Temperature Inefficiencies in Veoride Bicycles

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Introduction

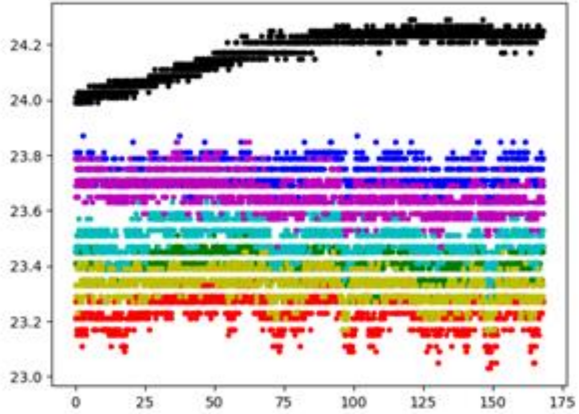
We used non-contact infrared sensors to measure temperature changes in the chain and tire of a Veoride bike.

We were able to quantify the energy lost to heating in the tire and chain.

Melexis MLX90614

A photodetector in the MLX90614 outputs a varying voltage proportional to the infrared energy it detects.

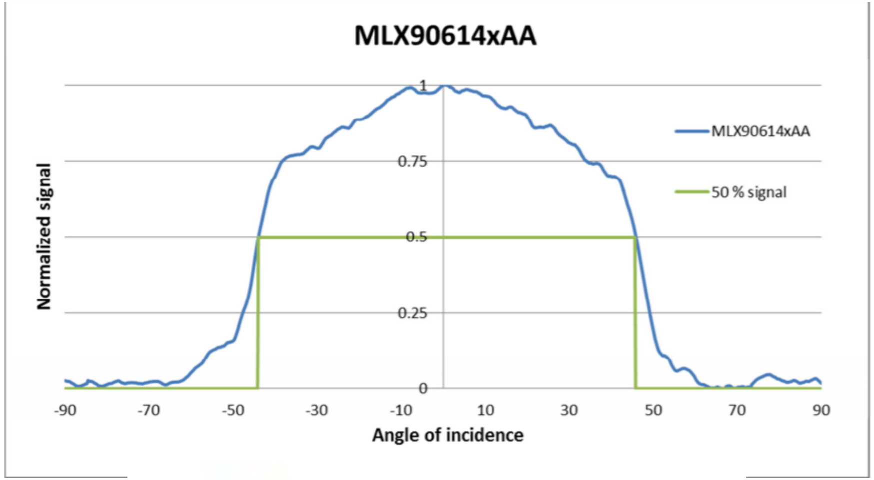
Each individual infrared sensor measures a slightly different temperature than the other.

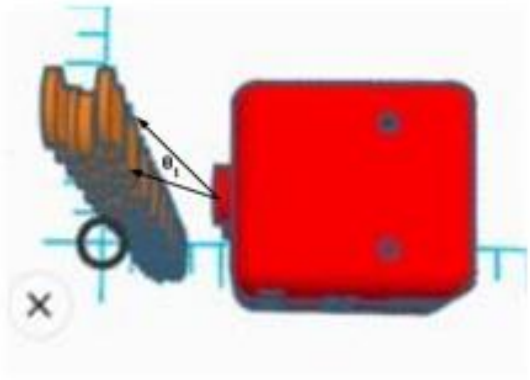


Melexis MLX90614

We used 6 IR sensors - two pointed at the chain, two pointed at the back tire, one pointed at a control piece of chain and one at a control piece of tire.

The chain was within a 90° viewing angle from the both chain sensors. The MLX is able to measure 50% of the infrared signal in this viewing range.





