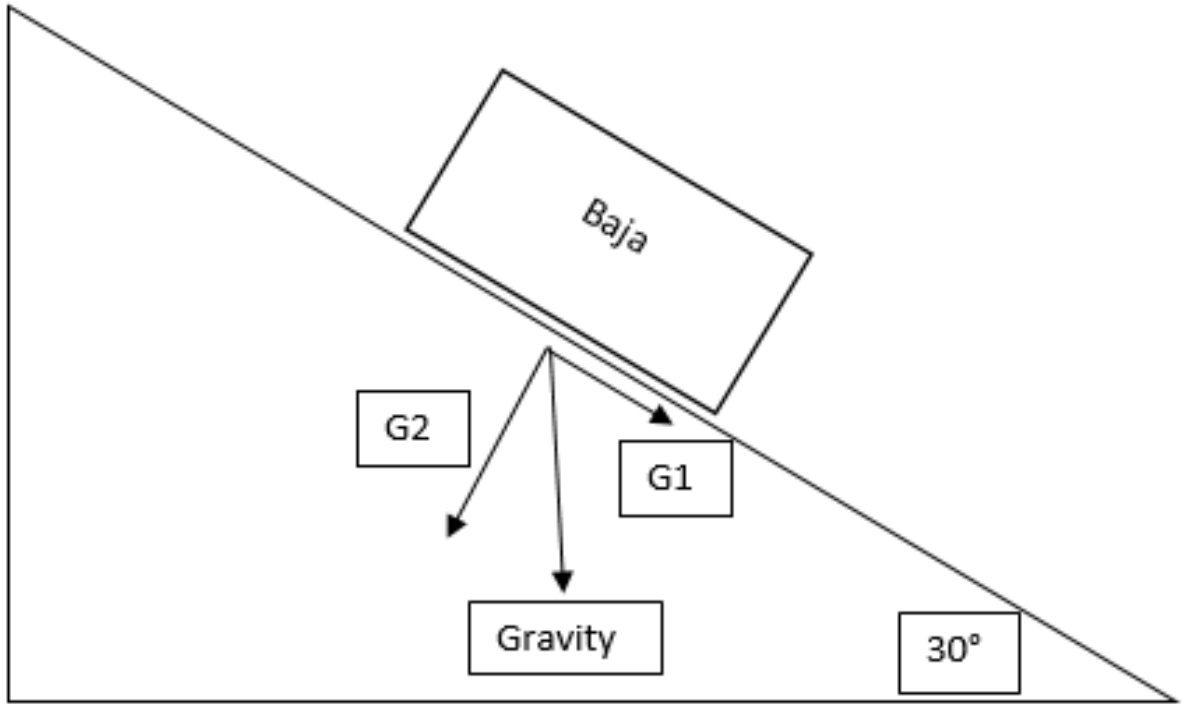
Recap

- The problem statement
  - The purpose of our team is to define and design the best possible drivetrain for the specific use of a single seater off road buggy.
- Concept generation
  - Manuel transmission
  - Automatic transmission
  - CVT transmission

Goals

- Torque
  - Reach the maximum torque 290 lb-ft on the wheels
- Speed
  - Reach the maximum speed 40 mph

General Analysis (Hill Climb)



General Analysis (Hill Climb)

- G1 = G * sin ∂ = 600lb * sin 30 = 300 lb
- Force per wheel = 150 lb
- Torque per wheel = 150lb * $\frac{D}{2}$ = 150lb * 11.5 in/12 = 143.75 lb-ft
- Total torque $(T_t) = 287.5\ lb - ft$

General Analysis (Acceleration)

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

General Analysis (Acceleration)

- The top teams averaged: 4 sec. to finish a 100 ft course.
- Assuming constant acceleration, we can calculate the maximum velocity:

