On Over-Unity Eddy Current Heating

International patent WO 03/0011002 Magnetic Heater Apparatus and Method assigned to MagTec LLC has aroused some interest. This describes a form of heater where an electrically conductive disc is rotated close to an array of permanent magnets. Eddy currents induced into the disc create heat that is transported away by contact with a fluid flow. Data is given on the performance of a heater where the fluid is air at a flow rate of $3200ft^3$/min provided by a fan consuming 1.76KW, the air being raised in temperature by 80°F from contact with the heated disc driven by an electric motor consuming 20.9KW. This equates to a COP of 3.58. The preferred material for the disc is stated as Cu.

This paper studies the eddy current flows within the moving disc. At low speed the currents are in phase with the induced motional electric **E=v×B** field, yielding magnetic forces on the disc that create a reaction torque as seen by the drive motor. That torque creates input power to the motor that accounts for the heating power delivered. It is then shown that at high speeds the electrical L/R time constant delay between the establishment of the induced electric field and the resultant eddy current creates an armature reaction where the forces occur at a different angular disposition, altering the torque and ultimately leading to over-unity behaviour. An explanation is offered for the excess energy where the closed loop eddy currents in the disc yield a closed loop reaction E field that, although being cyclic within the rotating reference frame of the disc, appears static in the reference frame of the magnets hence "loads" the atomic current circulations responsible for their magnetism.

Consider an endless strip of conductive material moving at velocity **v** over an array of permanent magnets as shown in top and side views in figure 1.

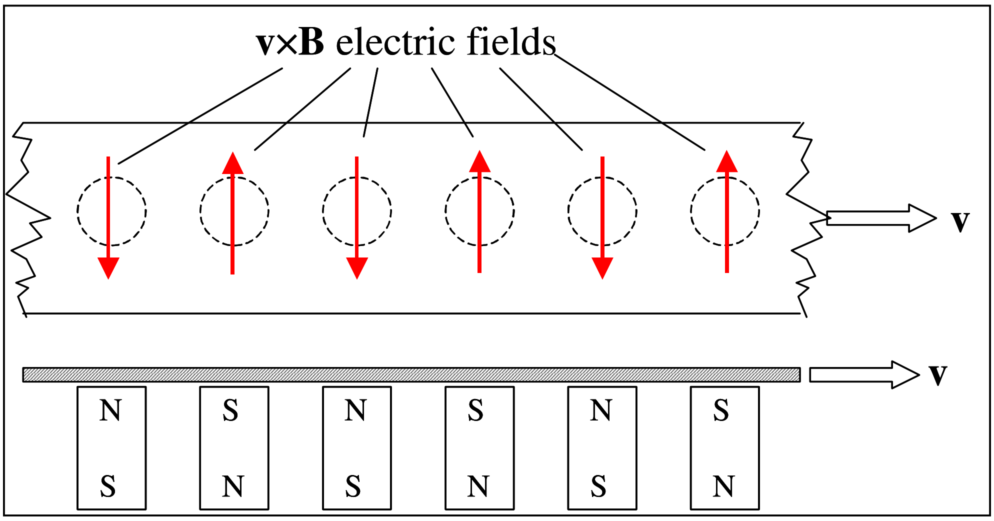

Figure 1. Conductive strip moving across magnet array.

The magnets are sequentially arranged with alternating polarity, hence the induced motional electric fields **E=v×B** have alternating directions above each magnet as shown by the red arrows. At low velocities these electric fields will drive eddy currents within the strip as illustrated in figure 2. Because the strip has finite conductivity energy will be dissipated in the form of heat. The source of that energy flow may be realized when each eddy current loop is viewed as an effective magnetic dipole, also illustrated in figure 2. It can be seen that these dipoles are positioned between the permanent magnets such that they experience a constant force upon them in a direction opposing the motion. Thus the mechanism driving the strip sees an opposing force and has to deliver mechanical power that exactly accounts for the electrical power dissipated in the strip.

