Electrostatic Motor

Electrostatics and its guiding principles are crucial in a wide variety of applications. Electrostatics is involved in things from printers to saran wrap, from transducers to electrostatic motors. The concept of charge repulsion is the foundation of electrostatic motors. In the following project, multiple variations of a model of an electrostatic motor were built. The goal was to construct a motor which would produce a maximum number of rotations per minute (rpm).

The platform of the motor was constructed out of a rectangular block of wood. A small hole was drilled in the center of the block. A bamboo skewer was fitted inside this hole to act as the axle for rotation. The housing bottle was constructed out of a pop bottle with the top cut off. Two sheets of aluminum foil (each 4 layers thick) were taped on opposite sides of the bottle (on the outside). A small tab was cut into the bottle's sides on each aluminum sheet. These tabs were bent inward. A hole was drilled in the bottom of the bottle so that it could be place through the skewer.

The rotating bottle was made of a bottle slightly smaller than the housing bottle. For one model, three equal strips of aluminum were taped symmetrically to the sides of the bottle. Small holes were drilled in the bottom of the bottle and in the cap. A small screw was inserted in the cap of the bottle. The rotating bottle was then placed inside the housing bottle so that the bamboo skewer fit through the hole in the bottom of the bottle and the tip rested in the head of the screw. To connect the housing bottle's plates to a voltage source, flexible copper wiring was initially used to connect the plates to a Wimshurst. One plate was connected to the positive terminal and the other to the negative. However the copper wiring proved to be unwieldy so the lab alligator clips replaced the copper wiring.

A total of two different housing bottles and four different rotating bottles were built. The first housing bottle was made from a 2 liter bottle. The second was made from a 1 liter bottle. Three small rotating bottles were made from 0.355 liter bottles. One of these bottles had two symmetric strips of foil attached, another had three, and the last one had five. The one large rotating bottle was made from a 1 liter bottle (actually slightly less than 1 liter, because the bottle was shortened in order to make it fit in the housing bottle). This bottle had three symmetric strips of aluminum foil.

As the Wimshurst was cranked, the bottle rotated (sometimes after an initial gentle push on the bottle). The Wimshurst was cranked at a fairly constant rate.

To actually “count” the rpm, a strobe light was used. In a closed room the motor was activated. The lights were shut off and the strobe like turned on. The idea was that when the flashes per minute (fpm) of the strobe light matched the rpm, the bottle would appear to be completely still. This would appear to be so because when the light initially flashed, the bottle would be in one position; then the light would switch off long enough for the bottle to make a complete revolution back to the same spot just as the light flashed on again. To make it easier to see the bottle rotating, a sector of the cap was colored black. (Note: it was possible that if the fpm were exactly half of the rpm, then the bottle would also appear completely still. To check that the fpm was not half of the rpm, it was necessary, once the fpm was set so that the bottle appeared stationary, to double the fpm. If the fpm was exactly twice the rpm of the bottle, the colored sector on the cap would appear to alternate between opposite sides of the cap.)

Rotations Per Minute

	1 L housing bottle	2 L housing bottle
~ 1 L bottle		
3 foil	not tested*	195
0.355 L bottle		
2 foil	142	not tested*
3 foil	880	371
5 foil	147	not tested*

*The ~ 1 liter rotating bottle was not tested in the 1 liter housing bottle because it would not fit. The two and five foil rotating bottles were not tested in the 2 L housing bottle because the three foil bottle was already determined to spin faster than them both in the 1 L housing bottle.

The concept that like charges repel and opposite charges attract is the guiding principle to the motor's functionality. The Wimshurst provides the voltage which produces the charge on the aluminum foil plates. The charge on the plates is directly proportional to the voltage applied and to the area of the plates. On the negative side, the foil plate is charged negatively; on the positive side, the plate is charged positively.

Looking first at the negatively charged plate, this charge runs into the inwardly bent tabs and on to one of the rotating bottle's foil strips. At this point, both the housing bottle's plate (and tab) and the rotating bottle's foil strip are charged negatively. The resulting repulsive force is a torque which causes the rotating bottle to rotate.

The same thing happens on the positively charged plate on the other side of the housing bottle. The positively charged tab pushes the foil strip (and consequently the bottle) to rotate. The negatively charged tab pushes the foil strip (and consequently the rotating bottle) in the same rotational direction. As the negatively charged strip rotates away from the negative tab, it is also attracted toward the positive tab, adding more rotating force. The same happens with the positively charged strip. Then once the negatively charged foil strip comes under the positive tab, it is charged positively, and so is once again repelled. The same goes for the positive foil strip. This cycle continues as long as one plate is being positively charged and the other is being negatively charged.

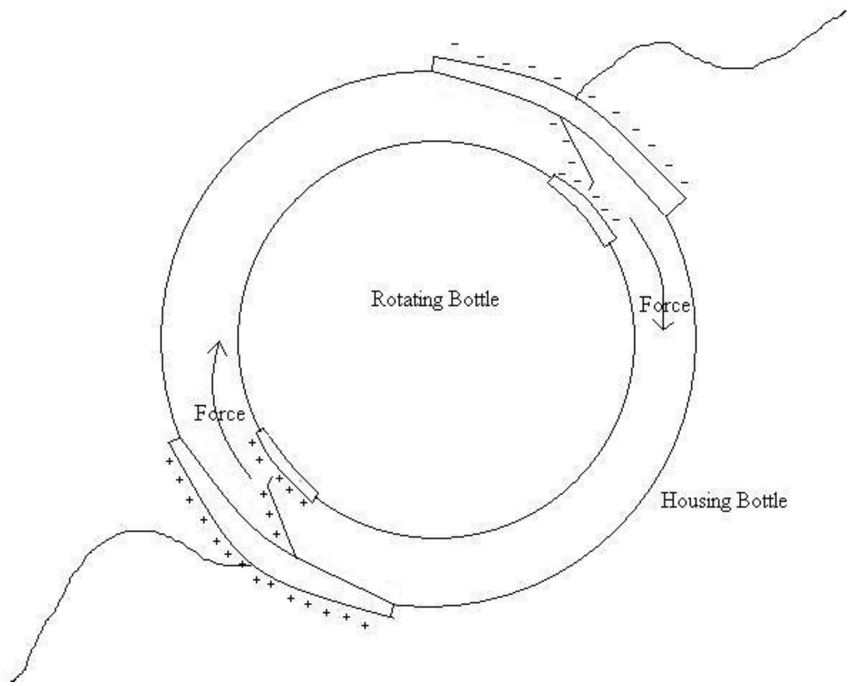

Figure 1. Top view of the electrostatic motor (2 foils)

For the rotating bottle, would it make a difference to have more or fewer foil strips? There should be an optimum number of foils. The three foil design had an rpm over 450% of the two and five foil designs.

The reason for having a larger housing bottle and larger rotating bottle was to increase the surface area of the foil plates and strips and thus to increase the charge. However, with increasing size of the rotating bottle, the inertia of that bottle would also increase. From this experiment it was evident that the increased inertia outweighed the increased charge. Then why didn't the small bottle rotate faster in the large housing bottle? Perhaps the larger size of the housing bottle allowed the small bottle to wobble too much, and maybe the inward tabs did not reach far enough.

This experiment successfully constructed working electrostatic motors. In creating a good electrostatic motor, it was necessary to find a design that maximized the force of repulsive charge. After testing the motors in terms of bottle size and number of foils as they relate to rpm, the optimum design was the smaller housing bottle with the smaller three strip bottle.

Works Cited

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