

Hybrid Powertrain and Control Assignment

Kyle Turner

November 2021

1 Introduction

This report will investigate and identify the typical duty cycle for the Blitzworld Renegade DX10 Corporate off-road buggy. To achieve this, a track consisting of multiple different surfaces and at least 20 meters of elevation were created and the buggy has been simulated traversing the track. As the vehicle is intended for corporate entertainment events, a number of considerations have had to be made. The vehicle must not exceed 30mph, the acceleration should be suitable and it should have sufficient grade-ability. Due to a lack of information a series of assumptions have been about the buggy which has likely affected the accuracy of the simulation, however it is likely the actual buggy would perform better with regards to resistive forces as some values are over-inflated.

2 Theory

In order to attempt to model the buggy the Specification shown in Table 1 was used.

Engine CC	278
Power (hp)	18
Torque (Nm) @ 5500rpm	22
Top Speed (mph)	30
Length (m)	2.62
Width (m)	1.65
Height (m)	1.62
Vehicle Mass (kg)	365
Ground clearance (m)	0.3
Tank Size (l)	29
Fuel Mass (kg/l)	0.74
Driver+ Passenger + Gear Mass (kg)	174
Rear Tyre Mass (kg)	9.3
Rear Wheel Mass (kg)	5.90
Rear Tyre Radius (m)	0.3175
Front Tyre Mass (kg)	6.44
Front Wheel Mass (kg)	5.90
k(rear)=0.9r (m)	0.2858
k(front)=0.9r (m)	0.3246
Total Mass of Vehicle and Passengers (kg)	560.46
Total Rear Wheel Mass (kg)	15.20
Total Front Wheel Mass (kg)	12.34
Wheel Width(m)	

Table 1: Vehicle Specification

As we were not given gear ratios I have selected them in order to comply with the requirements of the vehicle being adequate and entertaining, but not too dangerous. They are shown in Table 2

Gear Ratios			
1st	8	80	10
2nd	10	50	5
3rd	12	36	3.50
Final Drive			3

Table 2: Gear Ratios

In order to calculate the effect of different surfaces on the vehicle I have obtained a selection of rolling resistance coefficients, they are displayed in Table 3

Long Grass	0.09
Short Grass	0.07
Dry Earth Road	0.03
Dry Asphalt	0.02
Wet Asphalt	0.024
Wet Earth Road	0.04
Gravel	0.02
Sand	0.2

Table 3: Rolling Resistance Coefficients

In order to measure the drag I have assumed the buggy's coefficient of drag to be 0.5 by comparing it to other similar vehicles, however it is likely the drag would be lower given it is mostly open. To calculate the frontal area of the buggy I have once again assumed the buggy is enclosed and have used the specification to calculate the area using Equation 1.

$$Height \cdot Width - GroundClearance - FreeSpaceAboveWheels \quad (1)$$

I have calculated the equivalent mass for each gear ratio using Equation 2.

$$TotalMass + 2(FrontWheelInertia + RearWheelInertia) + \frac{EngineInertia \cdot GearRatio}{RearWheelInertia} \quad (2)$$

Using Equation 2 I have obtained the values of equivalent mass in Table 4.

Equivalent Mass (1st)	590.961
Equivalent Mass (2nd)	580.5832
Equivalent Mass (3rd)	578.8368

Table 4: Equivalent Masses

The resistive force due to air resistance was calculated using Equation 3.

$$AeroForce = 0.5 \cdot C_{drag} \cdot FrontalArea \cdot AirDensity \cdot Velocity^2 \quad (3)$$

The resistance due to the gradient has been calculated using Equation 4.

$$GravForce = g(GradientAngle) \cdot Mass \quad (4)$$

Rolling Resistance was calculated using Equation 5.

$$RollResForce = Mass \cdot g \cdot C_{RollingResistance} \quad (5)$$

From the Specification 1, we know the maxium power is 18hp and this occurred at 6500rpm, in addition to this the peak torque of 22Nm occurs at 6500rpm. Using Equation 6 and 7 we can calculate the torque and power for every rpm.

$$Power = \frac{AccelForce \cdot Velocity}{746} \quad (6)$$

$$Torque = \frac{Powewr \cdot 7127}{RPM} \quad (7)$$

The drive torque at the rear wheels was calculated using Equations 8 and 9.

$$DriveTorqueAtShaft = Torque \cdot GearRatio \cdot efficiency \quad (8)$$

$$DriveTorqueatRearWheel = DriveTorqueAtShaft \cdot FinalDriveRatio \quad (9)$$

I have assumed a 3% loss from the engine to the shaft.

