FSAE Continuously Variable Transmission

Team 13

Outline

- Problem Description
- Introduction to Continuously Variable Transmissions
- Key Features: Tuning Parameters
- Performance Analysis
- Implementation and Key Design Analyses
- Cost
- The Future

The Problem

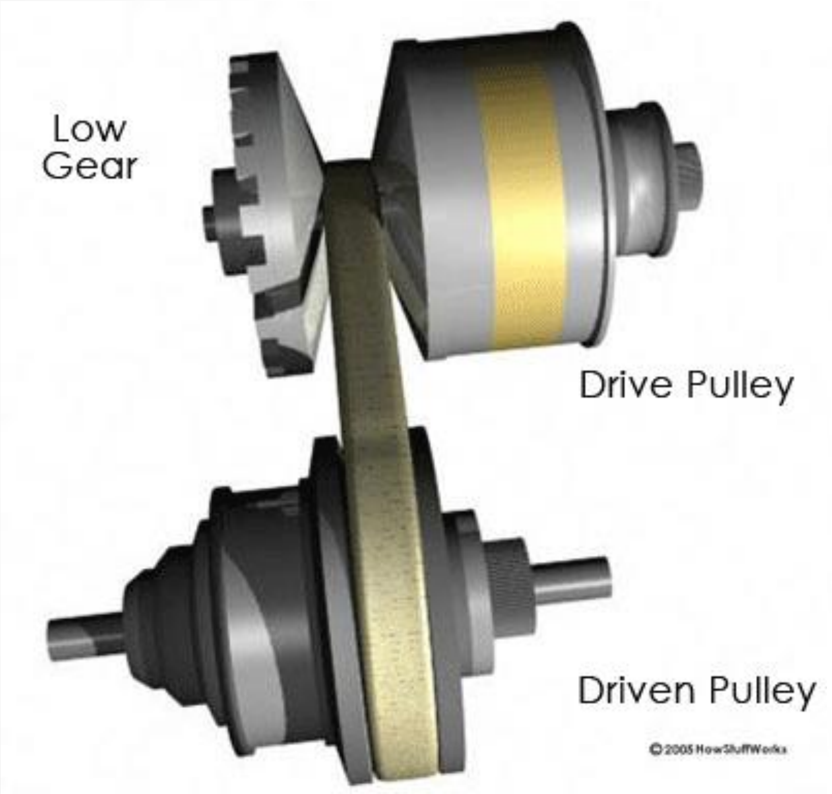
Goal:

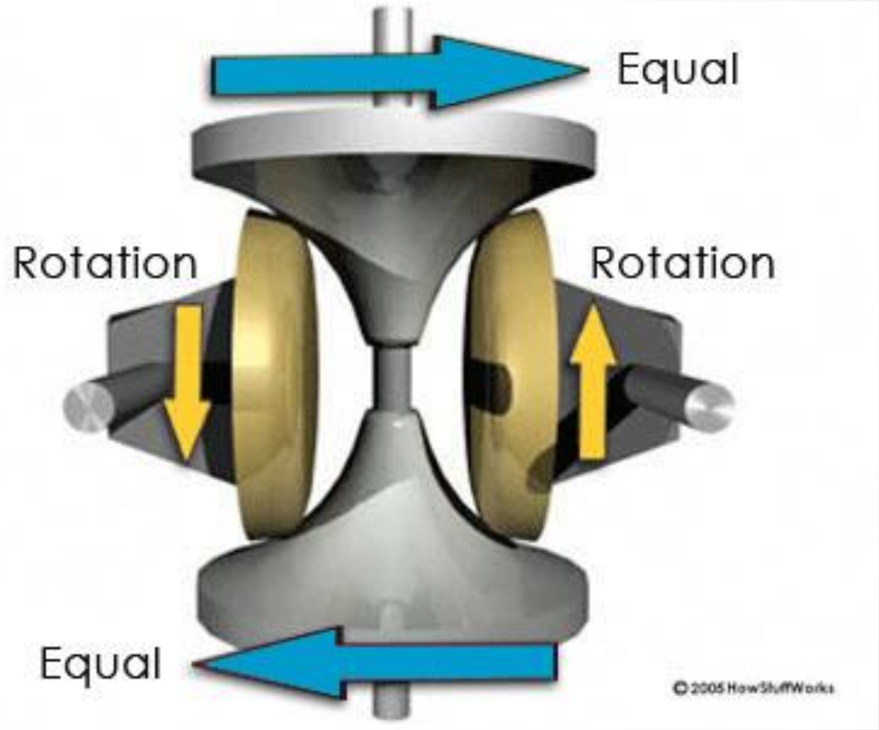
- Optimize engine power transmission
- Reduce driver error
- Increase vehicle acceleration
- Accomplish these with a CVT

Restraints:

- Mass, rotational inertia, size, cost, etc.
- Compatible with current vehicle

What is a CVT?





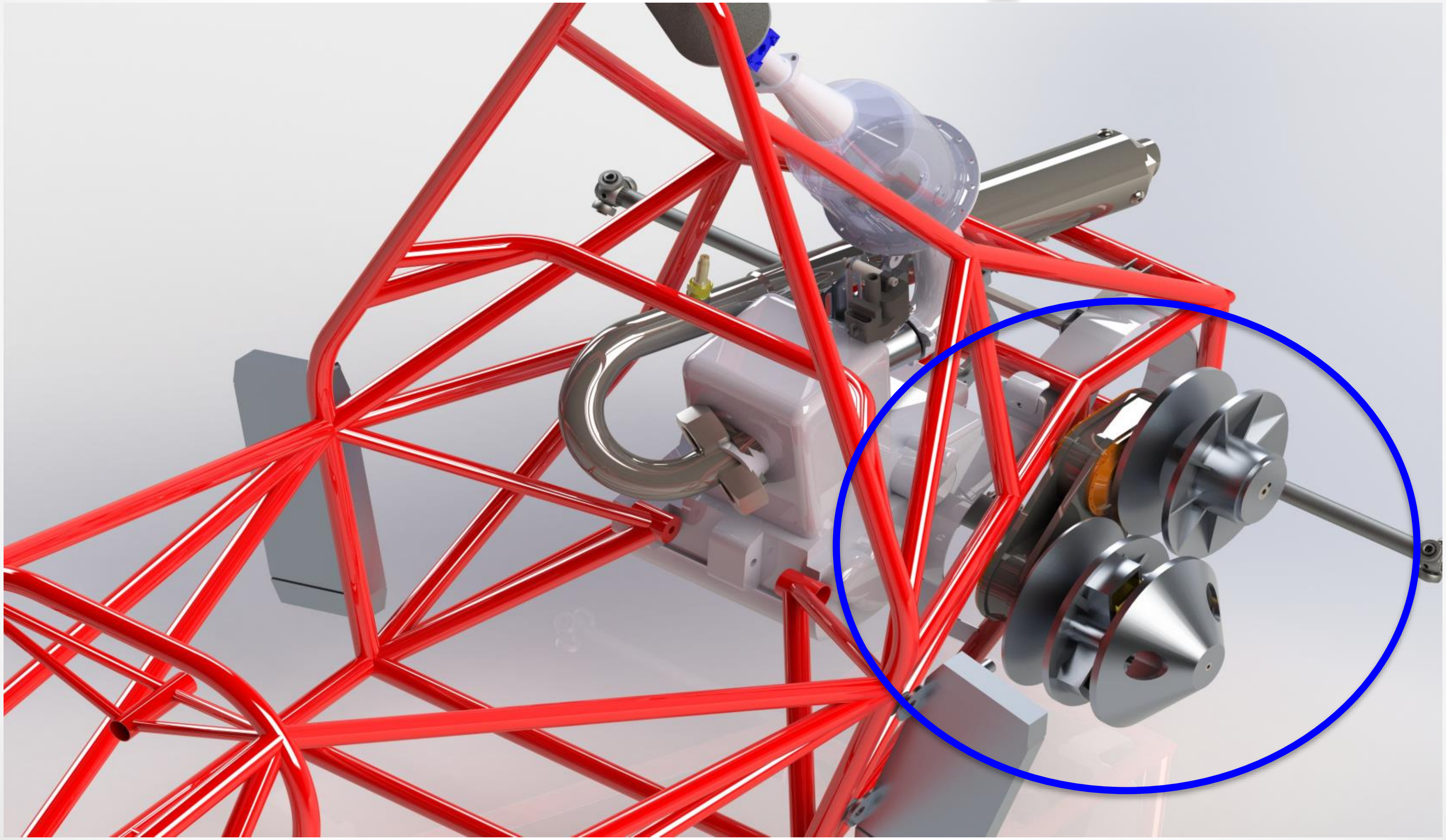
https://auto.howstuffworks.com/cvt2.htm

https://auto.howstuffworks.com/cvt3.htm

CVT vs. Sequential Gearbox

CVT	Sequential
• Transmission gear ratio is variable • Peak power achieved throughout operation	• Engine Speed is variable • Peak power achieved only for certain speeds in each gear
• Typical mechanical efficiency – 96% • Complex control mechanism	• Typical mechanical efficiency – 98% • Simple control mechanism