Theory

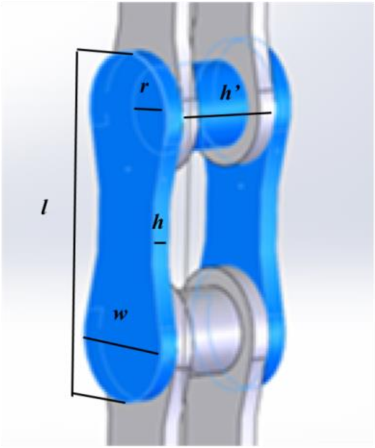
The internal energy of an object can be changed by introducing matter, by transferring heat, or by doing thermodynamic work onto the object.

Heat transfer is in the forms conduction, convection, and radiation.

Thermodynamic work is a result of friction, inelastic collision (for the chain) and other non-conservative quantities doing work onto the system, which will always increase the internal energy of the system.

The amount of change of matter is negligible.

Theory



The net effect of radiation is given by:

$$|P_{net}| = |P_{radiation,out} - P_{radiation,in}|$$

$P_{radiation,out}$ and $P_{radiation,in}$ are proportional to $A*T^4$

Before the experiment, the tire and the chain have almost exactly the same temperature as the ambient temperature, so the convection and conduction appears to be stationary.

$$|P_{net}(t = 0)| = |P_{radiation,out}(t = 0) - P_{radiation,in}(t = 0)| = 0\ W$$

The maximum radiation powers produced by the chain and the tire are $1.2X10^{-6}$ W and 0.1 W, which will change the temperature by $1.3*10^{-5}$K and 0.127K, which are negligible.

Both images are screenshots of 3D model from GrabCad
https://grabcad.com/

Theory

$$U_t(x, y, t) = C^2 \nabla^2 U(x, y, t) - \beta P$$

Procedure

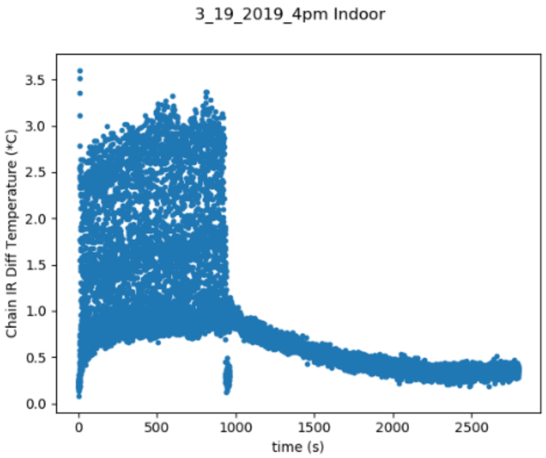
After letting the bike reach a constant temperature the measuring program is started up, ready to write data to an SD card

The rider would attempt to ride at a fairly constant speed on flat concrete bike paths outdoors and on a roller assembly indoors

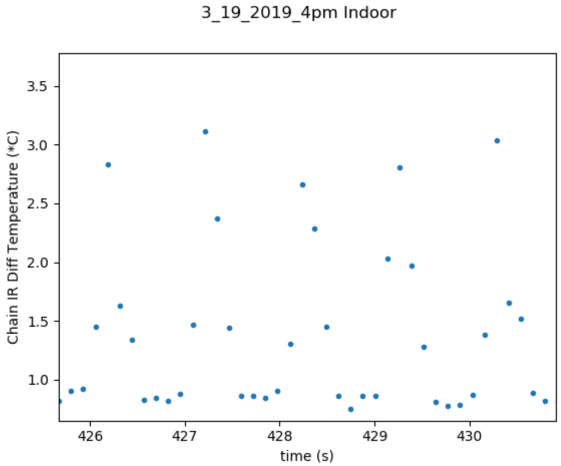
The rider then sets up the bike to cool with the same ground material and sunlight with the chain held taut to stay in the IR sensor image area

$$P_{tot} = \frac{mc}{t_{heat}} \int_0^{t_{heat}} T \quad dt + \frac{mc}{t_{cool}} \int_0^{t_{cool}} T \quad dt$$

Results



The chain showed a heating profile with high variance. We discovered with analysis that it was periodic, and with experimentation it was from the rider's leg entering and exiting the imaging area.