In order to calculate the fuel consumption I have used a Brake Specific Fuel Consumption (BSFC) graph and converted it into a lookup table. The BSFC is the rate of fuel consumption divided by the power produced by the engine, and I have used a chart modified to match the RPM and torque given by the buggy's engine. By using this chart the BSFC for each RPM and torque combination can be calculated.

BSFC	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000
22	0	0	0	0	0	0	0	0	0	0	450	0	0	0
21	0	0	0	0	0	0	0	0	0	470	435	0	0	0
20	0	0	0	0	0	0	0	0	480	460	410	470	0	0
19	0	0	0	0	0	0	0	0	475	440	390	455	505	0
18	0	0	0	0	0	0	490	480	465	430	370	440	490	555
17	0	0	0	0	0	0	495	485	450	395	360	405	485	540
16	0	0	0	0	510	500	500	490	445	370	350	365	480	530
15	0	0	0	0	515	505	490	490	440	350	325	335	440	480
14	0	0	0	562.0805	520	510	480	475	405	330	305	330	425	475
13	0	0	0	575.5387	540	515	470	455	380	310	280	320	450	520
12	0	0	0	590.992	555	520	490	460	430	290	305	320	475	535
11	0	0	0	601.4215	575	550	510	470	435	350	340	315	500	540
10	0	0	600	609.6616	590	580	520	495	470	370	360	310	505	535
9	0	0	610	619.6886	605	590	575	530	490	395	400	420	510	550
8	0	0	625	648.4883	625	600	580	535	495	415	430	495	560	630
7	0	0	640	687.573	660	625	616	580	525	460	460	540	595	665
6	0	610	680	630	680	635	650	600	560	500	490	590	605	675
5	0	680	690	745	725	705	690	650	620	590	570	625	670	730
4	670	710	710	775	775	755	720	700	680	660	650	695	735	780
3	870	850	840	800	825	805	757	745	740	730	752	760	780	810
2	1080	995	910	900	875	855	830	845	830	810	790	810	820	840
1	1210	1140	1070	995	980	965	950	945	920	890	860	860	850	845
0	1490	1400	1320	1240	1160	1110	1070	1025	990	950	910	905	880	870

Figure 1: BSFC Lookup Table

The Fuel consumption of the buggy can be calculated using Equation 10 and 11.

$$FuelUsage(g) = BSFC \cdot Energy(kwh) \quad (10)$$

$$FuelUsage(l) = \frac{FuelUsage(g)}{1000 \cdot DensityOfPetrol} \quad (11)$$

Finally the velocity and acceleration are calculated using Equations 12 and 13.

$$Acceleration = \frac{AccelForce - RollResForce - GravForce - AirResForce}{EquivalentMass} \quad (12)$$

$$Velocity_2 = \sqrt{2 \cdot Acceleration + Velocity_1} \quad (13)$$

The maximum velocity of the buggy in each has also been calculated by converting the RPM into wheel velocity, from this I have found, if not for the electric limiter the buggy could likely go much faster.

3 The Track

The track I have used is described in Table 5. In addition to this there 8 bumps, 2.5m in height spread along the straights of the track, see Figure 5. By equation the centripetal force equation with the force due to friction between the tyres and the track I have calculated that the maximum speed around the corners far exceeds the speed limit of the buggy, guaranteeing the safety of the driver and passenger.

	Distance(m)	Radius(m)	Arc(deg)	Surface
Straight 1	300	0	0	Dry Asphalt
Corner 1	125.66	40	180	Dry Asphalt
Corner 2	62.83	40	90	Dry Asphalt
Straight 2	200	0	0	Dry Dirt
Corner 3	62.83	40	90	Dry Dirt
Straight 3	320	0	0	Dry Dirt
Corner 4	125.66	40	180	Dry Dirt
Corner 5	62.83	40	90	Dry Dirt
Straight 4	160	0	0	Wet Dirt
Corner 6	62.83	40	90	Wet Dirt
Corner 7	62.83	40	90	Wet Dirt
Straight 5	10	0	0	Wet Dirt
Corner 8	62.83	40	90	Wet Dirt
Straight 6	100	0	0	Dry Asphalt

Table 5: The track the buggy has been simulated travelling around.