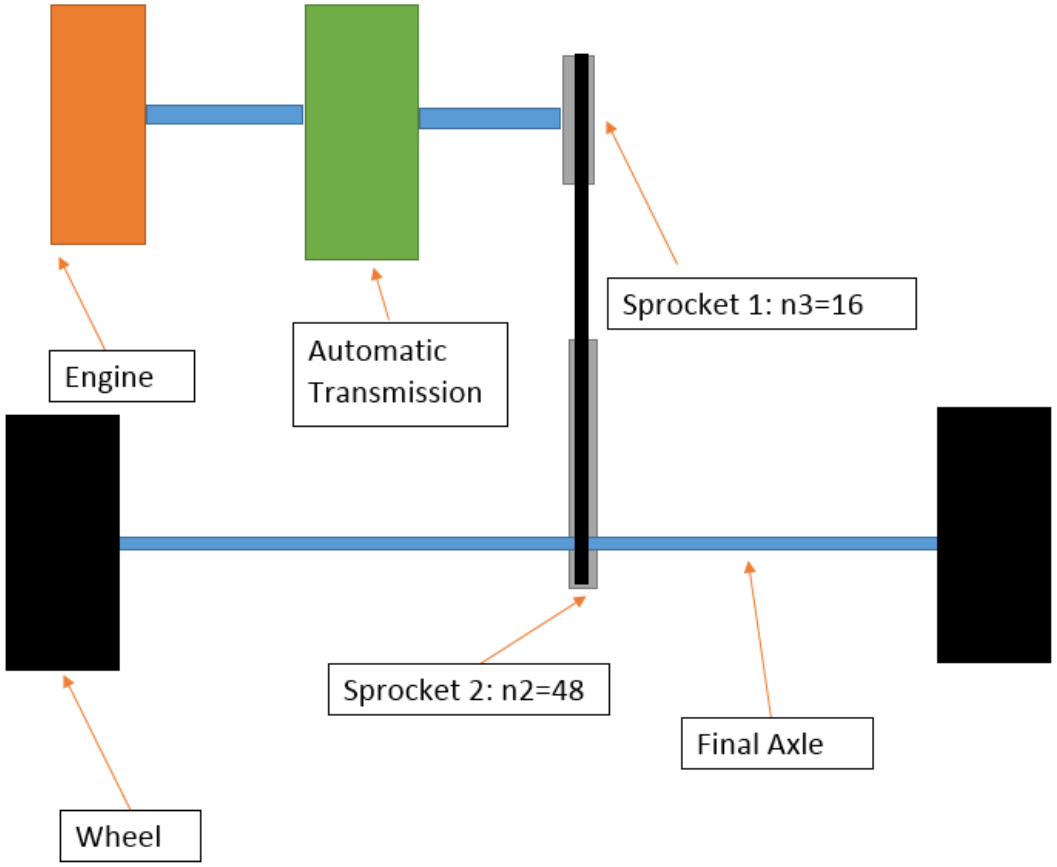
Distance = Max Velocity * time / 2

Max velocity = Distance* 2 / time

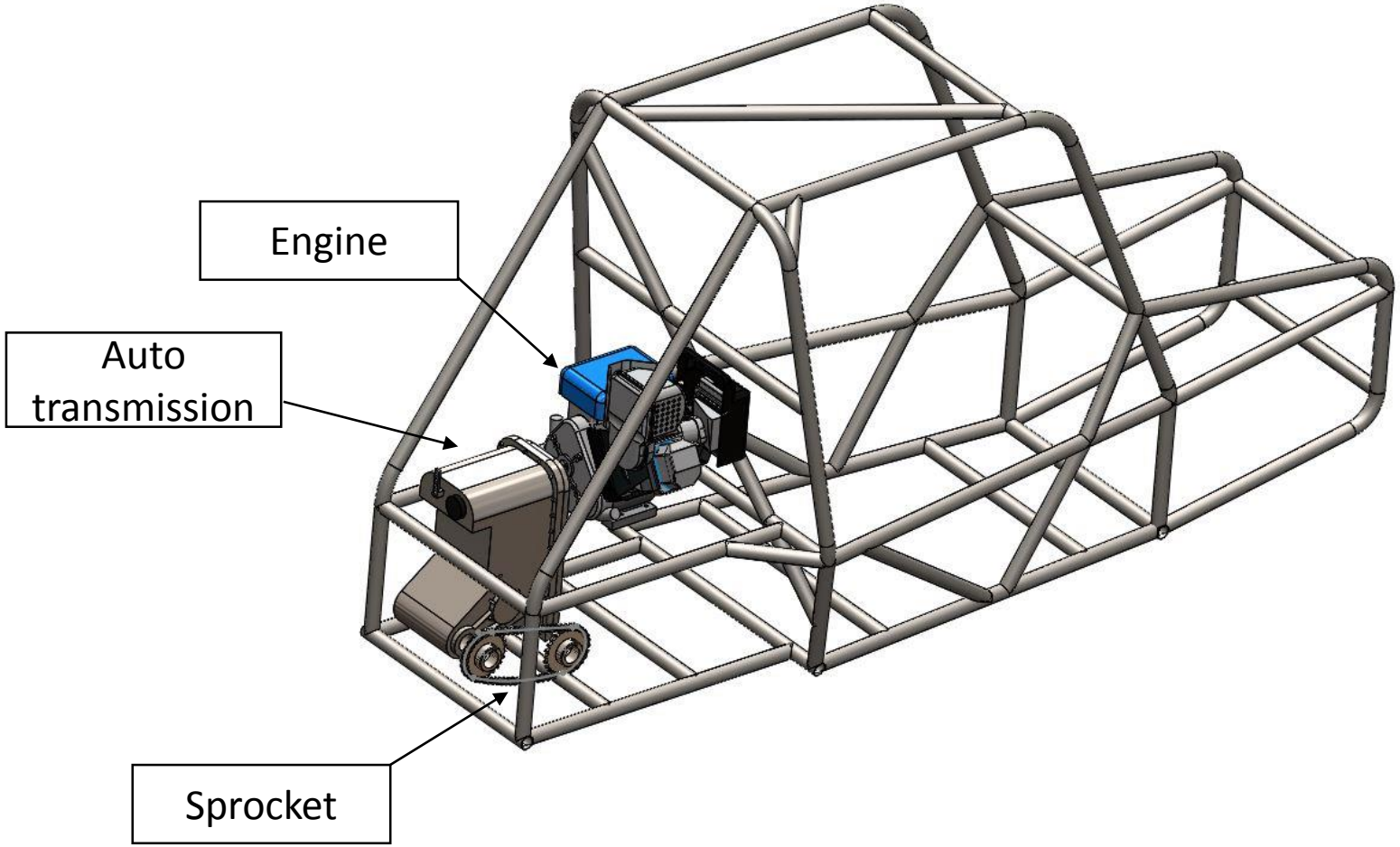
= 100 ft * 2* 0.68/ 4s

= 34 mph

Auto Design Concept



Auto Design Drawing



Auto Analysis (Assumptions)

- Wheel diameter(D): 23 inch
- Total weight (W): 600 lb (including the driver)
- Slope of the hill (∂): 30 degree
- Efficiency of Automatic(r_{auto}): 85%
- Automatic Transmission: high speed ratio (r_{h-auto}) : 2.88:1
  low speed ratio (r_{l-auto}) : 7.49:1
- Sprockets ratio(r_{second}): 3:1

Auto Analysis (Calculations)

- Total ratio(include sprockets): high speed ratio (r_h),
  low speed ratio (r_l)

$$r_h = r_{h-auto} * r_{second} \quad =8.64$$

$$r_l = r_{h-auto} * r_{second} \quad =22.47$$

- Maximum Torque on wheels = Torque output *r_l * N_{auto}*N_{sp}
- Maximum speed= $\frac{Wheel\ diameter * RPM\ from\ engine * \pi}{high\ speed\ total\ ratio * 12 * 60} * 0.68$