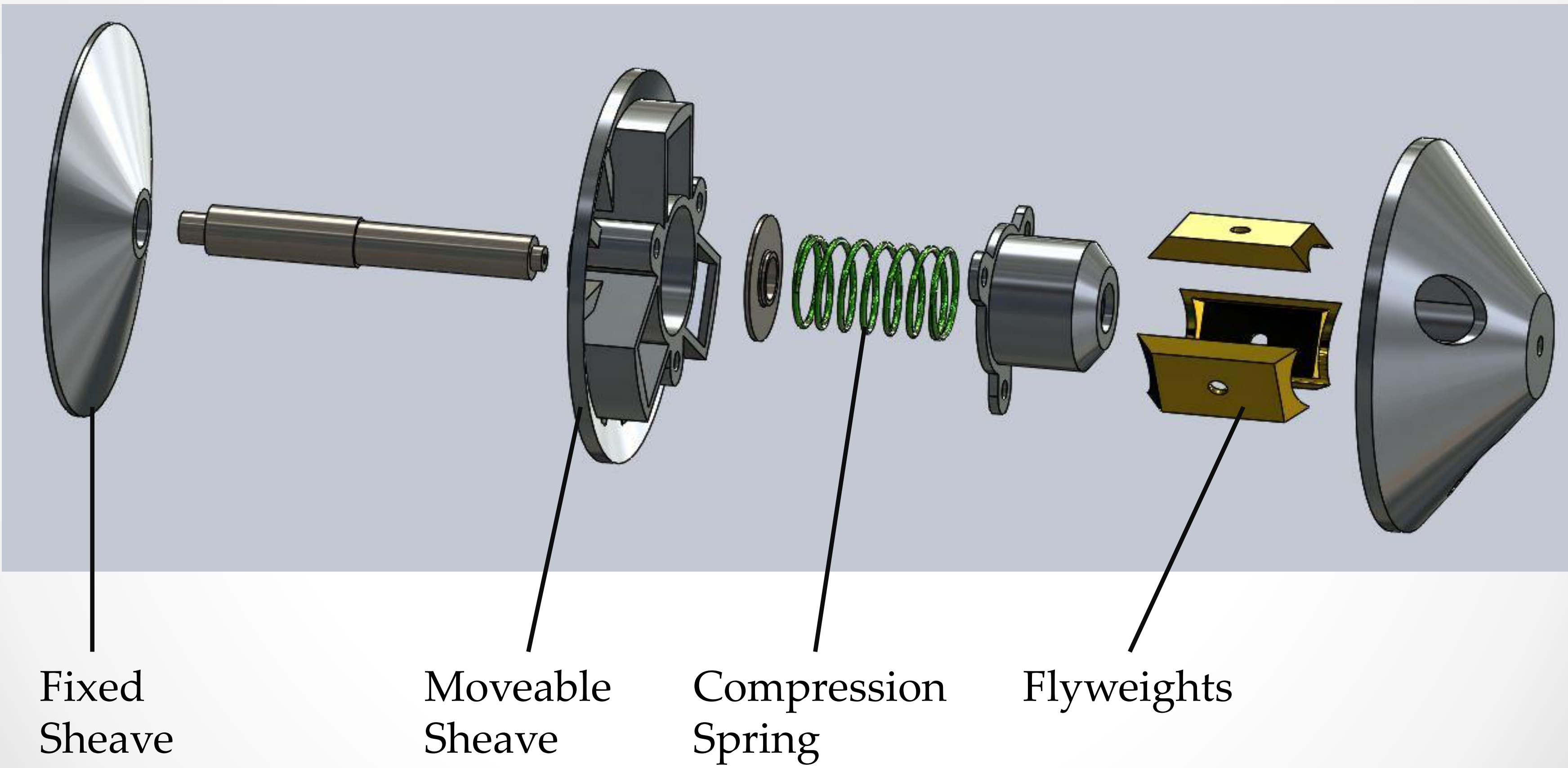
Our Concept



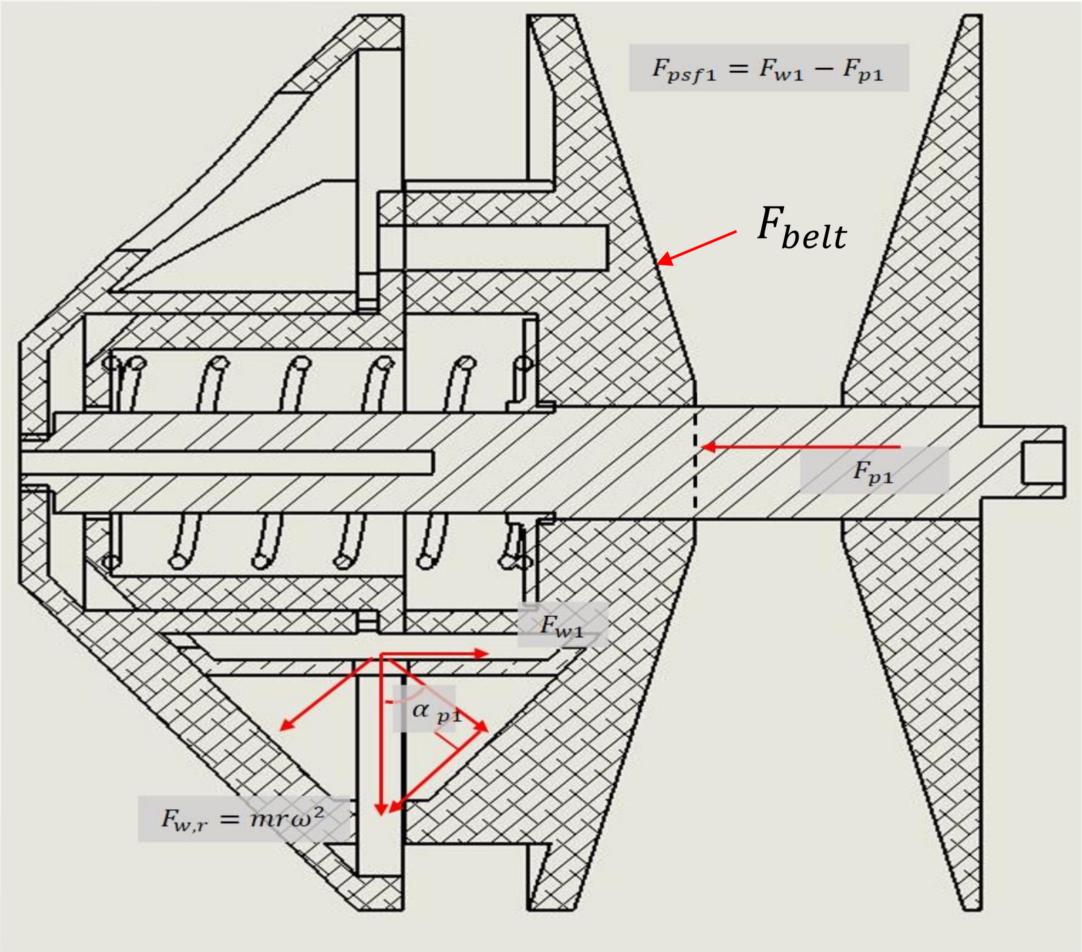
How does it work?