4 Results

From my simulation I have found that the buggy traverses my track with little difficulty, however it is hard to judge the entertainment value of a track which people cannot actually try. From the simulation I have calculated the buggy consumes 226.67 grams of fuel per lap, or 0.306 litres of fuel. This would allow the buggy to perform 94 laps before running out of fuel. Figure 2 shows the fuel consumption with distance travelled.

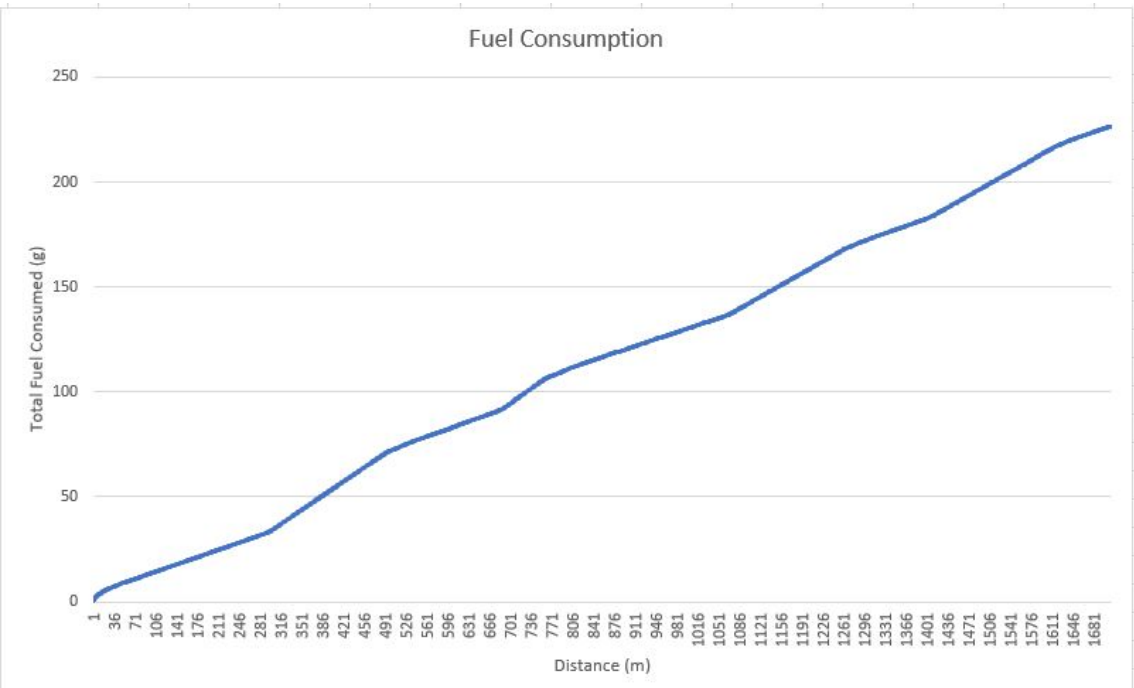


Figure 2: Fuel Consumption with Distance

Figure 3 Shows the forces acting upon the buggy, it is worth noting that the resistance forces should be inverted however they are not due to how I created the simulation.



Figure 3: Forces Acting on the Buggy

Figure 4 displays the relation between the velocity and aerodynamic resistance as predicted by Equation 3

