Shell Eco-Marathon Engineering Analysis

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Project Background

- **The purpose of this project is to design, build, and compete with a vehicle that maximizes fuel efficiency in the Shell Eco-Marathon Competition in April 2014.**
- **The team's primary focus is designing the engine, drivetrain, fuel and electrical systems for the design vehicle.**
- **The NAU Shell Eco-Marathon team has successfully completed Phase I registration (with Shell confirmation) and has began Phase II registration.**

Engine Selection Analysis

- **3 Honda engines analyzed**
  - **GX25**
  - **GX35**
  - **GY6-QMB**
- **The teams methodology for the analysis is to compare each engine’s respective Otto Cycle Efficiency and Brake Specific Fuel Consumption (BSFC) based upon the performance properties of the engine.**

Engine Selection Analysis

Table 1: Engine Performance Properties				
	Units	Honda GX25	Honda GX35	Honda GY6
Displacement	cc	25.00	35.00	50.00
Comp. Ratio	unitless	8.00	8.00	10.50
Power Output	kW	0.72	1.00	2.10
Torque Output	N-m	1.00	1.60	3.10
Initial Fuel Consumption	L/hr	0.54	0.71	1.04
Fuel Consumption Engine Speed	RPM	7000	7000	6500

Engine Selection Analysis

Air Standard Otto Cycle

- **Otto Cycle Efficiency Equation:**

$$\eta = 1 - \frac{1}{r^{k-1}}$$

- **r is the engine compression ratio**
- **k is the specific heat ratio**
  - **For ambient air, ~1.4**

Engine Selection Analysis

Table 1: Otto Cycle Efficiencies	
Engine:	**Efficiency:**
GX25	57%
GX35	57%
GY6-QMB	62%

Engine Selection Analysis

Brake Specific Fuel Consumption

- **Measure fuel consumption without considering driving habits**

$$BSFC = \frac{r}{T \times \omega}$$

- **r = fuel consumption in g/s**
- **T = engine torque in N-m**
- ω **= engine speed in radians/s**
- **Smaller number means less fuel consumed**

Engine Selection Analysis

Table 2: Brake Specific Fuel Consumption	
Engine:	**Efficiency: (g/J)**
GX25	**0.00072**
GX35	**0.00059**
GY6-QMB	**0.00048**

Engine Selection Analysis

After performing an engineering analysis on the engines that were selected from the concept generation process, the team concluded that the GY6 has highest efficiency and lowest brake specific fuel consumption of 62% and 0.00048, respectively. This was concluded by using the Otto Cycle Efficiency Equation and the BSFC Equation.

Drivetrain Selection Analysis

- **2 drivetrains analyzed**
  - **Continuously Variable Transmission (CVT)**
  - **Chain and Sprocket**
- **The teams methodology for the analysis is to compare each drivetrain's respective efficiencies for transmitting the amount of torque from the engine to the drive wheel.**

Drivetrain Selection Analysis

We estimate the required rotational speed in RPM by using the following equation:

$$RPM = \left(\frac{V}{C}\right)(60)\left(\frac{sec.}{min.}\right)$$

- **V = Velocity of the vehicle**
- **C = Circumference,** $C = 2 * \pi * Wheel\ Radius$

The selected GY6 engine has a power 2.8 HP(2.1kW) @ 6500 RPM, torque of 3.1 N-m @ 5500 RPM.

Keeping in mind that we can find the torque @ 6500 RPM from the equation:

$$T = \frac{(HP)(33{,}000)}{(2\,\pi)(RPM)}\ \text{(ft-lbs)}$$

Drivetrain Selection Analysis

For the CVT Belt transmission that is integrated with our engine, it has a gear ratio between 0.8 and 2.4, and a reduction of 62:14. The efficiency of a transmission can be calculated as following:

$$\eta = \frac{T_W}{T_{Engine}} * Gear\ ratio$$

- **η = The efficiency of the transmission.**
- T_w**= The torque of the rear wheel**
- T_{Engine}**= The torque of the engine**

Basically, the torque of the engine can be calculated by multiplying the total tractive effort, radius of the wheel and the resistance factor. Assuming that the contact surface is asphalt, the resulting effect is a surface friction of 0.9.