- Drive Pulley (Primary Clutch)
  + Driven Pulley (Secondary Clutch)= CVT
- Shifting forces generated based on vehicle operating conditions – load, engine speed, vehicle speed
- Transmission gear ratio is controlled to achieve desired driving condition
- Designed for maximum power output at full load

Drive Pulley



Drive Pulley



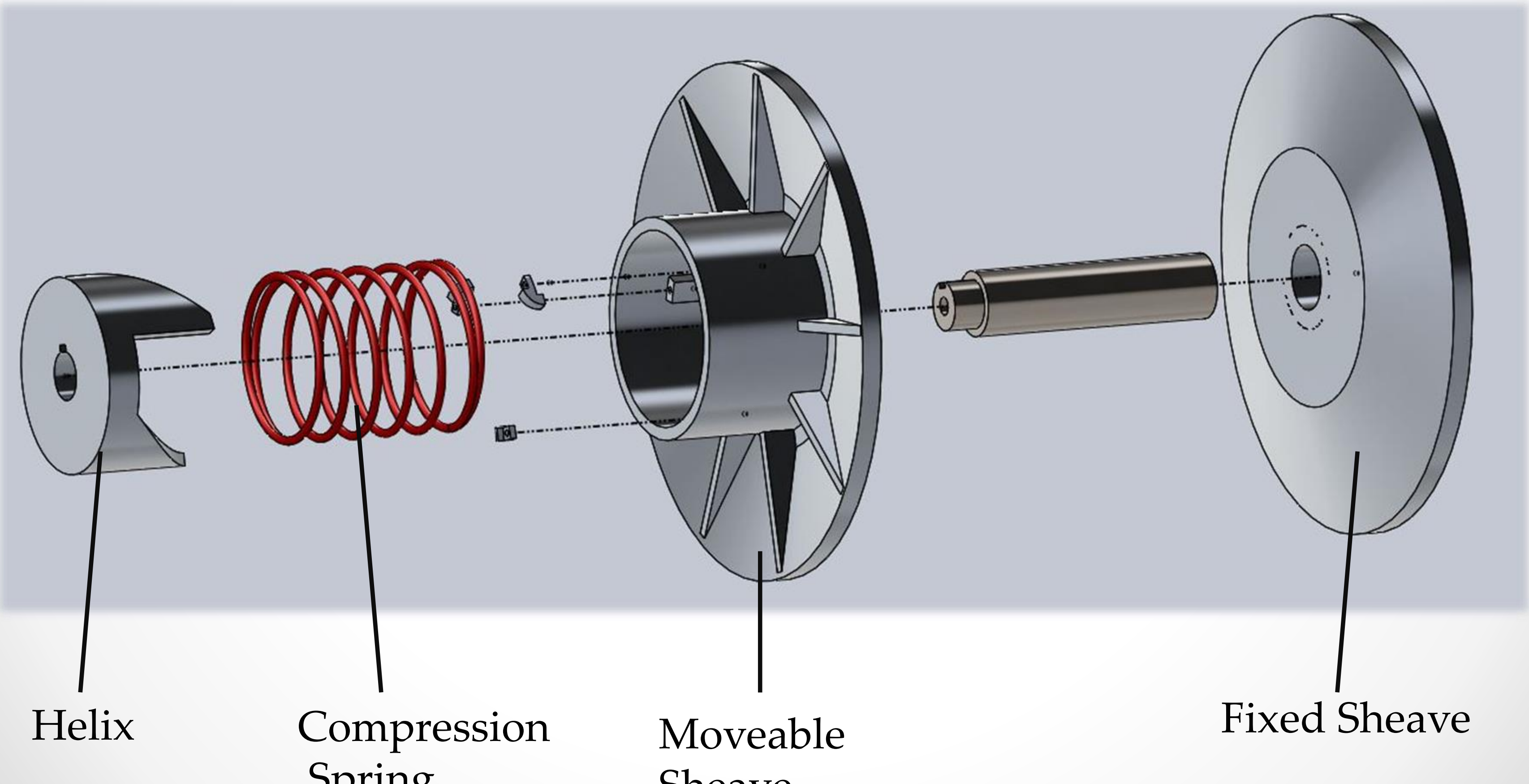
Shift Force FBD

- Shifting Forces from 2 sources

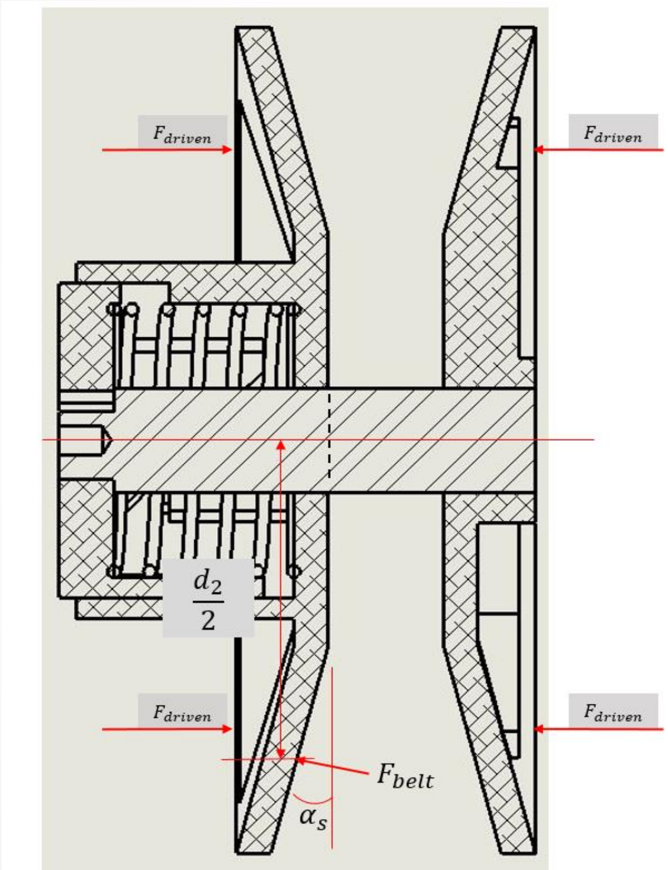