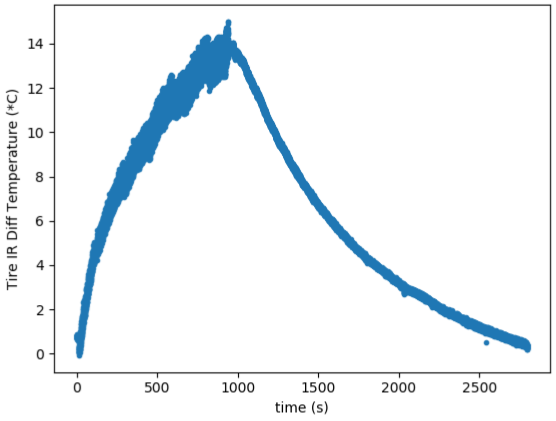


Our analysis justifiably excluded these higher values and continued with less data points to calculate the energy loss using integration and the specific heat energy formula. We found a power loss of ≈ 0.18 W and an energy loss of ≈ 300 J.

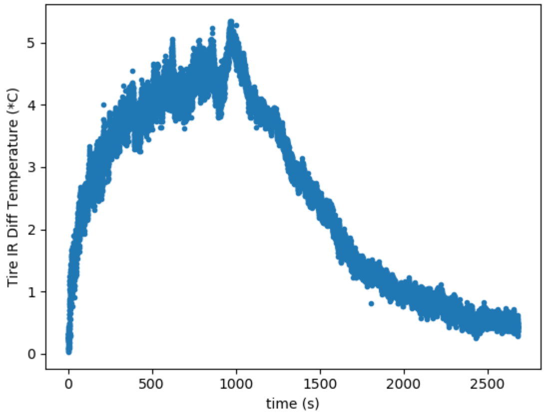
Results

$$P_{tot} = \frac{mc}{t_{heat}} \int_0^{t_{heat}} T \quad dt + \frac{mc}{t_{cool}} \int_0^{t_{cool}} T \quad dt$$

3_19_2019_4pm Indoor



4_2_2019_3pm Outdoor



The tires showed much more and more consistent heating and much more both inside and outside. It was also determined the inside results showed more heating at a lower speed due to nearly all energy use going to heating the tires with no movement occuring inside.

Our analysis used the same equation as the chain with different mass and heat capacity to calculate the power and energy loss. We found a power loss of ≈ 22.2 W and an energy loss of ≈ 62.0 kJ inside. Outside, we found a power loss of ≈ 11.0 W and an energy loss of ≈ 29.6 kJ.

Results

We used these numbers and the expected value of the chain power loss outside (source paper indicates it scales roughly linearly with speed) ≈ 0.45 W to calculate a chain to tire power loss ratio of 1:25. This is very high considering air filled tire bikes range from 1:8 - 1:17.

We have less energy loss than the expected value in the indoor case, but some product research of the Veoride suggests that may be due to the SG-3R40 internal gear shifter which we couldn't possibly measure the temperature of while riding and without taking apart the bike.

Conclusions

- The energy loss within a Veoride bicycle was analyzed primarily through the use of infrared temperature sensors
- Low expected emissivity and low sensor temperature variance allows simple macroscopic energy loss analysis with low expected temperature error
- Both the indoor and outdoor measurements showed clear and substantial heating on the bike tires ≈ (22.2 W inside, 11.0 W outside)
- The chain measurements were highly variable but showed heating from ≈ 0.18 W power loss inside
- The source of error allowed us to discount high temperatures in the chain and eventually determine riding speed and extrapolate an energy loss ratio of 1:25
- The Veoride bicycle has a slightly more efficient chain than the average road bike and far less efficient tires than the lowest quality bikes (due to solid foam tires)