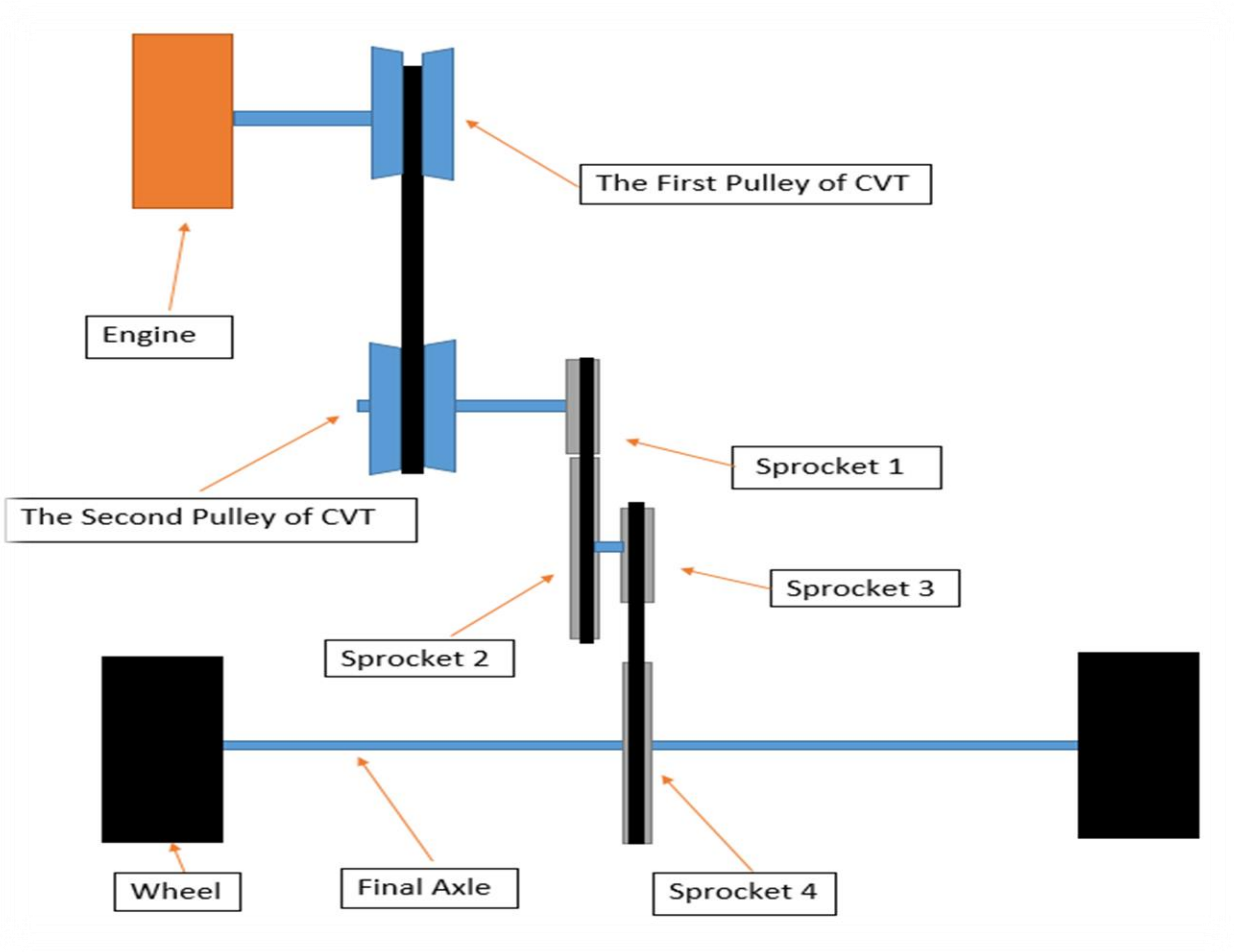
Auto Analysis (Results)

- Maximum torque(include system efficiency): 276.94lb-ft
- Maximum speed: 30.01mph
- Maximum torque on each sprocket:

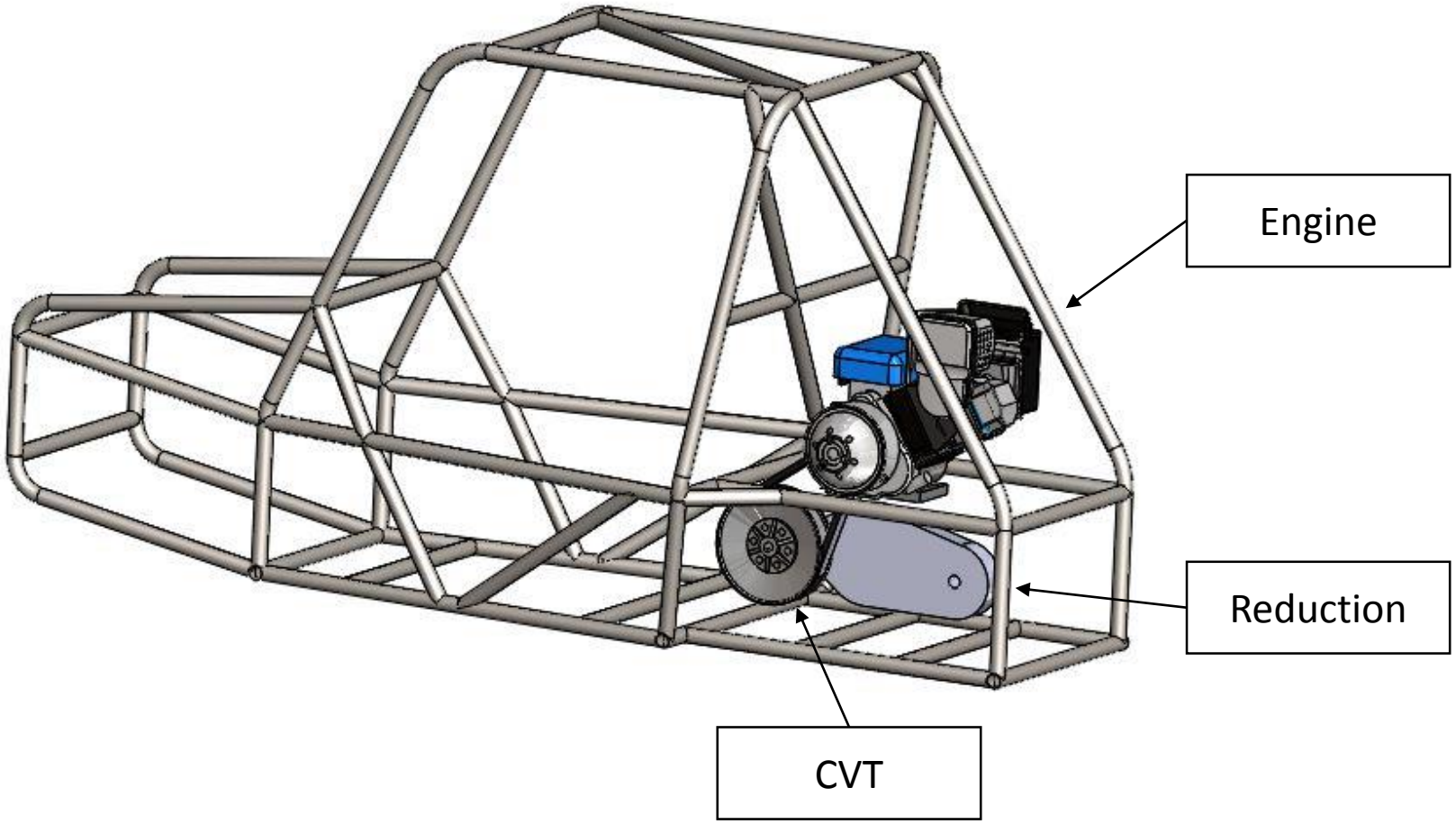
  T1=108.605lb-ft

  T2=325.815lb-ft

CVT Design Concept



CVT Design Drawing



CVT Analysis (Assumptions)

- Wheel diameter(D): 23 inch
- Total weight (W): 600 lb (including the driver)
- Slope of the hill (∂): 30 degree
- Reduction ratio (r_r): 12:1
- Efficiency of CVT(N_{cvt}): 88%