1. Flyweights
2. Compression Spring

- Oppose normal force of belt

Driven Pulley



Driven Pulley

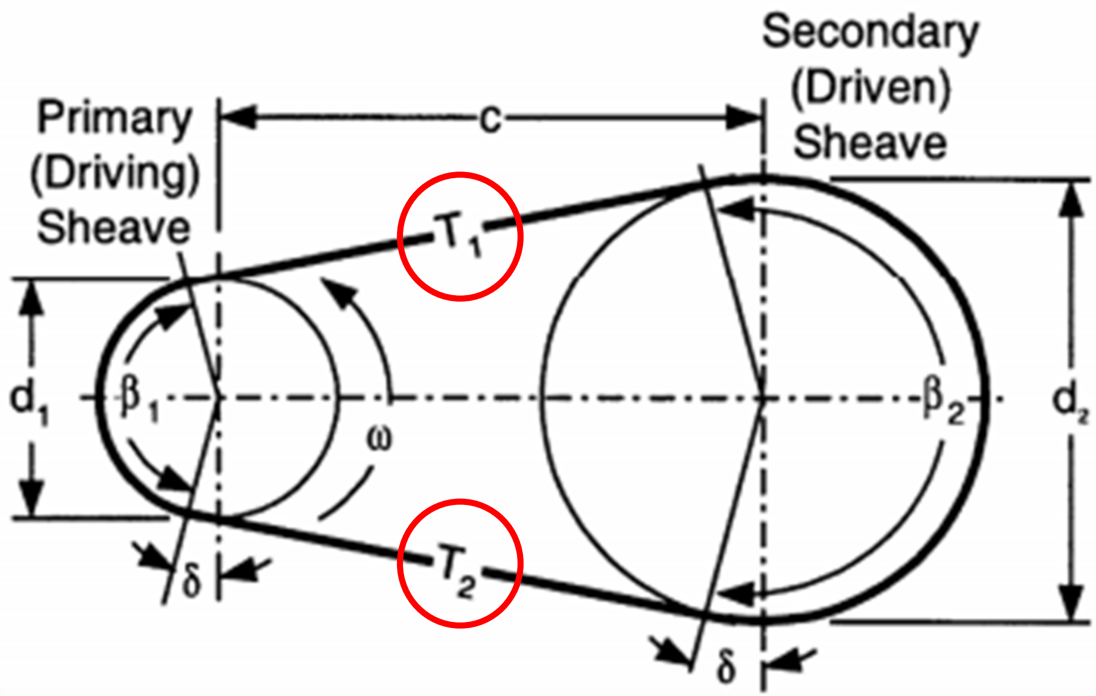


- Shifting Forces from 2 sources

1. Helix
2. Compression Spring

- Oppose normal force of belt

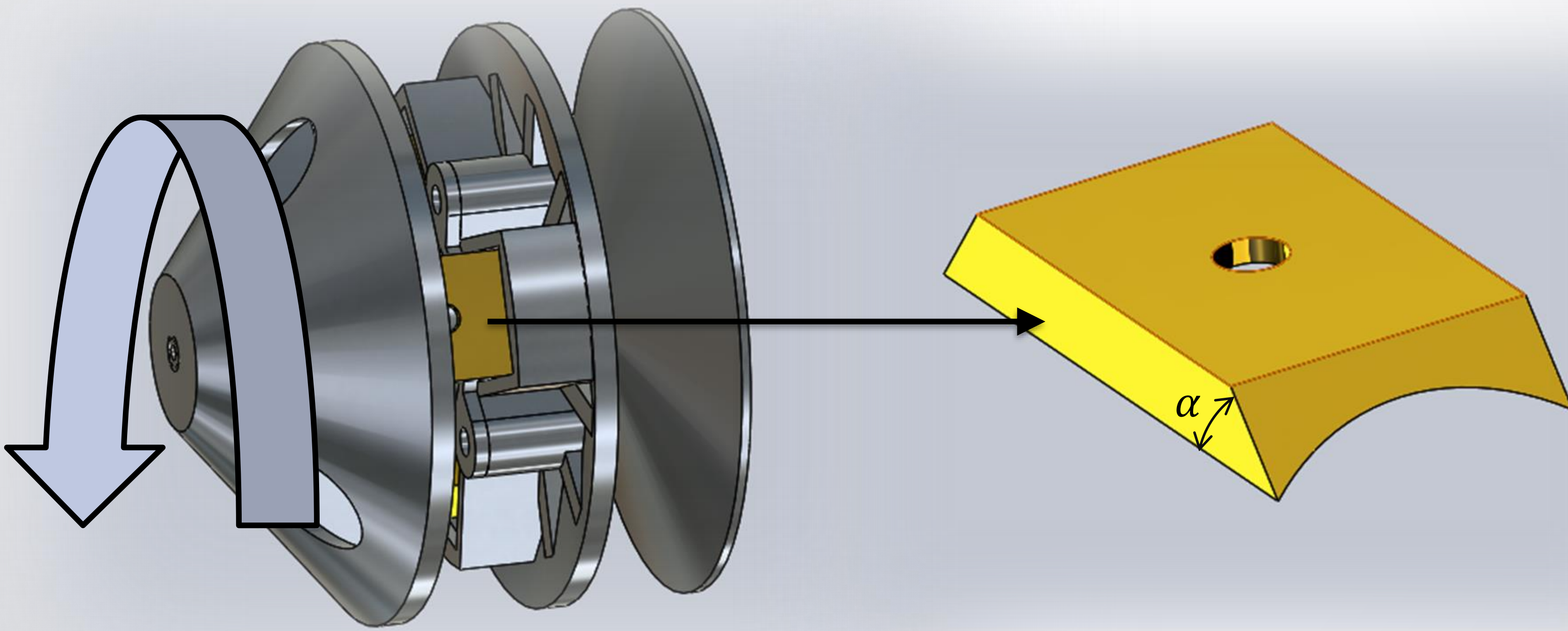
Power Transmission



$$Output\ Power \sim T_1 - T_2$$

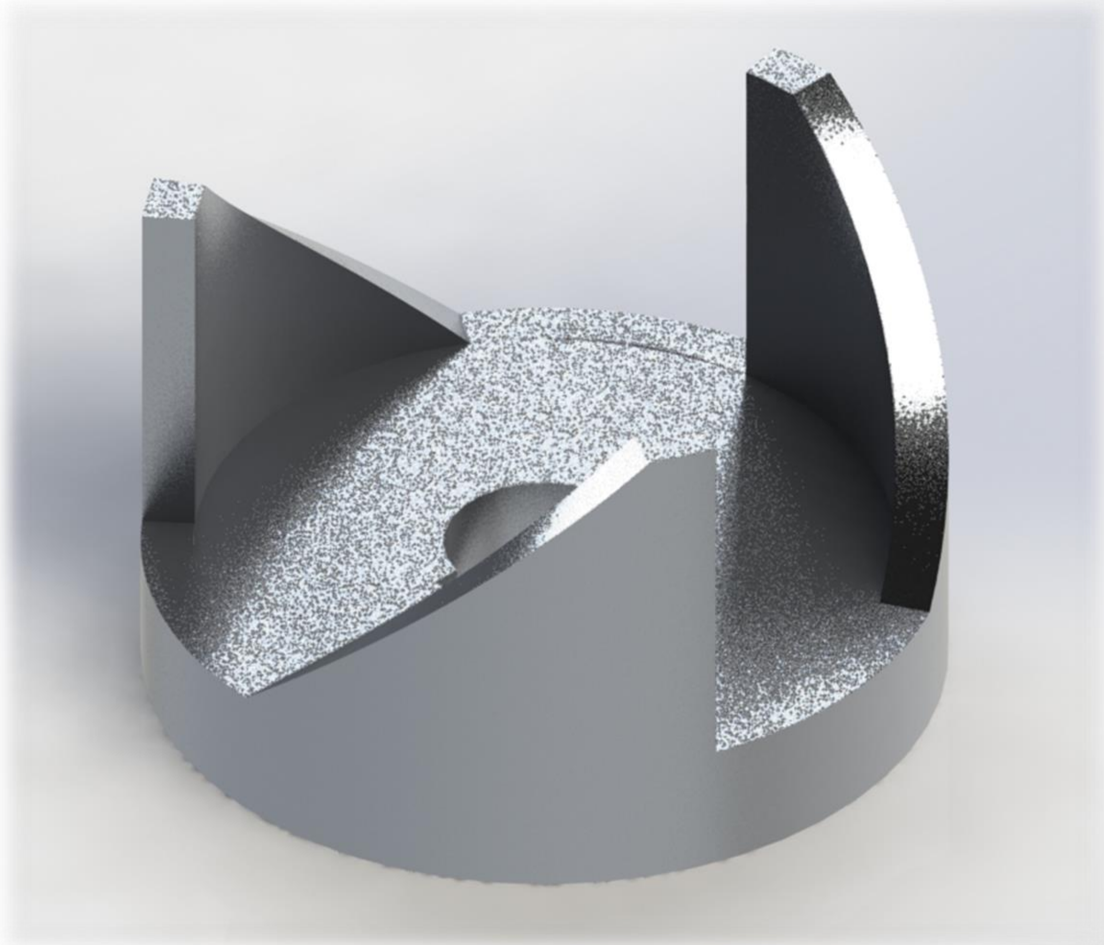
SAE Design Guideline: Metal Belt Drive Continuously Variable Ratio (CVT) Automatic Transmissions

