A Mechanical Capacitor

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ABSTRACT

I would like to propose research into using a clockwork mainspring as resistance on a sideways orientated differential gear, the resulting device being mechanical capacitor.

BACKGROUND & RATIONALE

As a thought experiment, I considered a motor running through a differential in the orientation shown in figure 1 and having varying resistances working on the output.

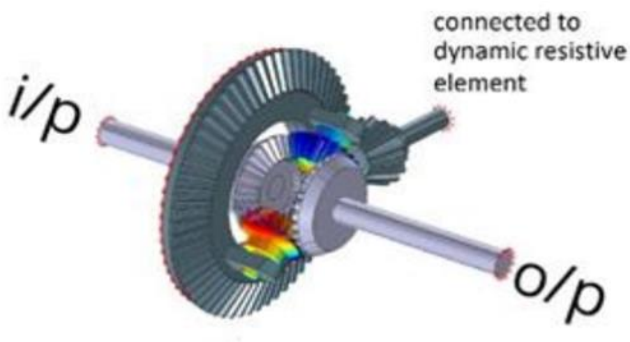


fig. 1

I realised quickly that the resistance on the output axle would only cause the ring gear to spin, so I questioned what would give the ideal resistance to act on the ring gear. I decided that a ratcheted spring (aka a pull-back motor) would be an intuitive choice as a resistive element on the differential's ring gear to stop it spinning freely.

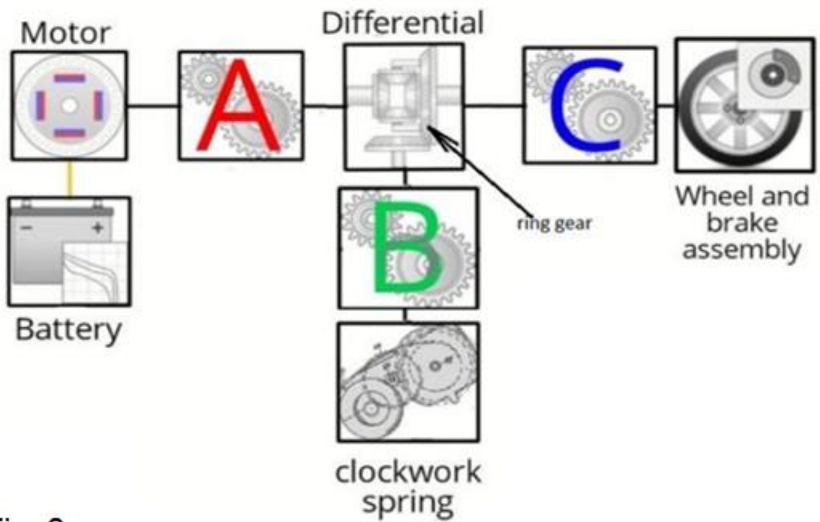


Fig. 2

PROOF OF CONCEPT AND FURTHER PROTOTYPING

The first of my experiments produced a surprisingly strong torque response for such a simple device:

[1.mp4 (dropbox.com)]

Experimenting with changing gearing between the elements (gearings A, B & C as in fig.1) led to different torque responses, as evidenced in the following videos.

[2.mp4 (dropbox.com)]

[3.mp4 (dropbox.com)]

APPLICATIONS & IMPORTANCE

This is at least an interesting idea that looks like it follows the same principles of flywheel kinetic energy storage, acting as a storage element for mechanical force and displacement.

I believe that a mechanical capacitor with the simplicity I am describing could be important in the evolution of small to micro-sized vehicles and bots, offering an action similar to that given by Continually Variable Transmissions (CVTs) to smaller applications than CVTs can be practically implemented into, and in some applications where CVTs would be overly expensive or otherwise impractical, this device can offer a simpler, lighter and cheaper alternative to conventional CVTs. CVTs are often computer controlled, whereas we might see this idea as being a little more Steampunk in comparison, but also a little more classically elegant. Applications may include personal mobility devices such as electric wheelchairs and electric power assist bicycles, but in smaller applications too such as use in microelectromechanical systems, in micro robotic devices. I reckon if I can build this device from LEGO, it could be 3D printed pretty easily.

Brushless motors and induction motors produce a good amount of torque. It is not intended to suggest this device would increase the amount of torque produced from these but can act as a mechanical capacitor to reduce stress from resistances on the motors' output being relayed straight onto the motor. In other words, it could be used for output smoothing.