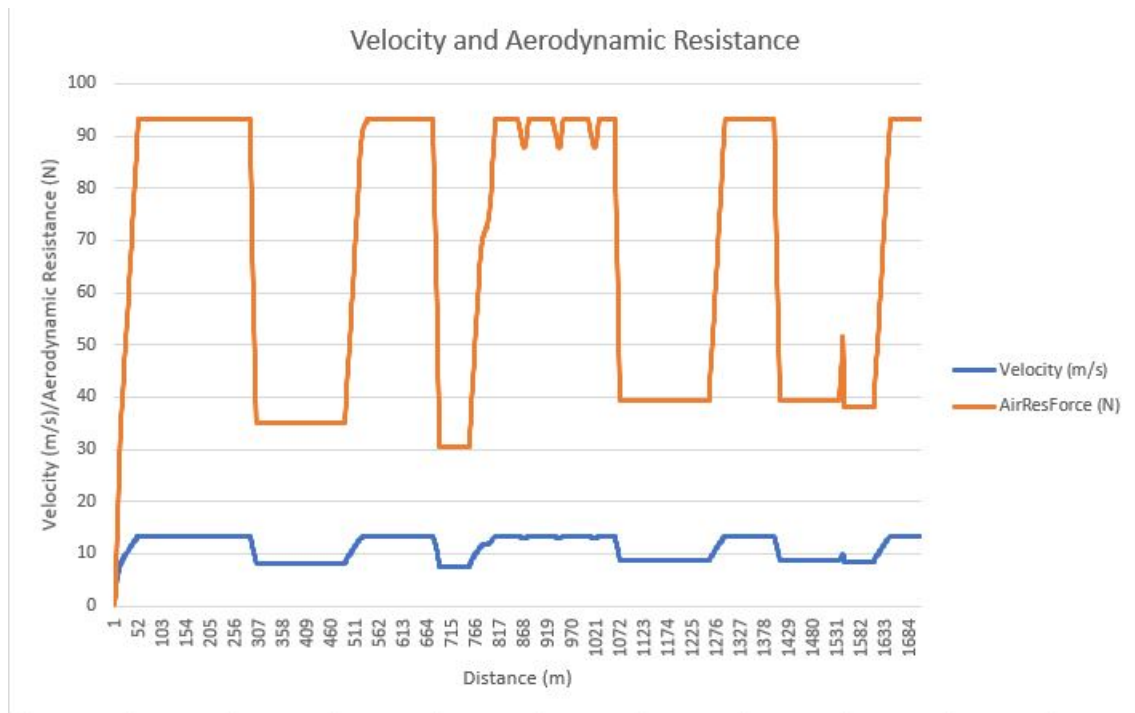


Figure 4: The Relationship Between Velocity and Aerodynamic Resistance

5 Analysis

In the process of creating this simulation, due lot of parameters that were not given, many assumptions had to be made. In order to improve the accuracy of the simulation I would like to obtain one of the buggies and perform the tests necessary to determine the actual parameters. These tests would include a dynograph, weighing the wheels and tyres, finding out the actual gear ratios of the vehicle, calculating the fuel consumption and creating a real BSFC graph as opposed to modifying an existing one to fit my needs.

Despite these assumption I believe the simulation to be accurate for the sake of the investigation. The inflated aerodynamic resistance serves to show the buggy would hold up in less ideal weather conditions, this applies for all of the dynamics of the vehicle as these would not change much. There are two assumptions which could endanger the

accuracy of the this investigation and that is the dynograph, which was used to calculate the torque at each RPM, and the BSFC which is just a modified BSFC from a different engine and is arguable not very representative of the actual engine in the Buggy. Looking at Figure ?? we can see that the resistive forces on certain surfaces are especially high, such as sand which would like cause trouble for the buggy were it to be used on it.

6 Conclusion

This report has shown a possible drive cycle of the Blitzworld Renegade DX10 off-road buggy across a single lap of the track I have created. From my investigation we know that the buggy is able to maintain its top speed around almost all of the track, looking at Figure 1 we can see the ideal area to run the buggy for minimum fuel consumption would be a torque of 13Nm and an RPM of 5500. It would be worthwhile to change the final gear ratio to achieve this as the buggy remained in the final gear ratio for most of the lap. Due to the large number of assumptions made during the initial stages it would be best to improve accuracy of the simulation by performing real world tests on an actual buggy to obtain the parameters which were assumed. This would allow me to create a far more accurate simulation instill better confidence in the results when discussing improvements.