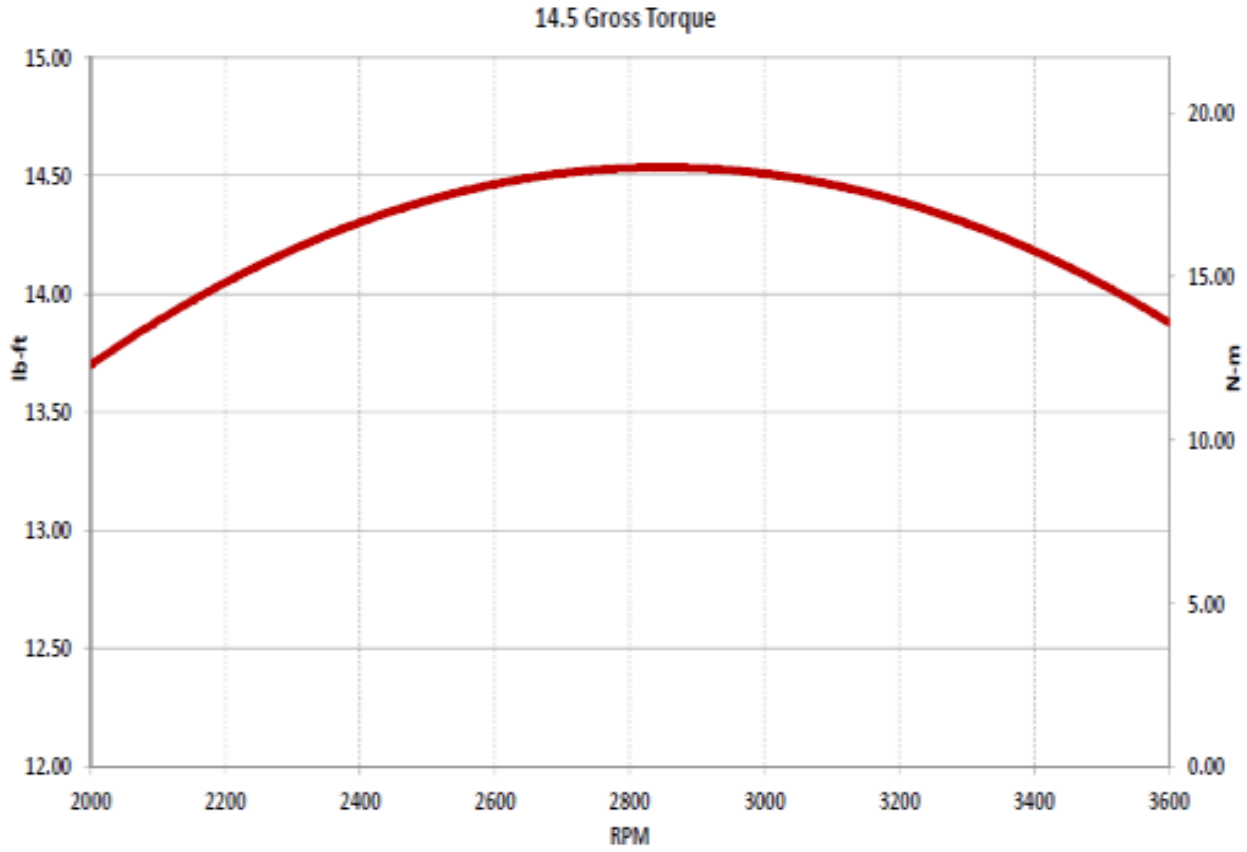
CVT Analysis (Assumptions)

- CVT: high speed ratio (r_{h-cvt}) : 0.5 low speed ratio (r_{l-cvt}) : 3
- Start RPM for CVT is 800 rpm and high speed ratio occur at 3600 rpm, assuming ratio varies linearly, we find the following relationship:

$$r_{cvt} = \begin{cases} 0 & \text{for } rpm < 800 \\ 3 - \frac{2.5*(rpm-800)}{2800} & \text{for } 800 < rpm < 3600 \\ 0.5 & \text{for } 3600 < rpm \end{cases}$$

- Total ratio: high ratio (r_h), low ratio (r_l)

