Carleton University

Raven's Racing

RR27

Drivetrain Design and Simulation

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Summary:

[insert once report is complete]

Revision History:

Date	Editor	Note
2026-05-23	Ahmad Bitar	Document Creation and Initial Report

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1.0 Introduction:

The drivetrain project includes various aspects and considerations. The report will begin with a Applied Racing Dynamics (ARD) simulation to select the ideal Final Drive (FD) ratio with considerations of multiple shift times in order to quantify the benefits of optimizing shifting time and weighing it against budget and design constraints. Once FD ratios are selected, sprocket sizes are up next. [then probably mounting designs +]

2.1 Simulation Set-up

2.11 Speed

D.12.2.2 The Endurance course will be designed with these specifications. Average speed should be 48 km/hr to 57 km/hr with top speeds of approximately 105 km/hr.

a. Straights: No longer than 77 m with hairpins at the two ends
b. Straights: No longer than 61 m with wide turns on the ends
c. Constant Turns: 30 m to 54 m diameter
d. Hairpin Turns: 9 m minimum outside diameter (of the turn)
e. Slaloms: Cones in a straight line with 9 m to 15 m spacing
f. Miscellaneous: Chicanes, multiple turns, decreasing radius turns, etc.
g. Minimum track width: 4.5 m
h. Designated passing zones at several locations

Figure 1: Formula SAE Rulebook stating endurance speed requirements @ 105 km/hr

Additionally, calculations were completed for the absolute best acceleration time at FSAE 2025, and the resultant max speed was around 130 km/h. (see Appendix A [1] for calculations)

Therefore, a max speed of 130km/h should be achievable by this FD ratio, since it is a dependent factor; it is not a parameter rather a consideration.

2.12 RPM Range

Idle Speed	1 300 ±50 r/min (rpm)	– – –

Figure 2: Kawasaki ZX-6R Manual stating that idle RPM is 1300

Given idle RPM, the max RPM was set to 15500 in ARD, as well as is planned to be flashed into the ECU as the rev limit.

2.13 Shifting RPM

Maximum Horsepower	95.4 kW (130 PS) @13 500 r/min (rpm) (SEA-B1) 85.2 kW (116 PS) @12 000 r/min (rpm) (US, CA, CAL) – – –
Maximum Torque	70.8 N·m (7.2 kgf·m, 52 ft·lb) @11 000 r/min (rpm) (US, CA, CAL) – – –

Figure 3: Kawasaki ZX-6R Manual stating that Max power is @ 12000 rpm.

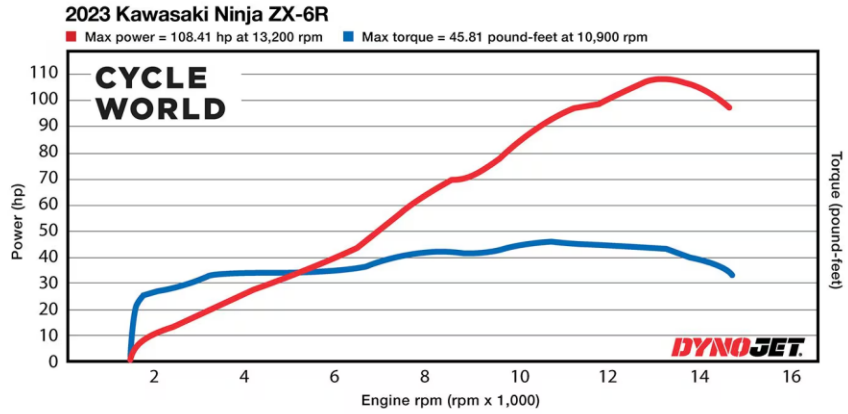


Figure 4: Sample Kawasaki ZX-6R Torque Curve, showing that 11-13k RPM is the optimal powerband

To get an optimal power band, RPM drop post shift is about 2k and decreases as u go up in gears. Considering acceleration, speed, and other factors, shifting times were simulated.

These were deemed to be the best shifting RPMs for each gear.