References

- [1] www.blitzworld.co.uk. (n.d.). DX10 Renegade Corporate Buggy Off Road Buggy from Blitzworld. [online] Available at: <https://www.blitzworld.co.uk/Adult-Buggies/Renegade-DX10-CORPORATE-300cc-Auto> [Accessed 30 Nov. 2021].
- [2] Young, H.D., Freedman, R.A. and A Lewis Ford (2016). University physics with modern physics. Boston, Ma: Pearson Learning Solutions.
- [3] Hpwizard.com. (2010). Tire friction and rolling coefficients. [online] Available at: <http://hpwizard.com/tire-friction-coefficient.html>.
- [4] Wong, J.Y. (2001). Theory of ground vehicles. New York: John Wiley.
- [5] Petterson, T.C. and Gooch, S.D. (2020). ROLLING RESISTANCE OF ATV TYRES IN AGRICULTURE. Proceedings of the Design Society: DESIGN Conference, 1, pp.2561–2570.
- [6] Tyre N Tube Choice Ltd. (n.d.). Kenda K299 Bearclaw ATV Tyres — Tyre Choice. [online] Available at: <https://www.tyre-choice.co.uk/Kenda-K299-Bearclaw-ATV-Tyres/> [Accessed 30 Nov. 2021]. -engineer.org (n.d.). Brake Specific Fuel Consumption (BSFC) – x-engineer.org. [online] Available at: <https://x-engineer.org/brake-specific-fuel-consumption-bsfc/>.

7 Appendix

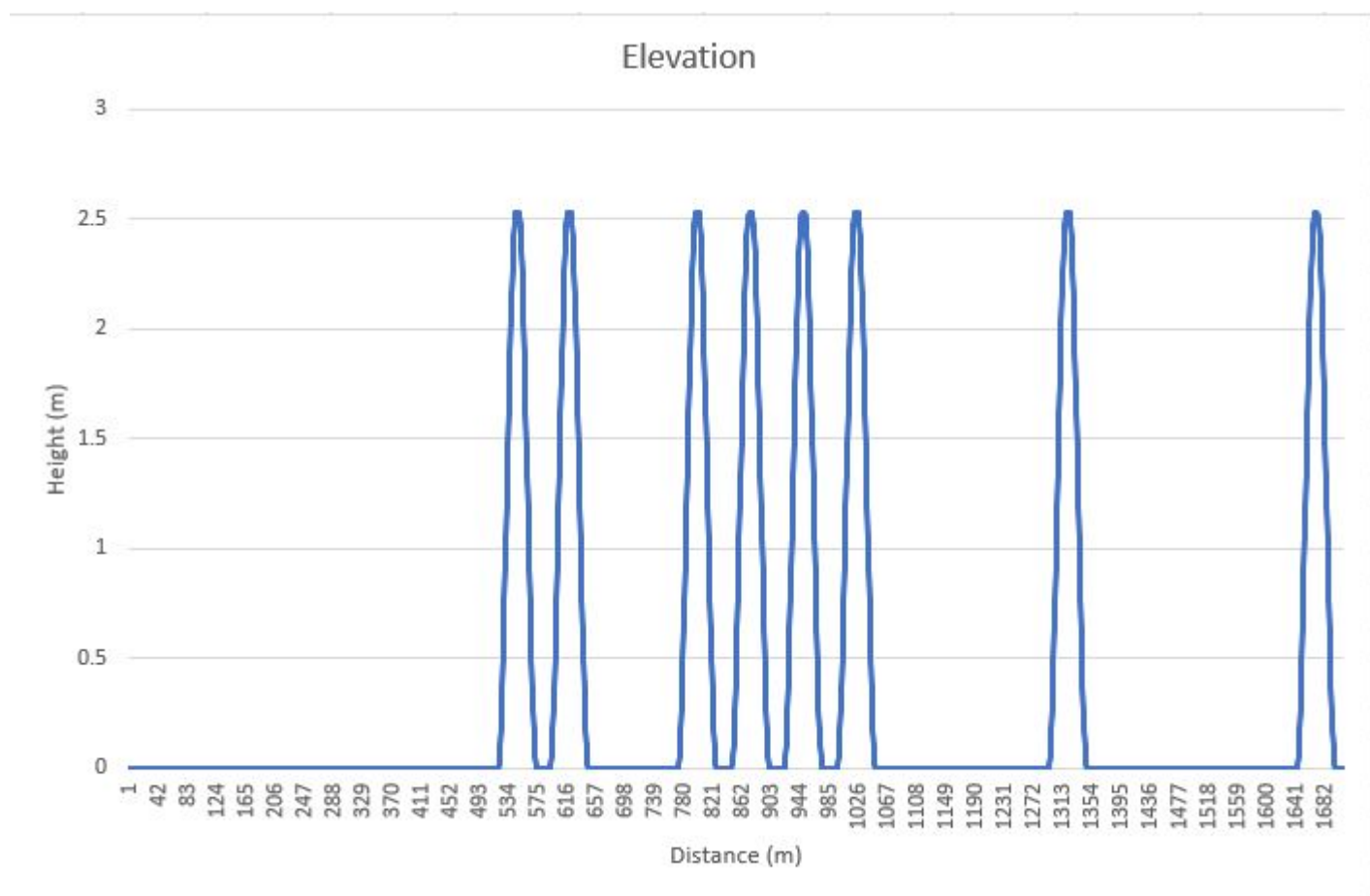


Figure 5: This shows where the elevated points are on the track.