Tuning Parameters: Flyweights



Tuning Parameters: Helix

- Torque “Sensing”
- Clamp Belt in Driven Pulley
- Helix Angle and Radius



Tuning Parameters: Compression Springs

Drive Pulley

- Opposes clamping force

Preload

- Defines Transmission Engagement

Rate

- Balances Pulley forces
- Influences upshift/downshift behavior

Driven Pulley

- Contributes to clamping force

Preload

- Select to ensure sufficient belt clamp force

Rate

- Balances Pulley forces
- Influences upshift/downshift behavior

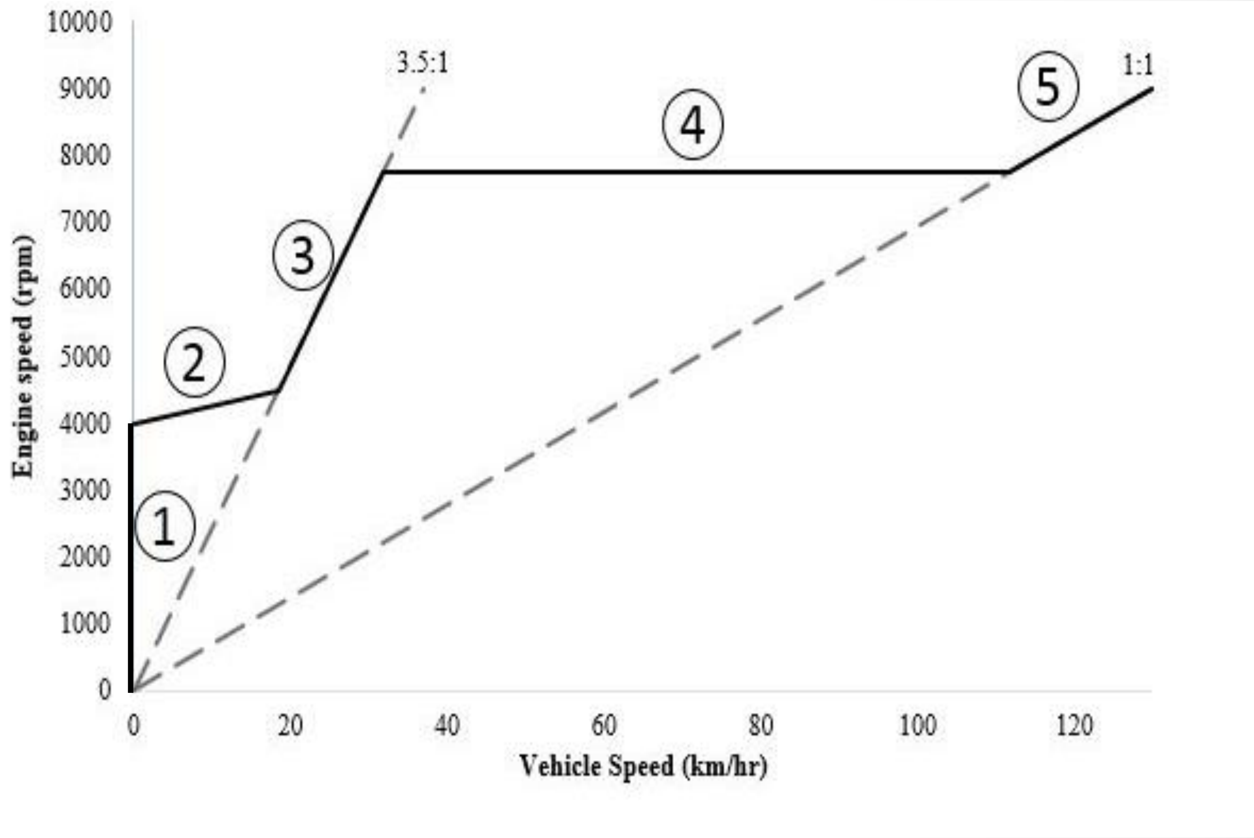
Tuning Parameters: Compression Springs

- Spring Preload and Rate

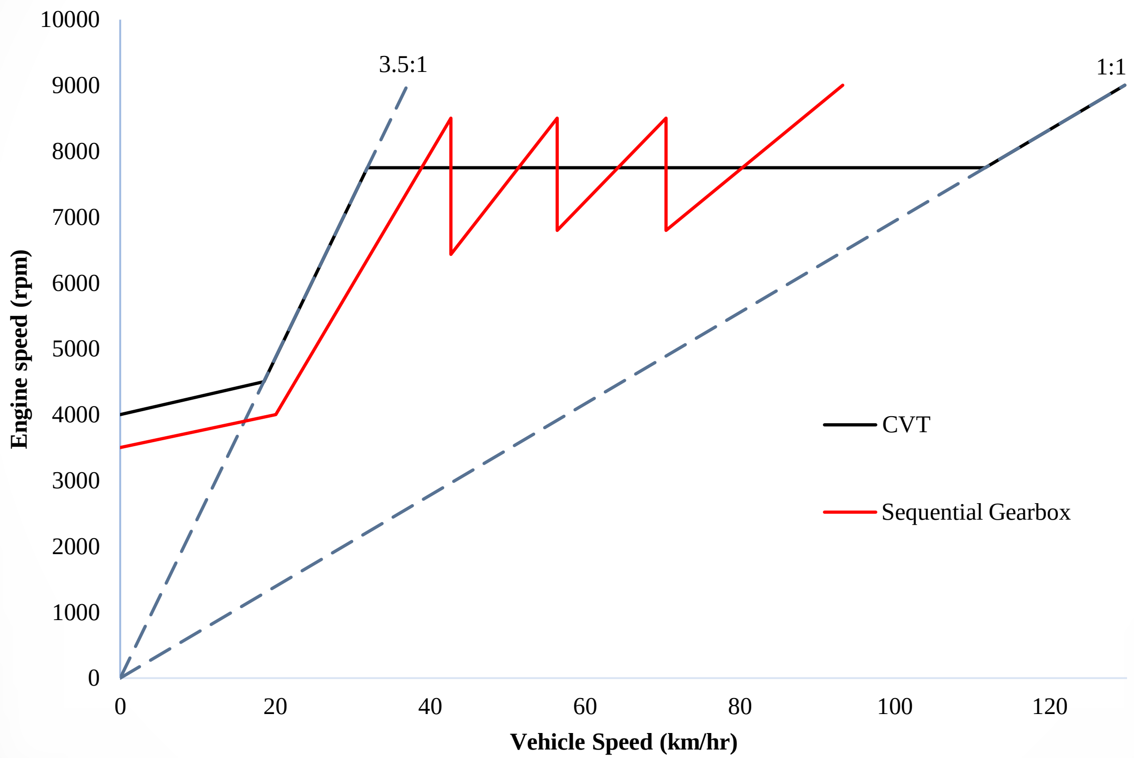
$$F_{preload} \leq \sim 1\ \mathrm{kN}$$

CVT Shift Curve

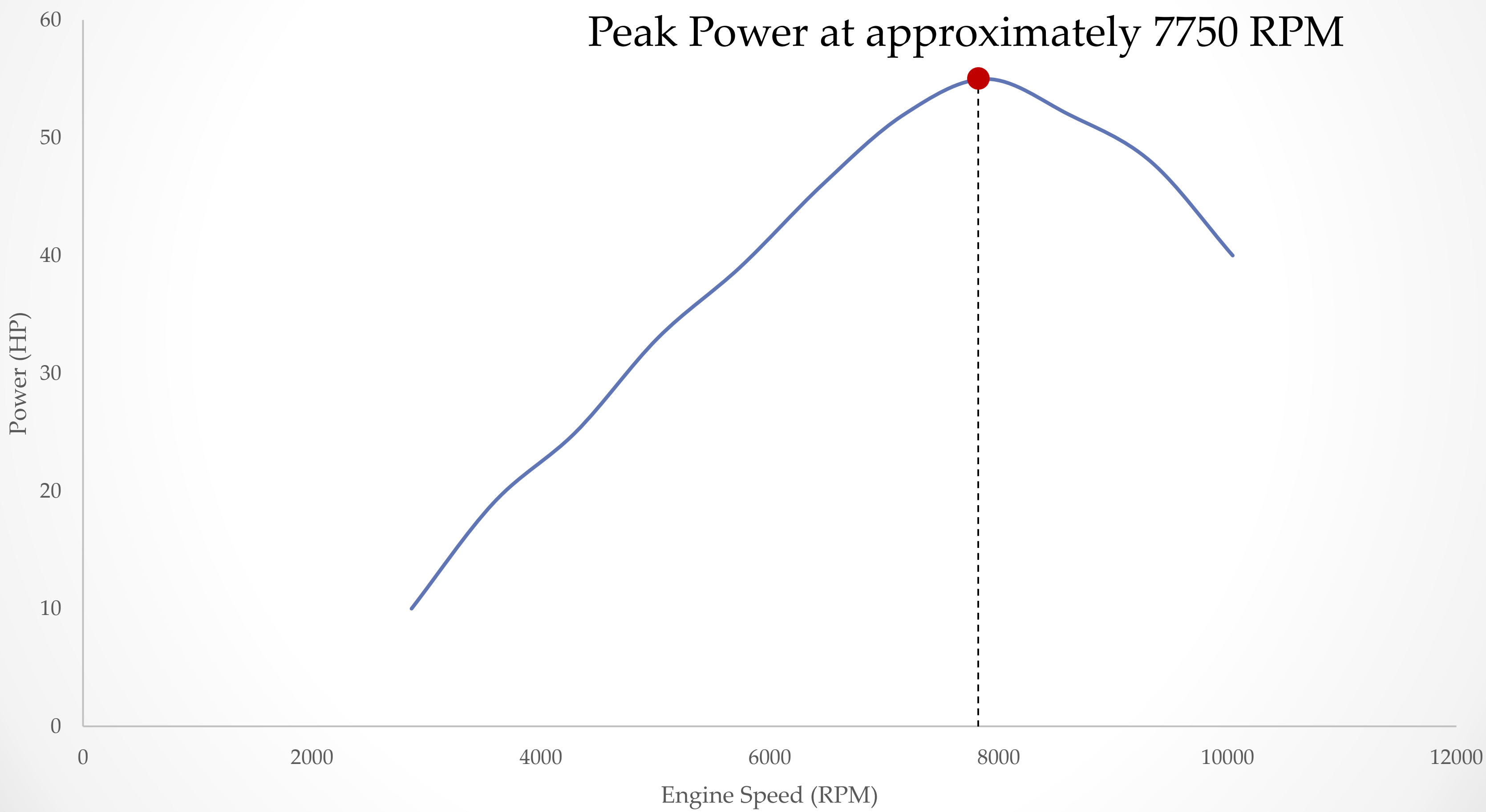
1. Idle
2. Engagement
3. Low Gear/ Shift in
4. Shift
5. High Gear/ Shift out



