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**Equations for Motorcycle Optimization**

This should describe the equations that will be embodied in a program to optimize the battery pack size and other parameters. I am writing this with the program outline that I emailed to you earlier in mind, but these are physical equations that are valid for any electric motorcycle.

**Sign Convention:**

In this document all quantities are considered to be scalars. The direction of forward motion of the motorcycle is positive.

**Variables:**

|  |  |  |
| --- | --- | --- |
| **Variable** | **Description** | **Units** |
| **m** | Mass of the motorcycle and rider | kg |
| **x** | Distance along the path of the motorcycle (including changes in elevation, i.e. the actual distance is longer than what it appears on a map because of hills and valleys) | m |
| **v** | Forward speed | m/s |
| **a** | Forward acceleration | m/s2 |
| **vmax** | Maximum possible v of a given configuration | m/s |
| **Fapp** | Applied force, the force that the ground exerts on the tires of the motorcycle. | N |
| **Fmax** | Maximum possible Fapp of a given configuration | N |
| **Frr** | Force of rolling resistance | N |
| **Fd** | Force of drag | N |
| **Fg** | Force of gravity |  |
| **Pbatt** | Power output of the batteries | W |
| **η** | Efficiency of the entire drivetrain, batteries to road | dimensionless |
| **E** | Energy capacity of the battery pack | J |
| **Crr** | Coefficient of rolling resistance | dimensionless |
| **g** | -9.8m/s2 | m/s2 |
| **ρ** | Air density | Kg/m3 |
| **Cd** | Coefficient of drag | Dimensionless |
| **A** | Frontal are | m2 |
| **r** | Wheel radius | m |
|  |  |  |

**Math:**

Newton’s Acceleration Law states that:

relates to the energy of the batteries by the equation:

So we must find the at every x on the course.

However, Crr, m, and A vary depending on the parameters that we want to optimize, so the relations of these will be inputs into the optimization algorithm.

**All of this in the context of the program:**

Like I said at the begging, I am writing this with the structure I emailed you in mind, but these are physical equations that hold true for any motorcycle. So, I will attempt to explain how these equations fit into the structure of the program that I emailed you earlier.

Parameters to optimize:

* E
* r

Inputs to the algorithm:

* vmax(E, r)
* Fmax(E, r)
* “race function” v(x, E, r, vmax, Fmax)
* Crr(E, r)
* m(E, r)
* A(E, r)

Outputs of the algorithm

* Ideal pair of E and r

As you can see, the actual math used for optimization is extremely simple. The core of this kind of optimization lies in modeling the inputs. This is not something I can do. This will probably take the form of modeling bikes with different E’s in CAD, then comparing their A’s and interpolating to find A(E, r). **IMPORTANT:** These input functions should not be confused with the parameters to optimize, the input functions are fundamental equations that describe how certain design characteristics relate to one another.