CVT Analysis (Torque curve**)**



Source: Briggs & Stratton

CVT Analysis (Calculation**)**

- CVT ratio = 3 - $\frac{2.5*(rpm-800)}{2800}$ for 800<rpm<3600
- Total ratio = $r_{cvt} * r_r * N_{cvt} = r_{cvt} * 12 * 0.88$
- Torque on the wheel = Torque output * Total ratio * N_{cvt}
- Speed = $\frac{D * RPM * \pi}{total\ ratio * 12 * 60} * 0.68 = \frac{23\ in*RPM*\pi}{total\ ratio * 12 * 60} * 0.68$

CVT Analysis (Calculation)

Engine rpm	Torque output (lb-ft)	CVT ratio	Total ratio	Torque on wheel (lb-ft)	Speed (mph)
1800	13.20	2.107	22.251	293.719	5.52
2000	13.70	1.929	20.366	279.010	6.70
2200	14.10	1.750	18.480	260.568	8.12
2400	14.30	1.571	16.594	237.298	9.87
2600	14.45	1.393	14.709	212.539	12.06
2800	14.52	1.214	12.823	186.188	14.90
3000	14.50	1.036	10.937	158.589	18.72
3200	14.40	0.857	9.051	130.341	24.13
3400	14.20	0.679	7.166	101.753	32.38
3600	13.80	0.500	5.280	72.864	46.53

CVT Analysis (Calculation**)**

- Chose the CVT: *PULLEY SERIES 0600 AND DRIVEN PULLEY SERIES 5600* from CVTech-AAB Inc.
- 0.45 high ratio to 3.1 low ratio
- CVT ratio = 3.1 - $\frac{2.65*(rpm-800)}{2800}$ for 800<rpm<3600

CVT Analysis (Calculation)

Engine rpm	Torque output (lb-ft)	CVT ratio	Total ratio	Torque on wheel (lb-ft)	Speed (mph)
1800	13.20	2.154	22.742	300.191	5.40
2000	13.70	1.964	20.743	284.177	6.58
2200	14.10	1.775	18.744	264.290	8.01
2400	14.30	1.586	16.745	239.456	9.78
2600	14.45	1.396	14.746	213.084	12.03
2800	14.52	1.207	12.747	185.093	14.99
3000	14.50	1.018	10.749	155.854	19.05
3200	14.40	0.829	8.750	125.996	24.96
3400	14.20	0.639	6.751	95.862	34.37
3600	13.80	0.450	4.752	65.578	51.70

CVT Analysis (Calculation**)**

- The maximum torque applied on the sprockets are followed by the equations below :

(T is the torque output from engine, T1,2,3,4 is the torque applied on each sprocket)