As for an automotive application, I wonder if it might be useful in hybrid vehicles. I spoke with the Penn State motorsports team, and we agreed it would work on bikes, but the spring needed to haul anything heavier might be too huge to be practical. So, this device will not replace a cars gearbox but can have smaller applications in a drivetrain. We use traction control systems to limit how fast the engine spins to match the speed the tires can spin without losing traction. Now imagine the traction control uses this capacitor to store excess energy while maintaining top engine speed with the correct tire speed. Then when the driver shifts gear the spring relaxes and the stored power is used to maintain acceleration. Or it just uses that stored energy whenever the engine can't turn the wheels fast enough. There may also be applications in power steering.

Haven spoken with a number of engineering and physics experts and historians, it does seem that this device is novel, and that it might well rely on some unexplored mathematics. I can't prove it, but I have a strong inkling that Lorentz force calculations aren't required to model this device. I will go on to describe the maths I have been able to explore.

LITERATURE REVIEW

(I accept I've a bit of a cheek calling this section a literature review, given the lack of literary references herein.)

To further understand the mathematics governing the push-pull relationship between the spring and differential, and the resultant torque response against output load resistance, I tried to find studies of such a combination of these elements and found that there were none I could find. This could be because I am a pedestrian looking in pedestrian places and if I knew the correct terminology for what I was looking for I might find them easily enough. I had expected to find more from searches for "sprung differential." Similarly, I could not find anything mixing the mathematics of springs with the mathematics of differential gears.

I found one website with an equation explaining torque transfer through a differential, and I will go on to show how this equation can be a start for research into modelling this device with a view to exploring practical applications as described in the previous section of this report.

Differential as a planetary bevel gear - Simulink (mathworks.com)

With regards to using the arbour of a mainspring as a resistive element, I was able to find equations within horology texts that relate to the torque response of a spring winding and unwinding, but not from the centre arbour. When transformed and mapped through the differential's physics, these equations can unlock understanding of the device's action.

Stop Work and Recoiling Clicks (vintagewatchstraps.com)

PROPOSED METHODOLOGY

The following is a proposal of how this device can be further investigated for practical use.

1. **Understanding the Differential**
   a. Further research the torque transfer from input to output in a 'sideways' differential;
   b. Produce equations describing this torque transfer (transforming the equation in the link referenced in the literature review to describe angular rotation distribution in the desired orientation);
   c. Produce equations describing the ring gears angular rotation as a product of resistance on the output axle.
   d. Understanding frictional losses within the differential;
   e. Reproduce equations above taking losses into account.
2. **Understanding Mainspring Arbour Torque Responses**
   a. Further research into spring materials and governing physics;
   b. Further research into pull-back motors and watch mainsprings;
   c. Produce a mathematical model of relevant springs, for use with the torque equations.

3. **Investigate spring material options and capabilities within a mainspring component.**

4. **Produce a mathematical model of a mainspring arbour working as resistance on a 'sideways' differential.**

5. **Investigate a clockwork-differential's use in drivetrains:**

   adding gears (A, B and C in fig 1.) to tune what is learnt from previous stages into desirable spring torque responses for different vehicle weights and applications.

6. **Produce simulations of clockwork differential drivetrains:**

   a. First mathematically mapping a mainsprings action through a differential and gears A B & C,

   b. then using simulation software, such as MatLab or SimulationX, to produce digital simulations and a system calculator.

7. **Source a suitable differential gear and motor for use in physical models proposed below.**

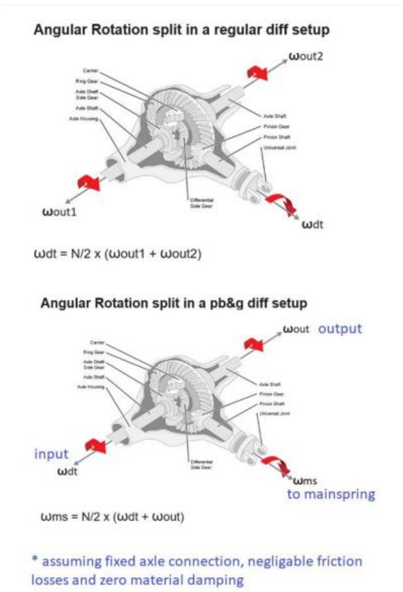
8. **Design and build two physical prototypes;**

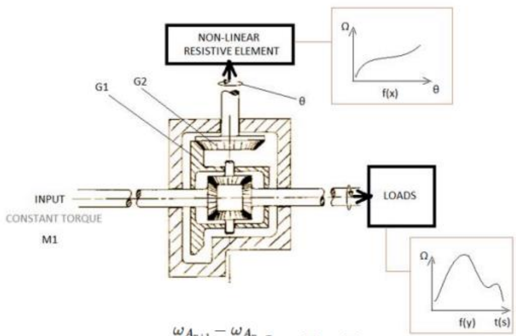
   a. one small drivetrain for personal mobility aids, scooters, hoverboards, etc.

   b. and the second a 3D printed micro-drivetrain, using a composite plastic housing, mainspring and gearset.

