Foot in the Pave: 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.**

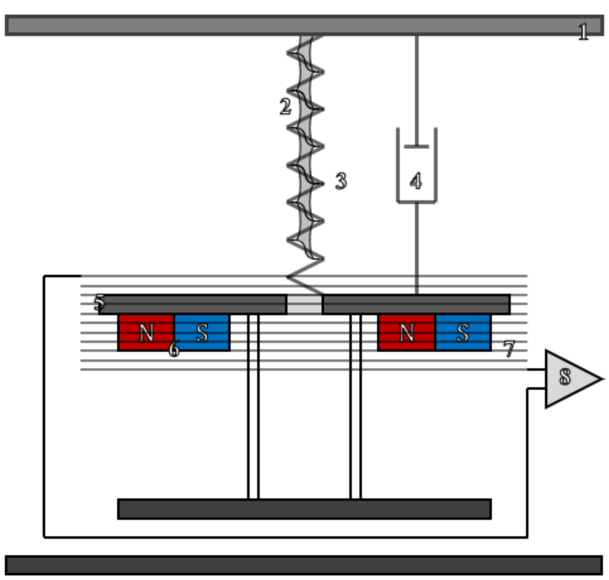
I. Mechanism Proposal

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.

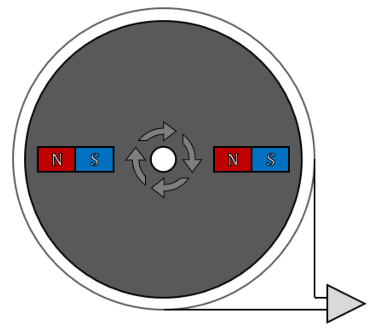
Fig. 1. Diagram of proposed mechanism to generate electricity from footsteps



Such mechanism could be seen via Fig. 1, with the spiral-driven internal gear shown with Fig. 2, and is comprised of the following components (refer to labels on Fig. 1):

1) Plate which a person is to step onto
2) Spiral which drives the flywheel disc & causes such to rotate

Fig. 2. Top-down view of spiral-driven gear & its attached magnets



3) Support springs which compresses when person steps onto the place & vice versa
4) Damper preventing the plate from being stepped on excessively & resulting in component damage
5) Flywheel disc, with rotation driven by the spiral
6) Magnets attached to the flywheel disc
7) Wire coil windings surrounding the entirety of the flywheel
8) System output; such harvests the current induced in the winding

B. Operations of Mechanism

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

1) One steps onto the plate (Comp. 1), pushing the self-attached spiral (Comp. 2) downwards & compressing the support spring (Comp. 3) and the damper (Comp. 4).
2) Spiral (Comp. 2) moving downwards passes through slot in flywheel disc (Comp. 5) with magnets (Comp. 6) attached to its sides; such is at a fixed, immutable height from the base, and is likely to rest on a low-friction rail (allowing such to rotate).
3) One steps away from the plate (Comp. 1), resulting in the spring (Comp. 3) and damper (Comp. 4) being coherently released. Such results in the attached spiral (Comp. 2) moving upwards to its original position.
4) The spiral (Comp. 2) moving upwards now results in the flywheel disc (Comp. 5), and thus the magnets (Comp. 6), to rotate.

5) The rotating magnets (Comp. 6) result in current induction in the wire coil (Comp. 7) surrounding & at the same fixed height as the flywheel (Comp. 5). Such induced current can then be harvested at the output (Comp. 8).

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

Generating electricity from footsteps adapts the fundamental theorems of mechatronics, prominent those involving electromagnetic induction.

A. Electromagnetic Induction

One recalls Faraday's **Law of Electromagnetic Induction** (and Lenz' Law)

$$E = -\frac{d\psi}{dt} \equiv -N\frac{d\phi}{dt} = -N\frac{dBA}{dt} \tag{1}$$

where such terms are defined per following:

- E: **EMF** generated within coil (V)
- ψ: magnetic **flux linkage** (Wb Turns)
- ϕ: magnetic **flux** (Wb)
- N: amount of wire turns within a coil (Turns)
- B: magnetic flux density (T)
- A: area of coil (m^2)

Per (1), one can observe (with reference to Fig. 1 & Fig. 2) that, as the flywheel (Comp. 5) rotates, the magnetic field generated by the magnets (Comp. 6) only crosses through the wire coil windings, whereas the coil's area does not get altered, and thus is stationary. (1) could thereby be simplified to the following (assuming coil is immute during operation):

$$E = -NA\frac{dB}{dt}$$

B. Work Done by Footstep

One recalls the general formula of **power**:

$$P = \frac{\Delta W}{\Delta t} \tag{2}$$

where P is power (measured in Watts), and W is **work done** (measured in Joules). Such is applicable in both **linear** & **rotary** motions' stages of the operation.

One can also recall the formula of **work done** via **linear motion**:

$$W = F_L d = (F_f + F_k + F_c)(s - x) \tag{3}$$

where:

- F_L: **aggregate force** exerted onto spiral, due to **linear motion** via person stepping on plate & spring and damper (N)
- F_f: **force** exerted by **person** onto plate (N)
- F_k & F_c: **forces** exerted onto plate by **spring** and **damper**, respectively; such forces oppose F_f & are in opposite direction to F_f, and thus are negative (N)
- d: maximum possible **displacement** which spiral/plate can travel downwards (m)
- s: **distance** between plate & disc (m)
- x: minimum possible **displacement** of compressed spring & damper, assuming both damper and spring compresses to the same displacement (m)

In this analysis, one concerns the operations in Operational Steps 4 & 5; such operations provided anlytical method becomes cumbersome & could be numerically analysed via MATLAB's SimScape to model & simulate the described mechanism.

NB While it is possible for self to continue the analytical analysis & calculate values of operations and outputs by hand (or with MATLAB), it is currently overly complicated & beyond self's capabilities (where such requires materials one will be studying in University of Bristol's EENG37000 Industrial Electronics 3).

III. Simulation

One utilises MATLAB's SimScape to simulate such mechanisms, and is comprised of three stages.

A. Schematic Diagram