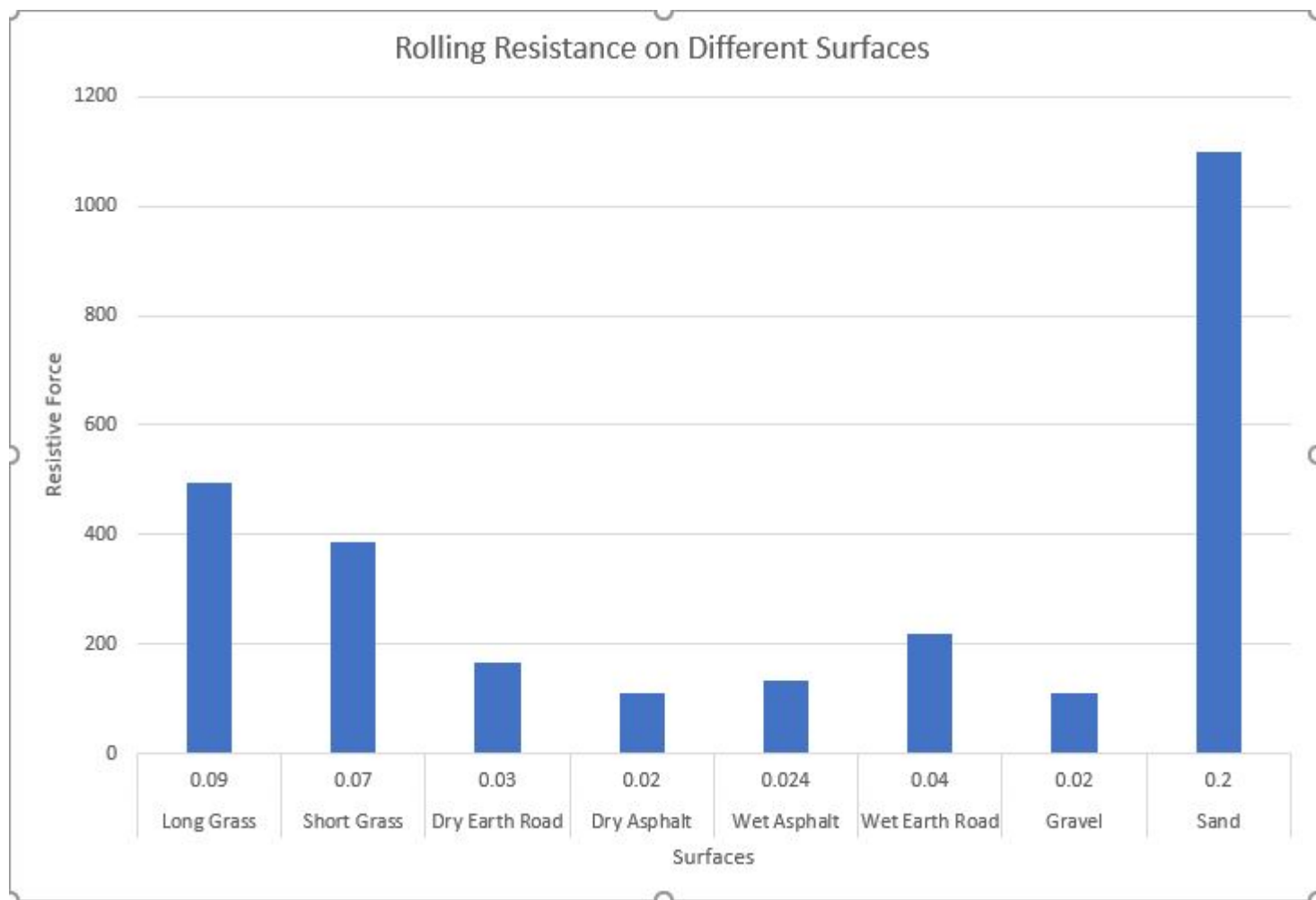


Figure 6: Figure 6 shows the differences in rolling resistances between the surfaces.