T1 = T * $r_{cvt} * N_{cvt}$=13.20 lb-ft * 2.154 * 0.88=25.02 lb-ft

T2 = T1 * $\frac{n2}{n1}$=25.02lb-ft * 4 = 100.08 lb-ft

T3 = T2 = 100.08 lb-ft

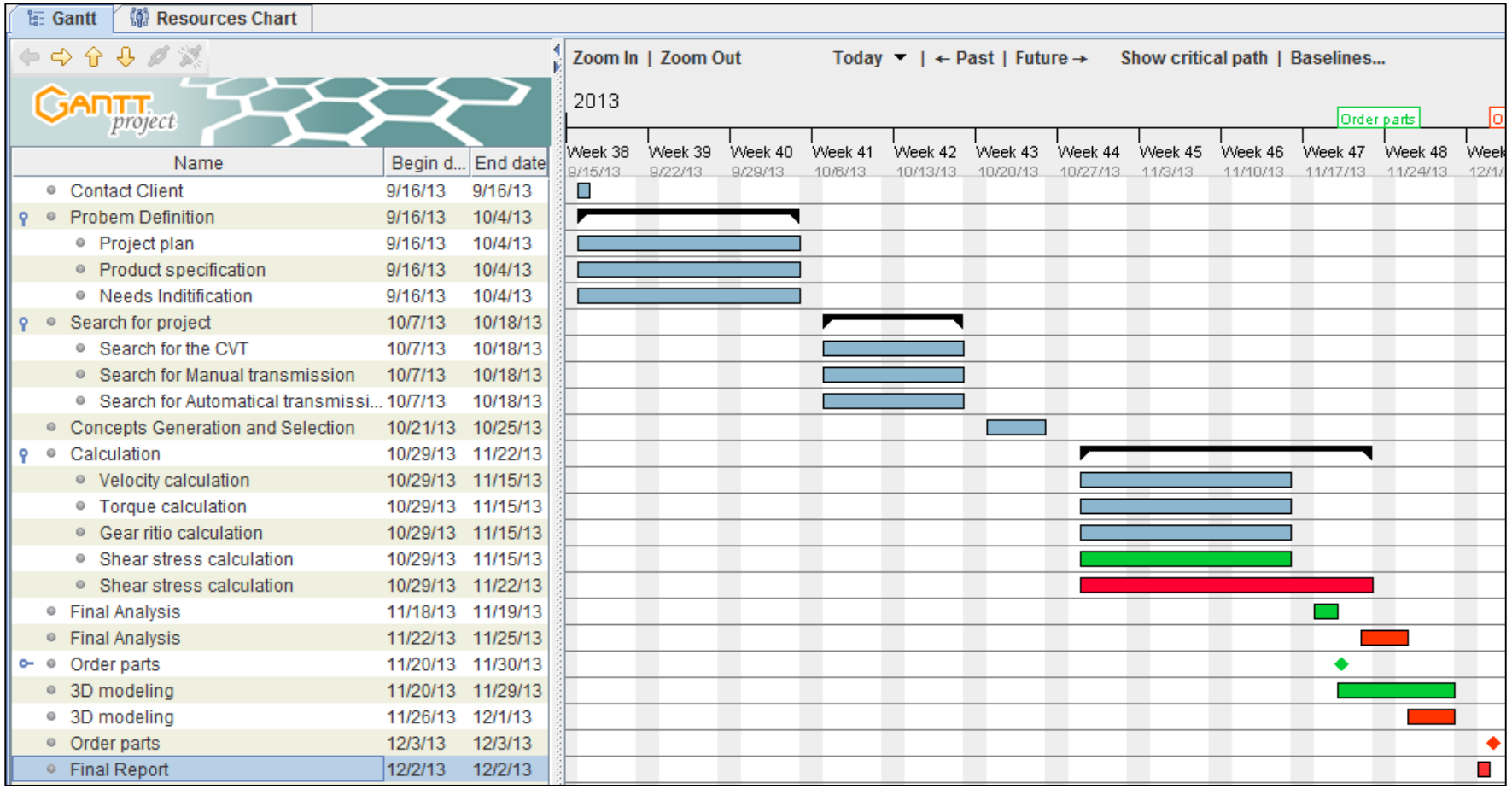
T4 = T3 * $\frac{n3}{n2}$ = 100.08lb-ft * 3 = 300.19 lb-ft

CVT Analysis (Results)

- CVT : 0.45 high speed ratio to 3.1 low speed ratio
- Max torque on the wheel: 300.191 lb-ft
- Max speed: 51.70 mph
- T1 = 25.02 lb-ft
- T2 = 100.08 lb-ft
- T3 = 100.08 lb-ft
- T4 = 300.19 lb-ft

Project plan progress

Gantt Chart



Conclusion

- Two concepts were generated and both preliminary evaluated
- Generally analyzed the overall system
- Analysis shows the auto transmission will not satisfy both goals
- Analysis shows that CVT will provide both a satisfactory speed and torque

References

- CVTech-AAB

Available:

http://www.numeriquetechnologies.com/cvtech/CatalogueCVTech-AAB_US_%202013.pdf

- Seamless AMT offers efficient alternative to CVT

Available:
http://www.zeroshift.com/pdf/Seamless%20AMT%20Offers%20Efficient%20Alternative%20To%20CVT.pdf

- Baja SAE Result

Available: http://students.sae.org/competitions/bajasae/results/

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- Marcelo de Jeus R, da nobrega, Souza Xavier Leydervan de, et al. "Modeling and Simulation of the Transmission System-Dynamic of a System equipped with a CVT for Mini-Baja vehicle." SAE Technical paper series. Sao Paulo: SAE Brasil, 2004. 5. Print.