For stage 4 (mathematical modelling) we might consider two approaches:

1. **Time stepping angular rotation equations back and forward through a mathematical model of an ideal differential and gearset, before addressing losses;**





$$\frac{\omega_{A_{n+1}} - \omega_{A_n}}{\Delta t} J_A = T_A - T_{A_i}$$

$$T_{A_i} = T_A - \frac{\omega_{A_{n+1}} - \omega_{A_n}}{\Delta t} J_A$$

$$T_{C_i} = T_A - \frac{\omega_{A_{n+1}} - \omega_{A_n}}{\Delta t} J_A \text{ (because } T_{A_i} = T_{C_i}\text{)}$$

$$T_{C_i} = T_A - \frac{\omega_{A_{n+1}} - \omega_{A_n}}{\Delta t} J_A \text{ (because } T_{A_i} = T_{C_i}\text{)}$$

2. **Describing the road as linear gradients and following a change in gradient to resistance on and absorbed by the mainspring component. I have made a small start on looking at the relevant equations:**

Vehicle stats and assumptions:

Weight of scooter and rider= 120kg

Wheel radius (R)= 100mm

Arbour Radius (Ra) =

Desired speed = 30km/h, 13.41m/s

Negligible air resistance

Kinetic friction co-efficient (= 0.68

Powertrain efficiency = 100%

Constant motor output = 1.1kW, T = 2.1Nm

ωa =

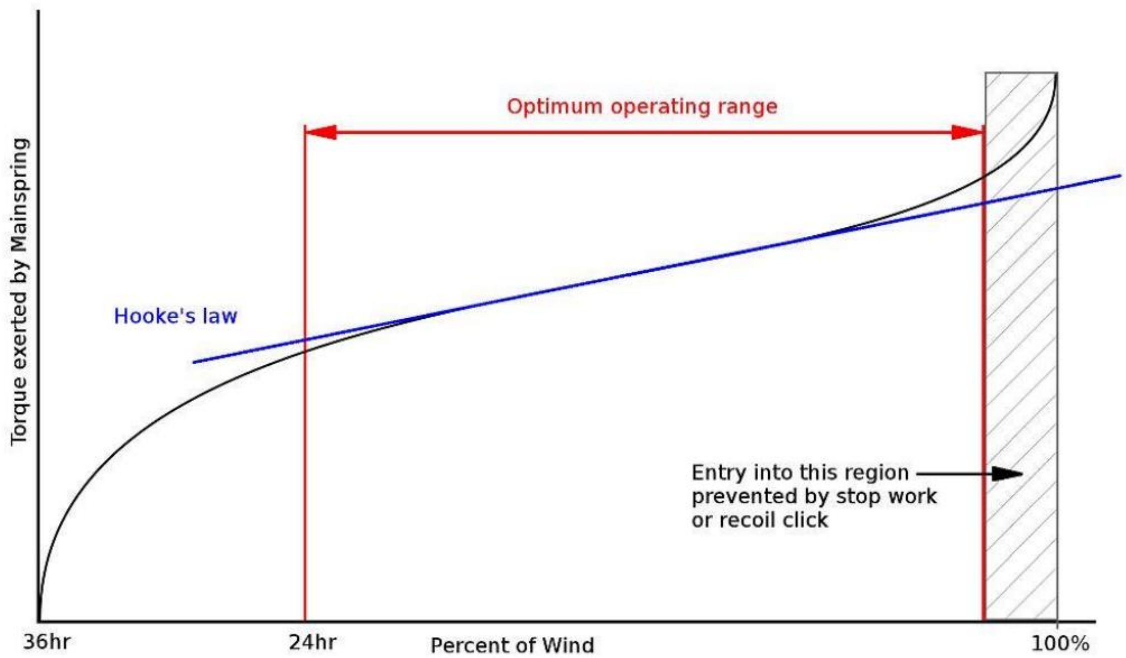
All axles are 12mm in radius

Gravity = 9.8m/s2

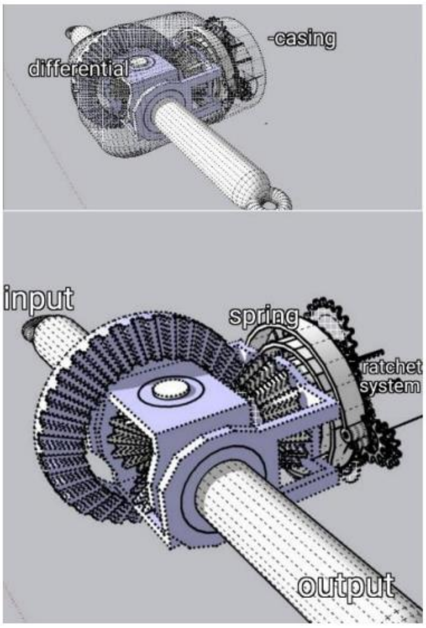
	STAGE 1 0 to 10m	STAGE 2 10 to 20m	STAGE 3 20 to 45m	STAGE 4 45 to 50m
Gradient θ°	0% gradient θ 1 = 0°	10% gradient, θ2 = 5.71°	20% gradient, θ3 = 11.31°	60% gradient, θ4 = 30.96°
Gradient force – Fg = mg*sin θ	Fg1 =	Fg2 =	Fg3 =	Fg4 =
Kinetic friction force = Fk = mg*cos(θ2) - μk*g*cos(θ)	Fk1 =	Fk2 =	Fk3 =	Fk4 =
Total friction forces – Ft = Fg+Fk	Ft1 =	Ft2 =	Ft3 =	Ft4 =
Required torque – T = Ft * R	T1 =	T2 =	T3 =	T4 =
Power required – P = T * V	P1 =	P2 =	P3 =	P4 =
Required wheel axle rotational velocity – ωb = P/ (π*R)	ω1 =	ω2 =	ω3 =	ω4 =