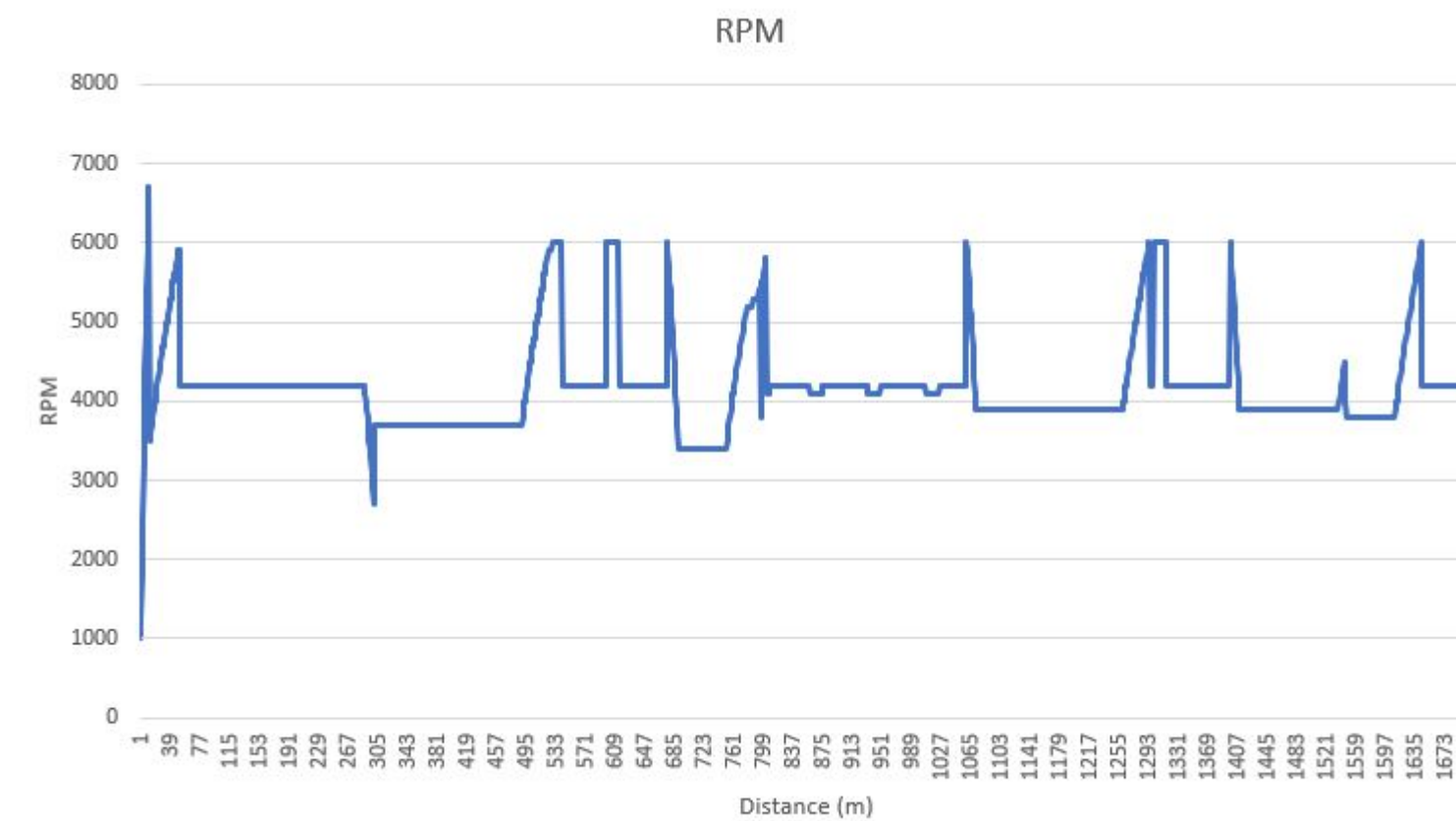


Figure 7: This shows the RPM of the buggy at specific positions on the track.