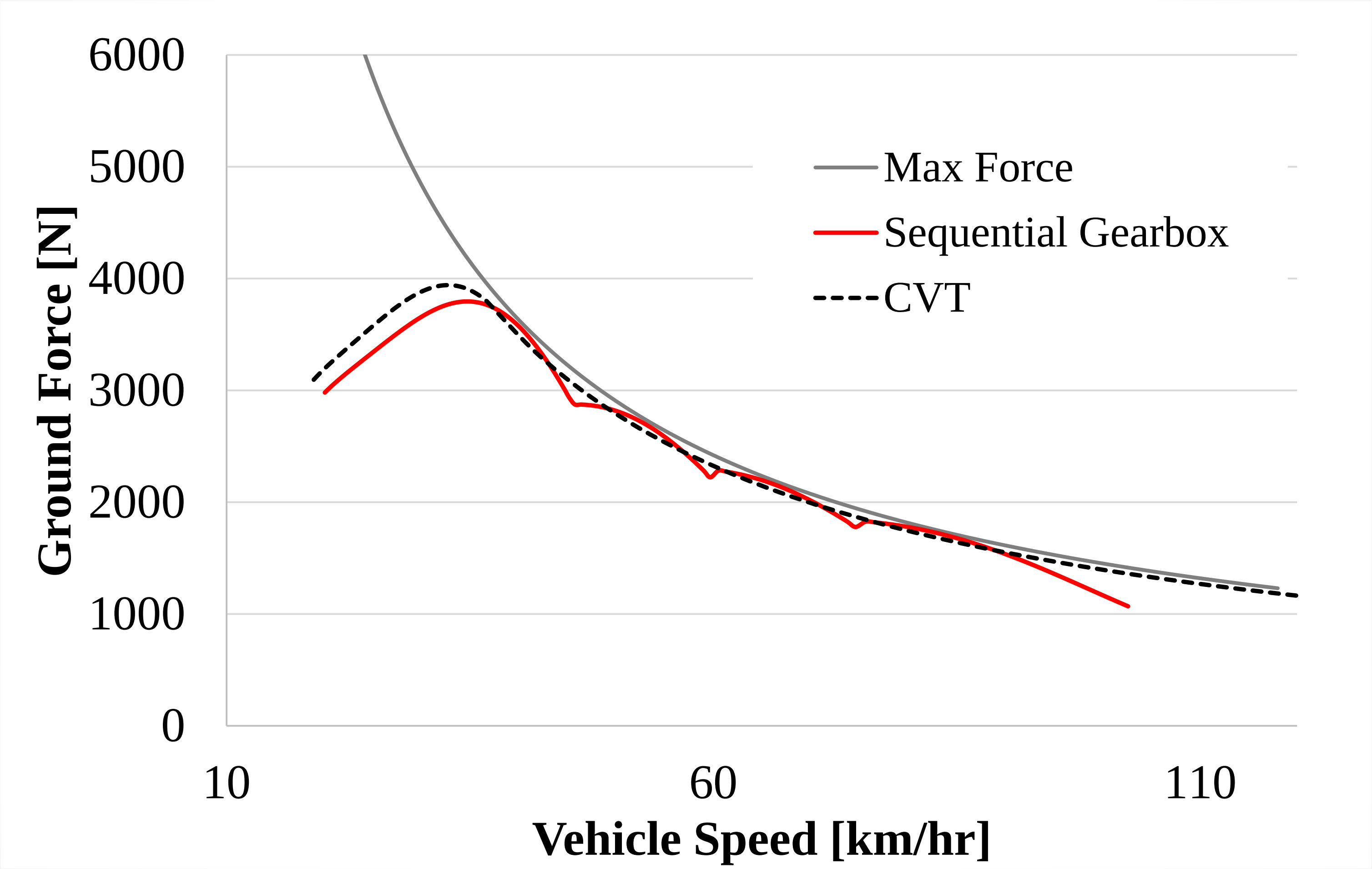
Shift Curve Comparison



Engine Power Curve



Ground Force

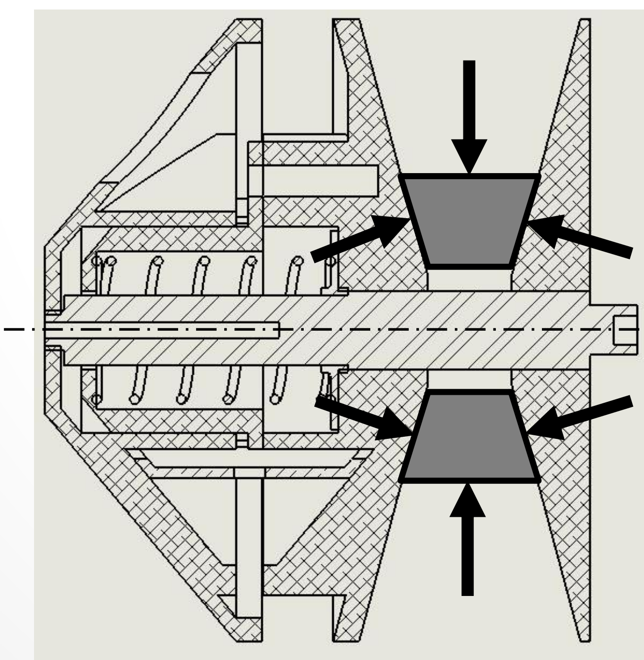


Design Considerations

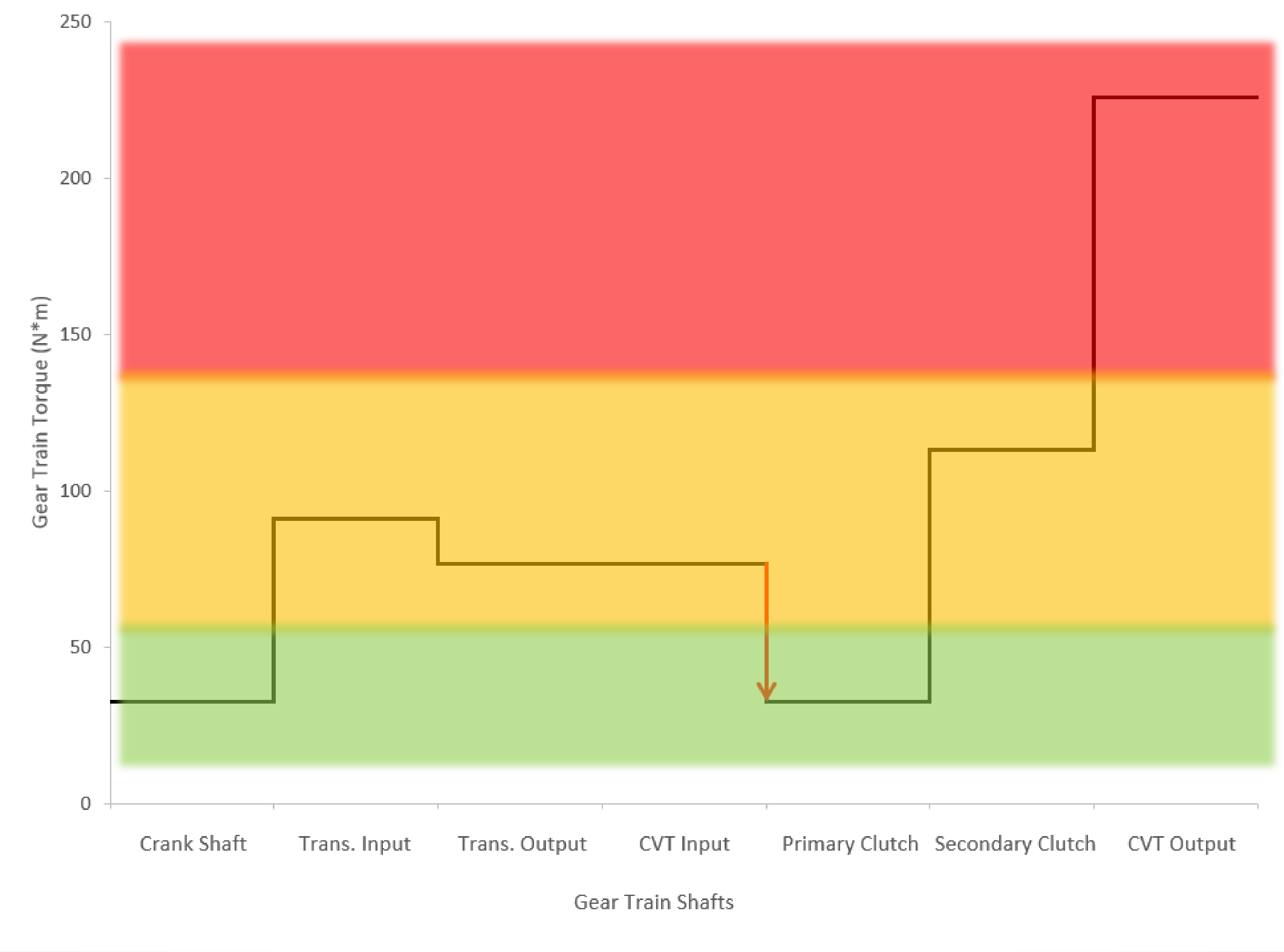
1. Friction Drive Requirements
2. Required Gearing Ratios
3. Functional Requirements
4. Design Calculations