Gears	Pre-shift RPM	Post-shift RPM
1-2	14,500	11,200
2-3	14,200	12,100
2-4	14,200	12,200
4-5	13,900	12,500
5-6	13,900	12,800

2.14 Gear Ratios

Gear Ratios:			
1st	2.846 (37/13)		
2nd	2.200 (33/15)		
3rd	1.850 (37/20)		
4th	1.600 (32/20)		
5th	1.421 (27/19)		
6th	1.300 (26/20)	Reduction Ratio	1.900 (76/40)

Figure 5: Kawasaki ZX-6R manual w/ each individual gear ratio and primary reduction

2.15 Shifting times

Shift time: 0.5s OR 0.05s (Mechanical vs. Pneumatic)

Shift lock time: 0.5s and 0.1s (safety measure, allowing gears to properly integrate then allowing for the next shift)

2.16 Tracks

Two different tracks shall be considered. (1) The endurance track, which accounts for a lot of the points, the endurance from 2023 was mapped into a CSV file and imported into ARD. (2) The acceleration track, since the acceleration is 0-75m, the track selection seems straight forward, however, in terms of velocity, time, and distance simulation, the track must be a loop, so a special track was designed to have an acceleration strait from 0-75m, and a braking zone from 75-124m, to which it has a generous curvature as to not force the simulated vehicle to brake earlier. The two tracks are shown in Figures 6 and 7.

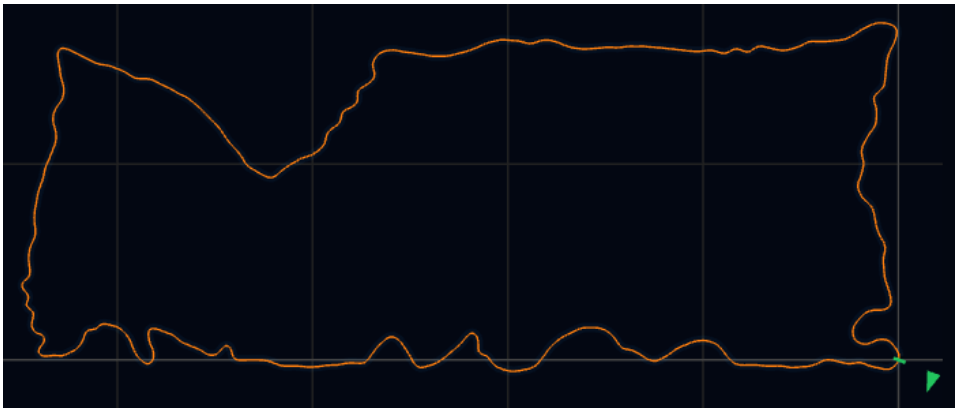


Figure 6: Processed CSV Endurance 2023 Track

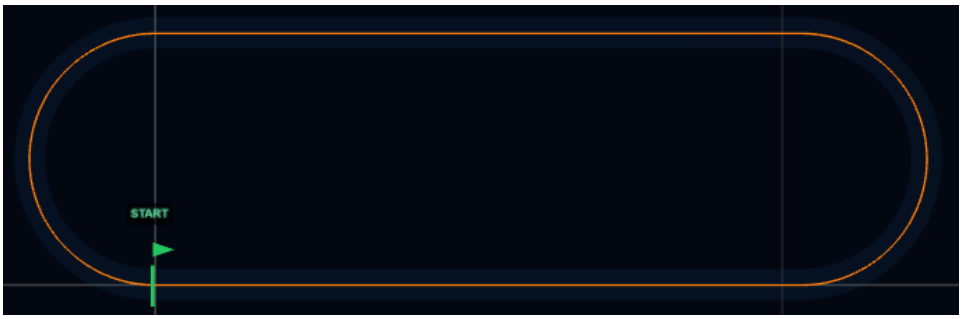


Figure 7: Processed Custom Acceleration Track

2.2 Simulations

2.21 Variables:

- FD ratio (3.0 - 4.0, step: 0.1) (See Appendix B for complete results)
- ST (0.5s or 0.05s)

❑ 2.22 Simulation Results:

ST: 0.5s

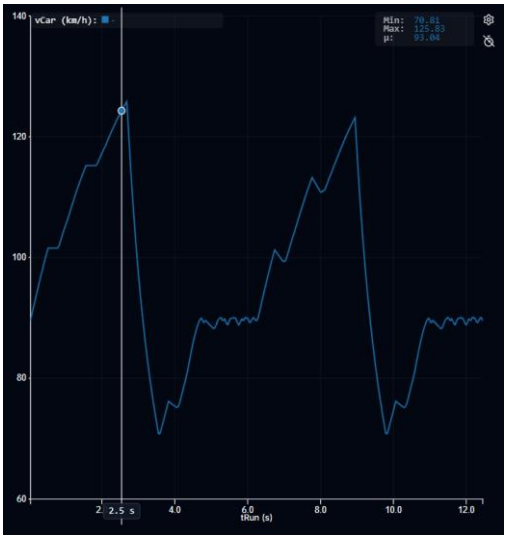


Figure 8: 0.5 ST, FD 3.5, ACCEL

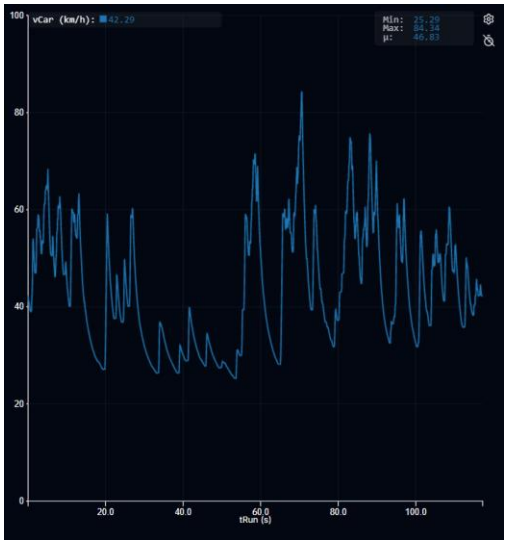
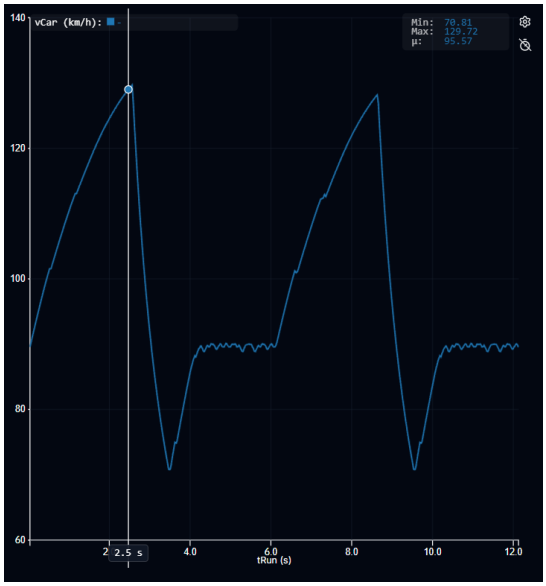


Figure 9: 0.5 ST, FD 3.5, ENDURANCE

Figure 8: 12.456s across the whole loop; 2.50s 0-75m across accel strait.

