Hot & Motored: Generating Electricity with Footsteps

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***Abstract*—This document examines the plausibility & efficiency of generating power via footsteps, which could be used on pavements to generate electricity used for various purposes, depending on the user's preferences.**
Excuse the pun.

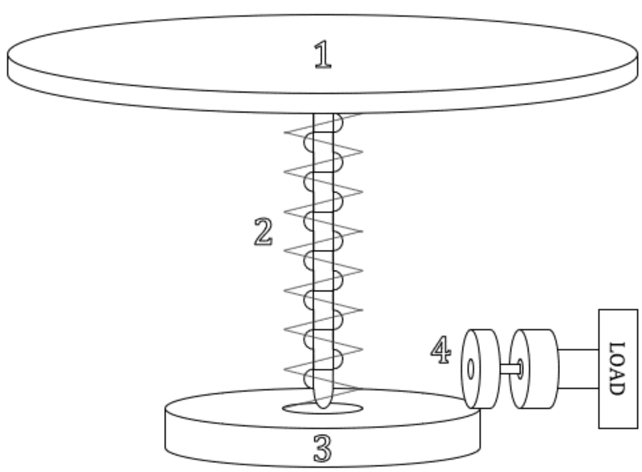
I. Mechanism Proposal

The proposed mechanism to generate electricity is comprised of multiple stages, and such operate in unison to provide the output voltage at the output stage.

A. Components Analysis

The mechanism itself involves a button/plate that, when pressed, would push a spiral down an entry point, compressing a spring. When such button/plate (thus, the spring) is released, the spiral is released to its initial position, in turn spinning the flywheel disc/gear that such spiral is fixed to, causing such to move in a rotational manner.

Fig. 1. Diagram of proposed mechanism to generate electricity from footsteps



Such mechanism is shown in Fig. 1 and is comprised of the following components (refer to labels on Fig. 1):

1) Plate which individual steps onto - such is supported by a compression spring
2) Spiral rod which inserts into Component 3's axle - such is attached to Component 1
3) Flywheel which Component 2 inserts into via an opening fitting the size of the spiral's rectangular body
4) Motor with additional gears connected to Component 3, where such is repurposed as a generator; such gears may include transmission stages

B. Operations of Mechanism

The mechanism is intended to operate per the following procedures (refer to labels on Fig. 1):

1) One steps onto Component 1, pushing Component 2 downwards & compressing the support spring
2) Component 2 moving downwards passes through slot in Component 3
3) One steps away from Component 1, resulting in the spring being released; such results in Component 2 moving upwards to its original position
4) Component 2 moving upwards now results in Component 3 rotating, causing Component 4's axle to also be rotated (due to the gear connection)
5) The rotation of Component 4's axle results in EMF being generated at its output

One can surmise that power from **linear motion** (due to Steps 1 and 2) is converted to that of **rotary motion** (given by Step 4), and later converted via **induction** (per Step 5).

II. Theory

This section concerns the generator's output characteristics & how such is linked to the mechanical stage prior. Such refers to [1] in regards to theory & formula behind such operations.

A. Assumptions of System

Given reality, that the system will encounter losses, and thus will not be 100% efficient. This therefore warrants for a number of assumptions to be made, to allow easier calculations & analyses of the system.

- An individual steps onto the slab & pushes the spiral to its maximum length
- There is no friction within the spiral - this results in the flywheel rotation a full revolution per one successful spiral turn
- Thermal losses (due to friction or thermal dissipation by the components) are neglegible
- The material themselves do not wear down or permanenently change form, thus allowing for sustained usage
- The torque & angular speed due to the flywheel is fully transferred to the motor/generator

B. Known Quantities

The following electrical values are either known or determined by the chosen equipment.

- The **electromagnetic constant**, **reluctance** and **voltage rating** of the motor/generator
- Desired voltage at load (i.e. 5V for a rechargeable battery)

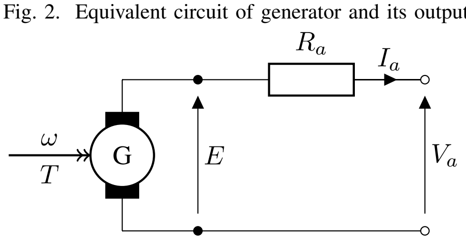
Similarly, on the mechanical domain one understands that the number of **spiral turns** is controlled by the spiral rod, and thus is a known value.

C. Generator Output Characteristics

The generator's output mechanism can be modelled as an equivalent circuit per Fig. II-C, where the following terms are defined:

- ω/T: Angular speed & torque of generator's input axle, dictated by its transmission gear & stages
- E: Output EMF of generator
- R_a: Generator reluctance
- I_a/V_a: Current & voltage at load output of generator

Fig. 2. Equivalent circuit of generator and its output



Such is governed by the equations given by (1), where k_e is the **electromagnetic constant** of the motor/generator.

$$T = k_e I_a \tag{1a}$$
$$E = k_e \omega \tag{1b}$$

Given Fig. II-C one can surmise the following information given by (1).

$$\begin{aligned} V_a &= E - I_a R_a \\ &= k_e\omega - \left(\frac{T}{k_e}\right) R_a \end{aligned} \tag{2}$$

where ω and T are determined by the prior stage, specifically the mechanical input stage.

D. Mechanical Input Characteristics

The following assumptions are to be made in regards to the mechanical stage, to alleviate calculations.

- The mass of the flywheel is represented as an arbitrary cylindrical mass of M_f kg with a radius of r_f metres
- The mass of the slab is, similarly, represented as a point mass of M_s kg
- The spring continuously obeys Hooke's Law

1) Spiral Rod vs Flywheel: Given the operations of the mechanism, compressing the spring to a certain distance x from its original position results in a force being exerted outwards (with intent of returning to its original shape), and thus obeys Hooke's Law per (3).

$$F = -kx \tag{3}$$

Due to Conservation of Energy & the assumptions made prior, it can be surmised that the elastic potential energy of the spring is fully transferred to the next stage, per (4) as derived from (3).

$$\textit{Work Done} = \Delta PE = \frac{1}{2}kx^2 \tag{4}$$

As the spiral rod passes through the opening gap inside the flywheel, force is exerted by the spiral rod incident to the opening's sides (assumed here to be point incidents), where work done by such action is given per (5).

$$\textit{Work Done} = Fr\theta \equiv T\theta \tag{5}$$

where r is the radius from the centre of the flywheel's opening to its edges, F is (assumedly point) force exerted onto the opening at its edge, and θ is the total angle which flywheel travels (in radians), given to be $2\pi N$ per N spiral turns.

Equating (4) and (5) (per Conservation of Energy and the full-efficiency assumption) results in an expression for force.

$$\frac{1}{2}kx^2 = 2\pi NFr = 2\pi NF_{edge}d$$

In the case of the equated expression, one could then obtain the tangential force exerted at the edge of the flywheel's body, per (6).

$$\frac{1}{2}kx^2 = 2\pi NF_{edge}d \tag{6}$$

References

[1] N. Simpson, *Electro-Mechanical Energy Conversion*. Bristol, United Kingdom: UNIVERSITY OF BRISTOL Department of Electrical and Electronic Engineering, 2017.