Drivetrain Selection Analysis

CVT Belt Transmission

- **Integrated into GY6 engine**
- **Efficiency of 88% (Assumed from research)**
- **Impossible to attach 20 inch wheel due to size constraints**

Sprocket and Chain Drive

- **Efficiency of 97% (Assumed from research)**
- **Proposed constant gear ratio of 25:1**

Drivetrain Selection Analysis

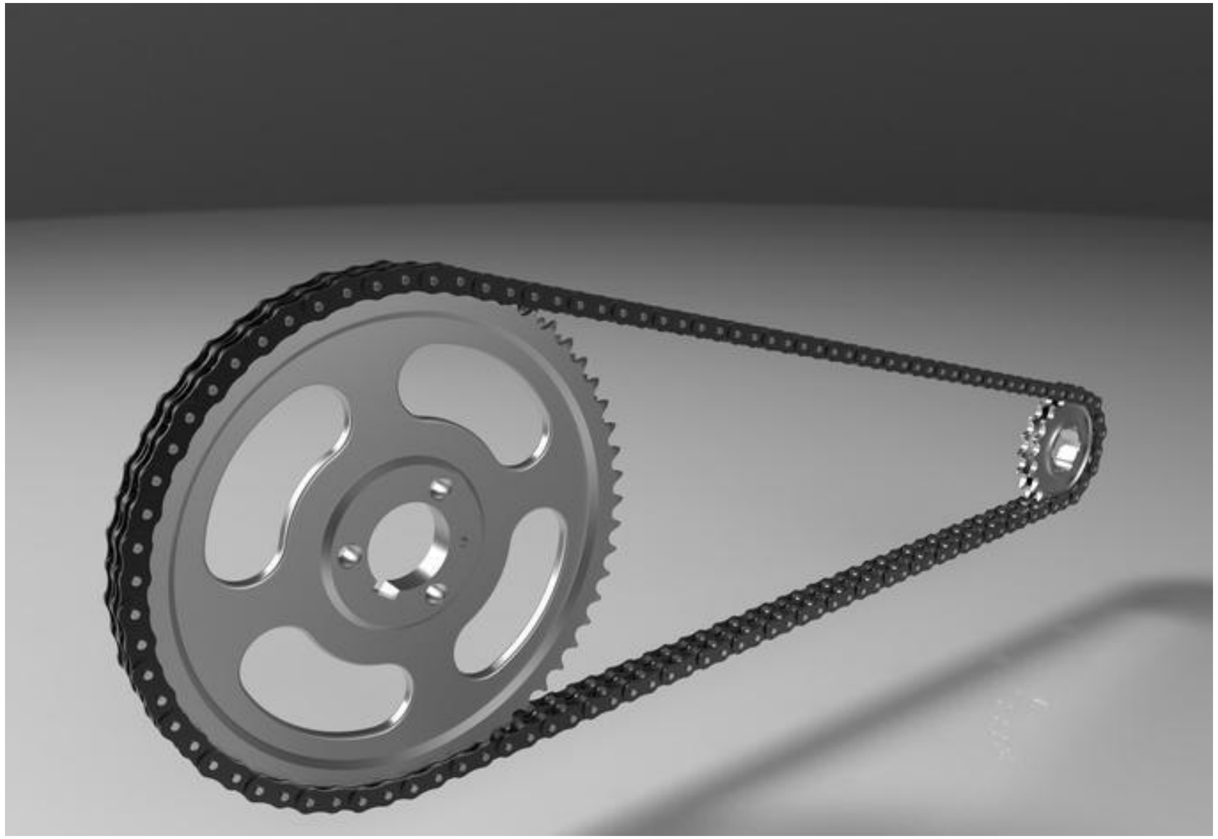


Image: **https://grabcad.com/library/roller-chain-drive-iso-606-05b-2**

Fuel System Analysis

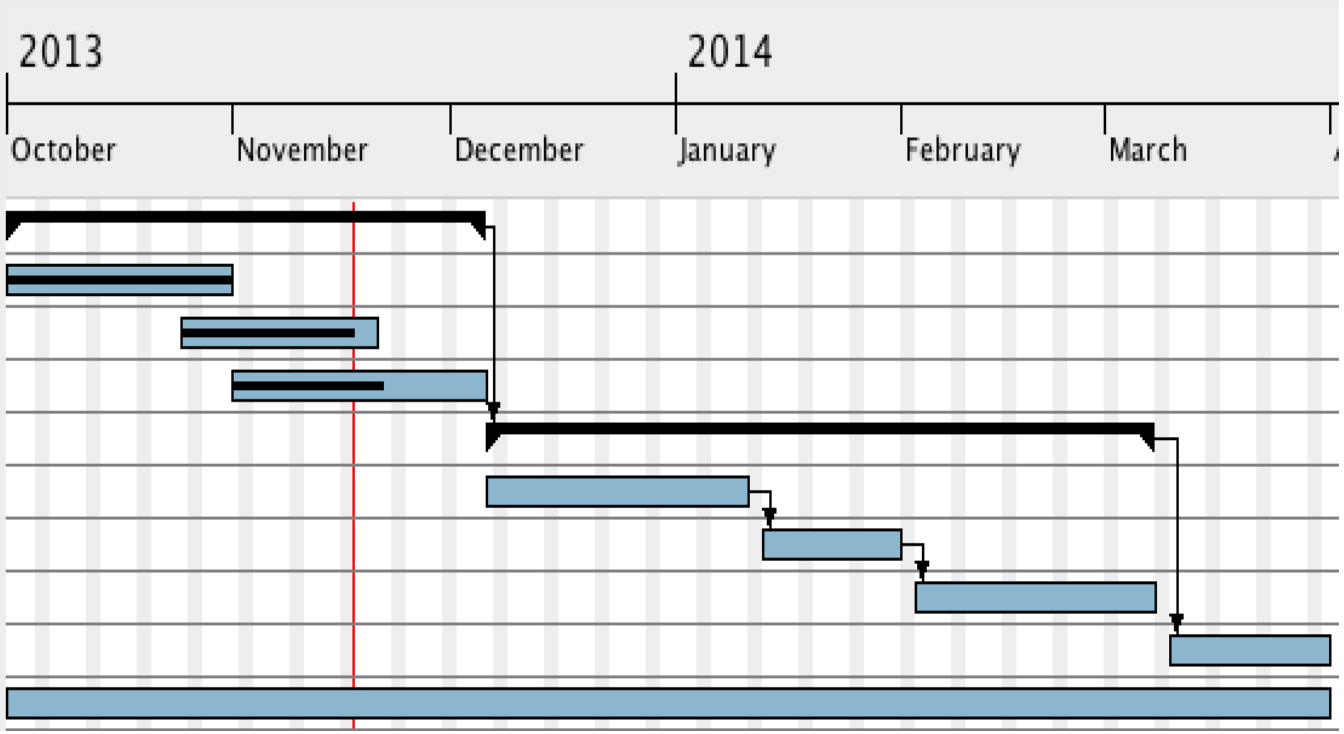
The team is limited to very specific rules and guidelines for the design vehicle in regards to the fuel system. Through the concept generation and concept selection the team feels that the fuel injection concept does not need to be analyzed at this time. This is because the chosen fuel injection system is compatible with the GY6 engine. Also, the fuel injection software will allow the team to precisely tune the fuel flowrate once the final vehicle is designed. This tuning will be an experimental process through various trials, analyzing fuel consumed for each trial.

Electrical System Analysis

The team is limited to very specific rules and guidelines for the design vehicle in regards to the electrical system. Through the concept generation and concept selection the team feels that the electrical system does not need to be analyzed in a engineering analysis. This is because the electrical system will be charged as the engine is running by an generator already integrated into the GY6 engine. Also, all electrical components will be ones used in common vehicle applications.

Project Planning

Name	Begin date	End date