Figure 9: 1:57.264

ST: 0.05s



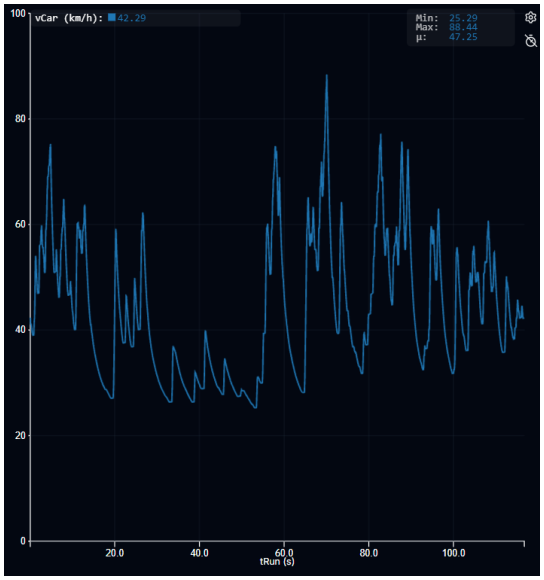


Figure 10: 0.05 ST, 3.5 FD, ACCEL

Figure 11: 0.05 ST, 3.5 FD, ACCEL

Figure 10: 12.131s across the whole loop, ~2.54s across the 0-75m accel straight

Figure 11: 1:56.736

2.23 Analysis:

A ratio of 1:3.5 was the overall winner across every category. Comparing track times, a difference of 0.04s in accel and 0.528s in endurance is observed from optimizing shift time from 0.5s - 0.05s.

To quantify this upside: time gain shall be converted to points

For the Endurance:

Adjusted Time	Time Score	Laps Score	Endurance Score
1295.297	250.0	25	275
1316.864	236.8	25	261.8
1325.399	231.7	25	256.7
1332.335	227.6	25	252.6

Figure 12: Top 4 Endurance Times

- Across 10 laps, the 0.528s becomes 5.28s, which in terms of points, is basically insignificant as the smallest delta is 7s, which even then was a difference in points of 3.9. In terms of the endurance, a pneumatic shifting system is not necessary in nature.

As for Accel

4.169
4.229
4.260
4.264
4.271
4.286
4.306

Figure 13: Top 7 Acceleration times of teams at FSAE International 2025

- A difference of 0.04s in acceleration the difference between second and 3rd or 3rd and 7th: ~2 or ~3 points, which in either case also does not currently justify an optimized shifting system for RR27.

2.3 FD Ratio & Sprocket Selection

Whether a mechanical or pneumatic shifting system is picked, an FD ratio of 3.5 is optimal in either case. Considering that a sprocket of 11 is the smallest viable option, and that the largest sprocket that would fit in our vehicle is around 70, a ratio of 42/12 is the most optimal and readily available.

Appendix A:

[1]

$\Delta d = v_1 t + \frac{1}{2} a t^2$

$a = 75m * (2) / (4.169s)^2$ *(best accel time from FSAE 2025)*

$a = 8.63033$

$a = \Delta v / t$

$\Delta v = (8.63033m) * (4.169s)$

$\Delta v = 35.97985$ m/s

$\Delta v = 129.527$ km/h

$\Delta v = 130$ km/h

Appendix B:

ST 0.5s:

Accel:

Type	Name	Vehicle	Track	Lap Time	Age	Notes
QSS 17	DT_0.5_accel_3.0	RR27_P... v233	FS_accel (2)	00:12.446	2h	
QSS 17	DT_0.5_accel_3.1	RR27_P... v234	FS_accel (2)	00:12.492	2h	
QSS 17	DT_0.5_accel_3.2	RR27_P... v235	FS_accel (2)	00:12.552	2h	
QSS 17	DT_0.5_accel_3.3	RR27_P... v236	FS_accel (2)	00:12.486	2h	
QSS 17	DT_0.5_accel_3.4	RR27_P... v237	FS_accel (2)	00:12.516	2h	
QSS 17	DT_0.5_accel_3.5	RR27_P... v238	FS_accel (2)	00:12.456	2h	
QSS 17	DT_0.5_accel_3.6	RR27_P... v239	FS_accel (2)	00:12.471	2h	
QSS 17	DT_0.5_accel_3.7	RR27_P... v240	FS_accel (2)	00:12.489	2h	
QSS 17	DT_0.5_accel_3.8	RR27_P... v241	FS_accel (2)	00:12.481	2h	
QSS 17	DT_0.5_accel_3.9	RR27_P... v242	FS_accel (2)	00:12.514	2h	
QSS 17	DT_0.5_accel_4.0	RR27_P... v243	FS_accel (2)	00:12.377	2h	

Endurance:

Type	Name	Vehicle	Track	Lap Time	Age	Notes
QSS 17	DT_0.5_endurance_3.0	RR27_P... v196	FS_endurance	01:58.168	2h	
QSS 17	DT_0.5_endurance_3.1	RR27_P... v197	FS_endurance	01:58.671	2h	
QSS 17	DT_0.5_endurance_3.2	RR27_P... v198	FS_endurance	01:58.397	2h	
QSS 17	DT_0.5_endurance_3.3	RR27_P... v199	FS_endurance	01:57.528	2h	
QSS 17	DT_0.5_endurance_3.4	RR27_P... v200	FS_endurance	01:57.480	2h	
QSS 17	DT_0.5_endurance_3.5	RR27_P... v201	FS_endurance	01:57.264	2h	
QSS 17	DT_0.5_endurance_3.6	RR27_P... v202	FS_endurance	01:58.300	2h	
QSS 17	DT_0.5_endurance_3.7	RR27_P... v203	FS_endurance	01:58.055	2h	
QSS 17	DT_0.5_endurance_3.8	RR27_P... v204	FS_endurance	01:58.501	2h	
QSS 17	DT_0.5_endurance_3.9	RR27_P... v205	FS_endurance	02:00.018	2h	
QSS 17	DT_0.5_endurance_4.0	RR27_P... v206	FS_endurance	01:59.202	2h	

ST 0.05s:

Accel:

Type	Name	Vehicle	Track	Lap Time	Age	Notes
QSS 17	DT_0.05_accel_3.0	RR27_P... v218	FS_accel (2)	00:12.124	2h	
QSS 17	DT_0.05_accel_3.1	RR27_P... v219	FS_accel (2)	00:12.133	2h	
QSS 17	DT_0.05_accel_3.2	RR27_P... v220	FS_accel (2)	00:12.135	2h	
QSS 17	DT_0.05_accel_3.3	RR27_P... v221	FS_accel (2)	00:12.158	2h	
QSS 17	DT_0.05_accel_3.4	RR27_P... v222	FS_accel (2)	00:12.172	2h	
QSS 17	DT_0.05_accel_3.5	RR27_P... v223	FS_accel (2)	00:12.131	2h	
QSS 17	DT_0.05_accel_3.6	RR27_P... v224	FS_accel (2)	00:12.155	2h	
QSS 17	DT_0.05_accel_3.7	RR27_P... v225	FS_accel (2)	00:12.192	2h	
QSS 17	DT_0.05_accel_3.8	RR27_P... v226	FS_accel (2)	00:12.173	2h	
QSS 17	DT_0.05_accel_3.9	RR27_P... v227	FS_accel (2)	00:12.224	2h	
QSS 17	DT_0.05_accel_4.0	RR27_P... v228	FS_accel (2)	00:12.220	2h	

Endurance:

Type	Name	Vehicle	Track	Lap Time	Age	Notes
QSS 17	DT_0.05_endurance_3.0	RR27_P... v208	FS_endurance	01:58.059	2h	
QSS 17	DT_0.05_endurance_3.1	RR27_P... v208	FS_endurance	01:58.059	2h	
QSS 17	DT_0.05_endurance_3.2	RR27_P... v209	FS_endurance	01:58.262	2h	
QSS 17	DT_0.05_endurance_3.3	RR27_P... v210	FS_endurance	01:57.271	2h	
QSS 17	DT_0.05_endurance_3.4	RR27_P... v211	FS_endurance	01:57.081	2h	
QSS 17	DT_0.05_endurance_3.5	RR27_P... v212	FS_endurance	01:56.736	2h	
QSS 17	DT_0.05_endurance_3.6	RR27_P... v213	FS_endurance	01:57.717	2h	
QSS 17	DT_0.05_endurance_3.7	RR27_P... v214	FS_endurance	01:57.597	2h	
QSS 17	DT_0.05_endurance_3.8	RR27_P... v215	FS_endurance	01:58.057	2h	
QSS 17	DT_0.05_endurance_3.9	RR27_P... v216	FS_endurance	01:59.651	2h	
QSS 17	DT_0.05_endurance_4.0	RR27_P... v217	FS_endurance	01:58.719	2h	

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