Differential mainspring output axle speed – ωms = N/2 * ωa - ωb	ωms1 =	ωms2 =	ωms3 =	ωms4 =
Distance spring is pulled – D = ωms * (π*R)	D1 =	D2 =	D3 =	D4 =
Spring torque – Ts, mapped from spring graph	Ts1 =	Ts2 =	Ts3 =	Ts4 =
Effective torque absorption – Tz= 2ωms / N	Tz1 =	Tz2 =	Tz3 =	Tz4 =
Total torque available – ωa+ωz				

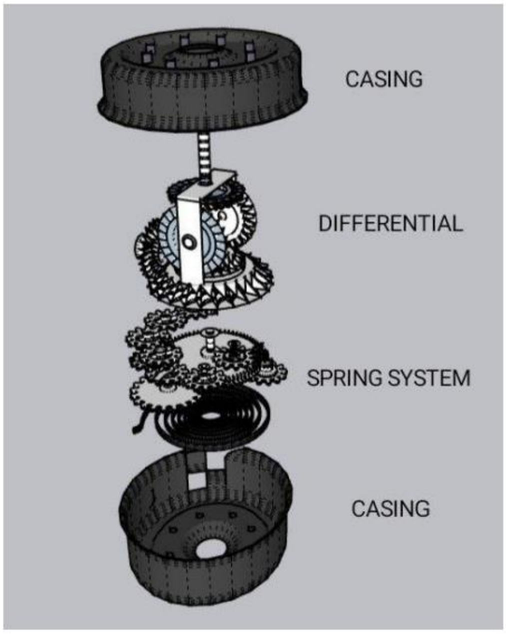
EXPECTATIONS

I expect investigations into deforming a coiled spring from the middle arbour will produce results very similar to a coiled spring being pulled in the conventional manner.



MECHANICAL COMPONENT VISUALISATIONS





CONCLUSION

I previously showed this to The Ford Motor Company, and they very cheekily claimed to be working on the same idea. I find the idea of this too wild, that an invention that could have been invented 120 years ago has been independently developed by two parties at the exact same time. Ford did send a retraction of words, but their initial claim proved to me that the independent researcher cannot hope to hold on to their own ideas, especially in classical engineering. Even if I was the right person to take this onto do good things, I would likely have a bear of a time trying to claim it as being original, it being so simply made from a few simple components. Wikipedia will suddenly have a page on 'sprung differentials' that was always there, and a plagiarising entity would just avail themselves of the same type of lawyers that argued Ed Sheeran wrote all his own music.

This invention means a lot to me but means nothing if it is never implemented anywhere. I see too many possibilities for good use to want to sit on it. It is my intention to make this invention free for anyone to use, and to declare it free from being owned by anyone.