Drivetrain Design	10/1/13	12/5/13
Fuel System Design	10/1/13	10/31/13
Power Transfer Design	10/25/13	11/20/13
Electrical Systems Design	11/1/13	12/5/13
Drivetrain Construction	12/6/13	3/7/14
Order OTS Parts	12/6/13	1/10/14
Integrate Engine System	1/13/14	1/31/14
Integrate Electrical Systems	2/3/14	3/7/14
Test Vehicle	3/10/14	3/31/14
Technical Documentation	10/1/13	3/31/14



Conclusion

After performing engineering analysis for the design vehicle systems the team has came up with the following findings:

- **The engine performance of the GY6 will yield a high efficiency of 62% and a low BSFC of 0.00048 g/J.**
- **The drivetrain performance has been analyzed to transmit 97% of the engine output torque to the drive wheel. This will be accomplished by using simple machined pinion and sprocket gears to achieve a gear ratio of**
- **The fuel system is compatible with the GY6 engine and will be analyzed by experimental trials to obtain the best fuel efficiency once the vehicle is completed during the teams tuning phase.**
- **The team is on schedule to complete the design vehicle systems by the initial deadlines.**

References

- **Acosta, B., Betancourt, M., Pinheiro, F., "Shell Eco-Marathon 25% of Final Report," B.S. thesis, Mechanical Engineering Department, Florida International University, Miami, 2012.**
- **Heath, R P G and Child, A J. "Seamless AMT offers efficient alternative to CVT". SAE 314-20075013**
- **Honda Engines, "GX25 Motor Specs," http://engines.honda.com/models/model-detail/gx25, Oct. 2013.**
- **Honda Engines, "GX35 Motor Specs," http://engines.honda.com/models/model-detail/gx35, Oct. 2013.**

Questions?