Friction Drive

- Sufficient belt clamping forces are needed to ensure belt slip does not occur
- Low belt friction is required
- Belt clamping forces are restricted



Gear Train Torque Analysis

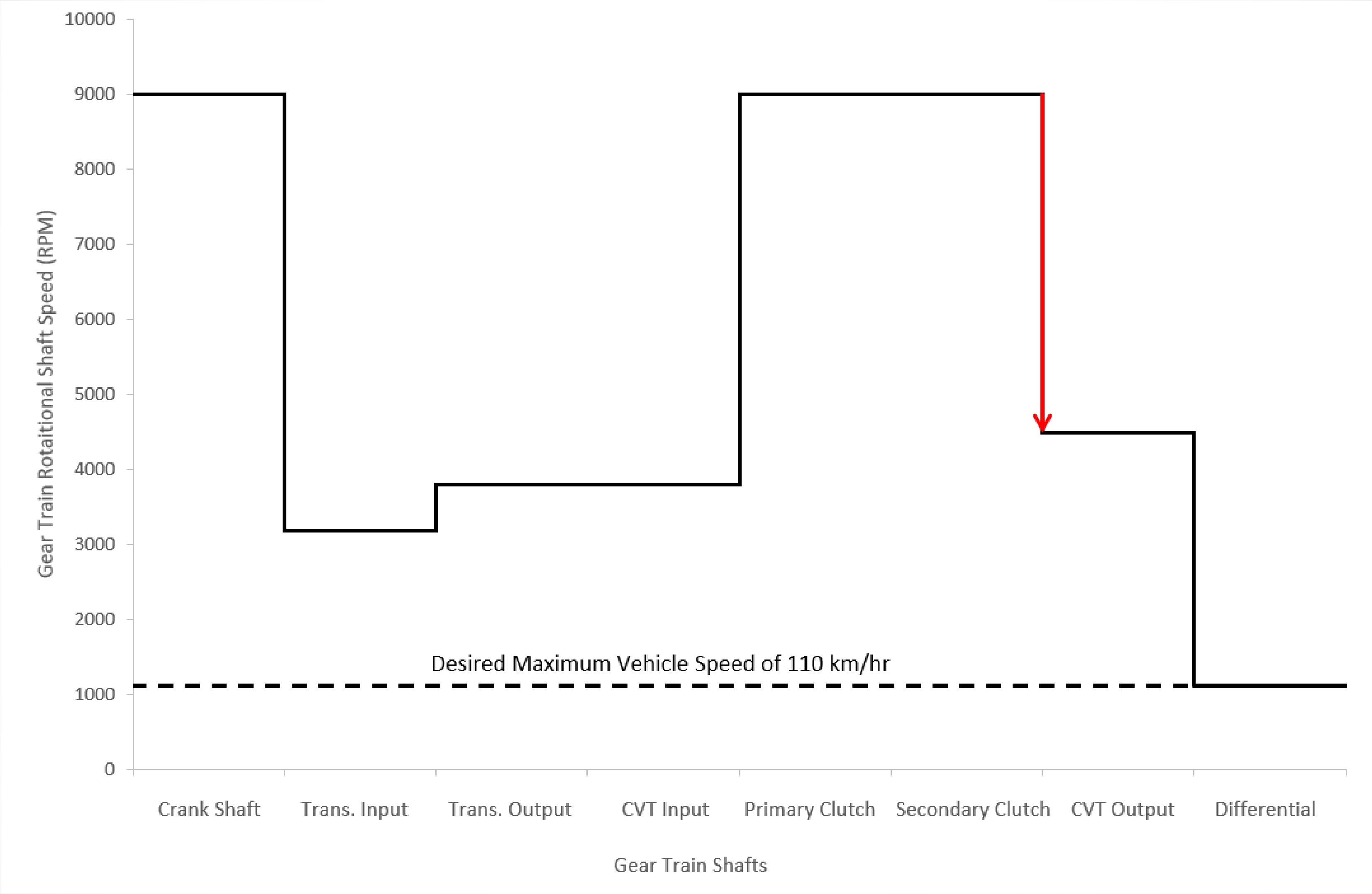


Gearing Ratios

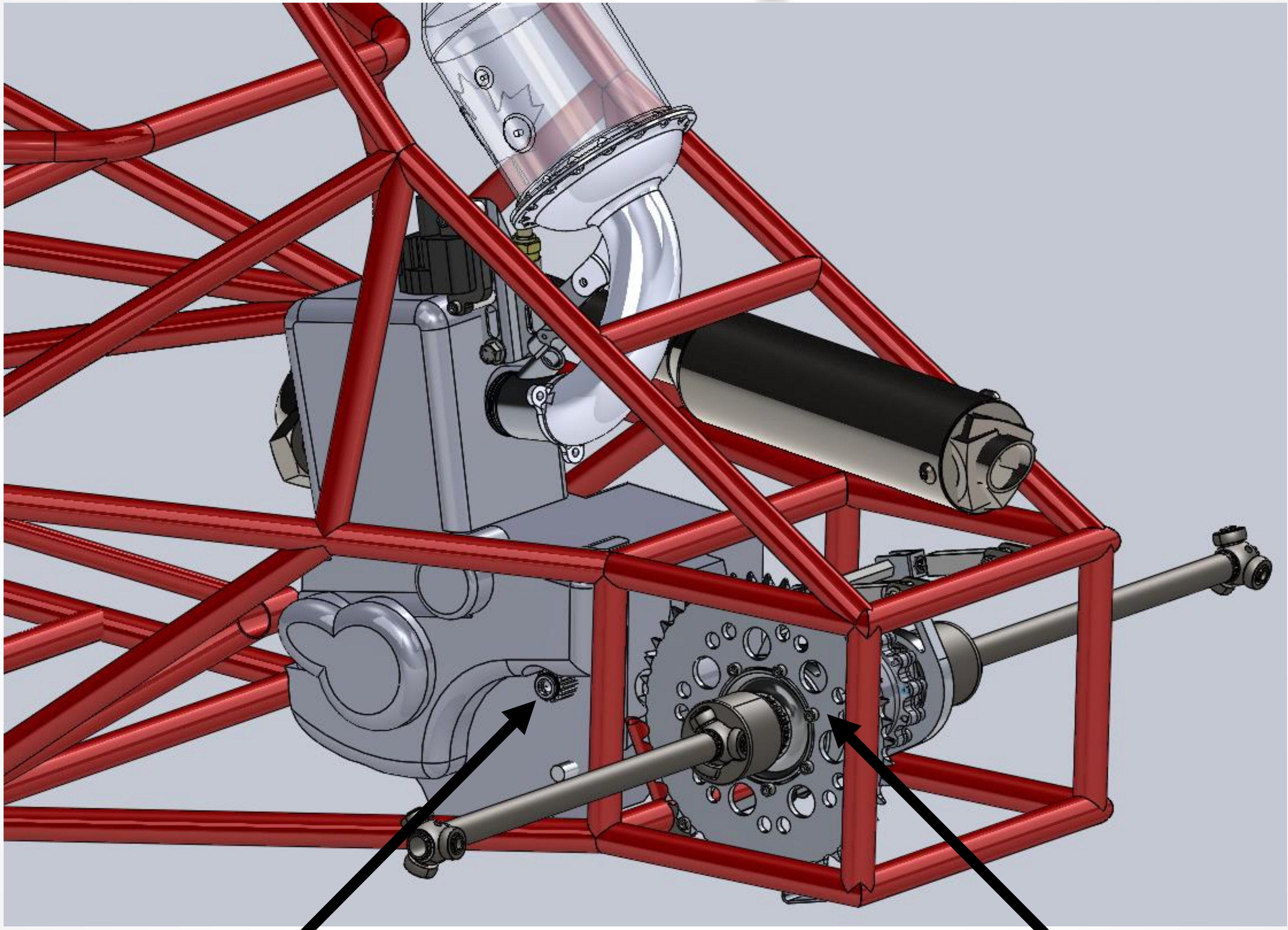
1. A gear train ratio change was needed to lower the primary CVT torque
   - A gear ratio was picked that would lower the torque and increase the rotational speed of the primary clutch to crankshaft speed (industry standard)

2. Another gear train was needed to lower the final rotational speed of the differential
   - A designed top speed of 110 km/hr at an engine speed of 9000 rpm was chosen for optimal vehicle performance

Gear Train Speed Analysis



Functional Requirements



Transmission Output Shaft

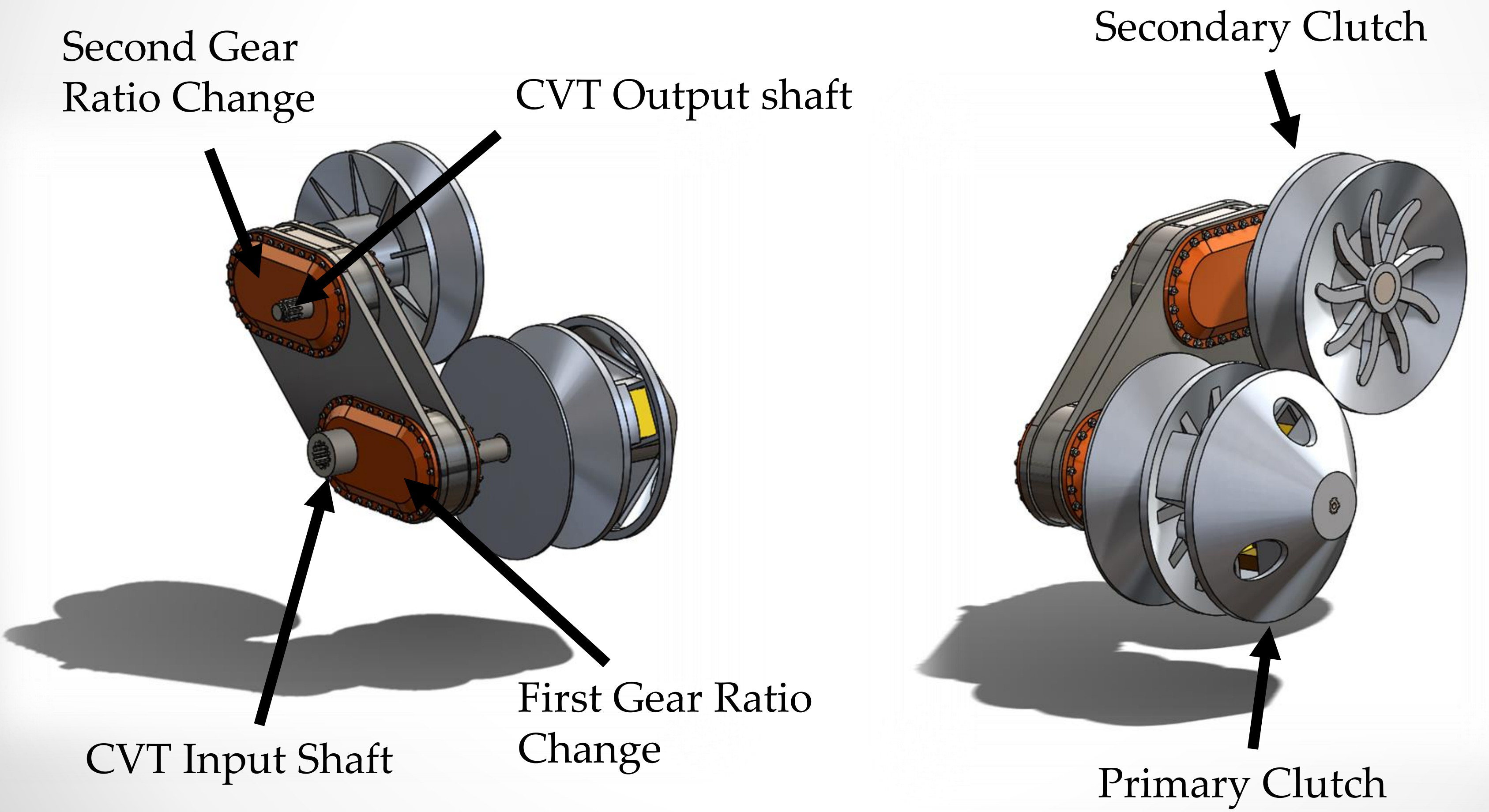
Differential Sprocket

Sourced Components

- Due to the complexity of the primary and secondary clutch designs we chose to:

1) Source the primary and secondary clutches from CVTech-ABB
2) Provide tuning specifications required for this application

Designed Transmission



Design Calculations

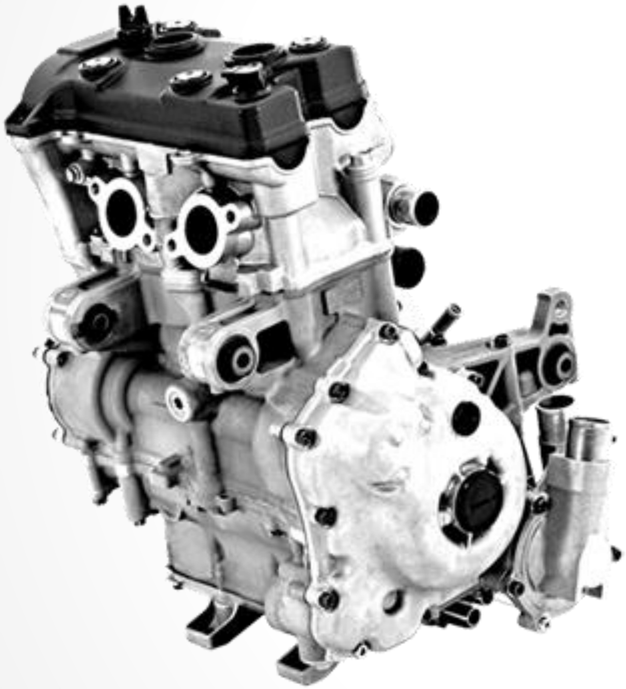
- Maximum transmission loading determined as the torque required to break traction on the rear tires
- Transmission was designed to withstand this continuous maximum load
- Shafts were designed for stress and fatigue *with a safety factor of 1.5*
- Bearings rated for at least 100 hours of maximum torque operation
- CVT rated for zero belt slip at operating conditions
- Total mass of transmission came to 13 kg

The Cost

Part	Source	Cost (USD)	Qty	Total (USD)
KSS3-15	QTC gears	$26.99	1	$26.99
KSS3-36	QTC gears	$84.93	1	$84.93
A 1C 1MYK30016	QTC gears	$35.66	1	$35.66
A 1C 1MYK30032	QTC gears	$82.08	1	$82.08
Gears Subtotal				**$229.66**
Shaft 1	Solidwork	$124.77	1	$124.77
Shaft 2	Solidwork	$88.13	1	$88.13
Shaft 3	Solidwork	$87.38	1	$87.38
Shaft 4	Solidwork	$185.19	1	$185.19
Shaft Subtotal				**$485.47**
Belt BD52-2167-5	CVTech	$84.99	1	$84.99
Driving pully 0600-0030	CVTech	$349.99	1	$349.99
Driven pulley 5600-0246	CVTech	$199.99	1	$199.99
CVT Subtotal				**$634.97**

Part	Source	Cost (USD)	Qty	Total (USD)
FAG QJ304-MPA Four Point Contact Bearing (For primary,secondary and output shaft)	Quality Bearings Online	$82.92	3	$248.76
7008-B-2RS-TVP (For trans output shaft)	Applied	$138.57	1	$138.57
52 mm Bearing Cap	Solidwork	$31.28	3	$93.84
68 mm Bearing Cap	Solidwork	$162.02	1	$162.02
Bearing Subtotal				**$643.19**
Socket Head Screws (10/pack)	Mcmaster	$8.99	6	$53.94
Hex Nuts (100/pack)	Mcmaster	$2.61	1	$2.61
Washers (100/pack)	Mcmaster	$3.23	1	$3.23
Frame Plate 1	Solidwork	$97.40	1	$97.40
Frame Plate 2	Solidwork	$97.04	1	$97.04
Gear Casing Subtotal				**$254.22**
Total Cost				**$2,247.51**

Future Recommendations



Yamaha Phazer 500 engine

1. Yamaha Phazer 500 engine
   - greater compatibility with CVT

2. Eliminate additional shafts and gears – weight and efficiency

3. A used Phazer 500 engine was $1600.

4. Tune the system – predicted and actual design performance WILL vary

Questions

Tuning Parameters: Helix

$$\sum F_{axial} = 0$$

$$\boxed{R_a \cos(\beta)} + \boxed{\mu_a R_a \sin(\beta)} = F_a$$

$$\sum F_{tangential} = 0$$

$$\boxed{R_a \sin(\beta)} - \boxed{\mu_a R_a \cos(\beta)} = F_t$$

F_a – *Axial Clamping Force*

F_t – *Force due to applied torque*