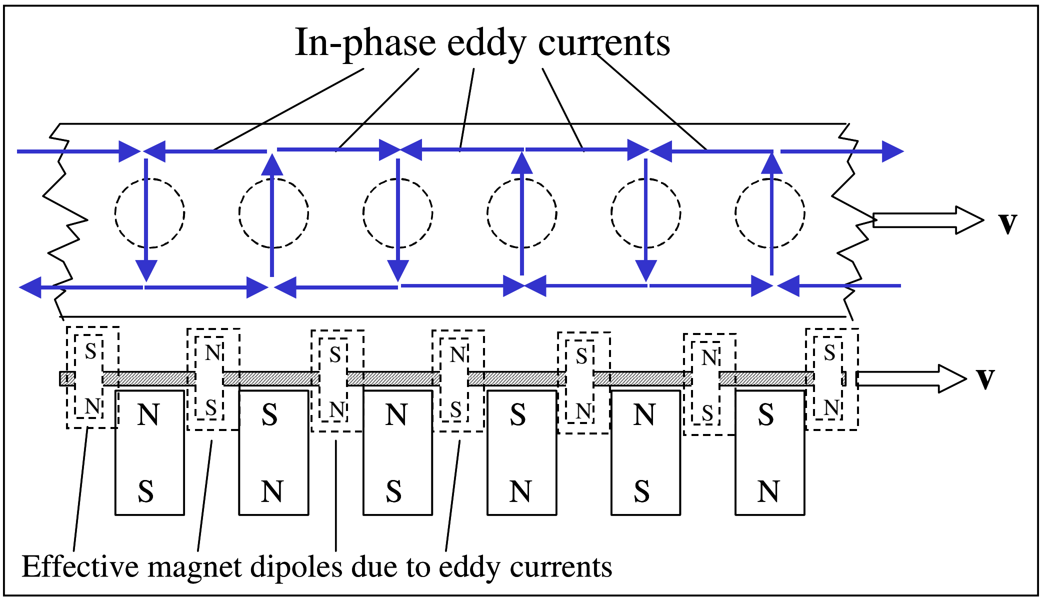

Figure 2. Eddy Currents and their effective magnetic dipoles.

Note that in the fixed reference frame of the magnets these eddy current loops appear fixed and constant, whereas in the moving reference frame of the strip they don't. Perhaps this is more clearly seen by considering an annulus of the strip material that contains one closed eddy current loop, see figure 3.

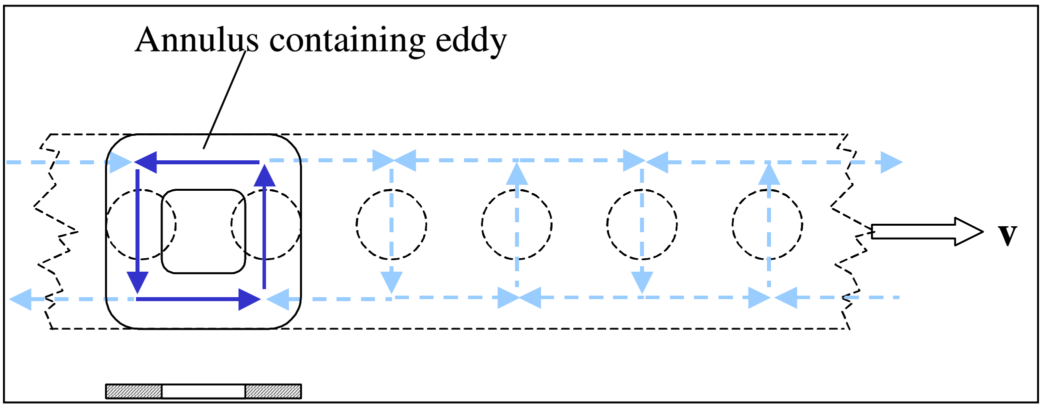

Figure 3. An eddy current annulus

If we examine this annulus a half cycle later we see that it has moved by one magnet separation distance and the eddy current has reversed direction, figure 4. Clearly within the strip the conditions are cyclic, and this leads to further considerations at greater speeds. It should be noted that the annulus is a single turn loop that has inductance determined by its dimensions, and also resistance due to the finite conductivity of the strip. Hence we have to consider the phase shift between the induced emf and the resulting current. To get a feel for this we can calculate the inductance of a typical and practical annulus of 50mm (2 inch) ID and 75mm (3 inch) OD of 5mm thick Cu. This is in the order of 4×10^{-8} H. The circular resistance is about 3×10^{-5} Ohms, yielding an L/R time constant of 1.33mS. Thus a cyclic frequency of just a few hundred Hz would introduce significant phase shift, and this is easily achievable in a rotating disc system using practical rotation speeds and a small number of magnets.

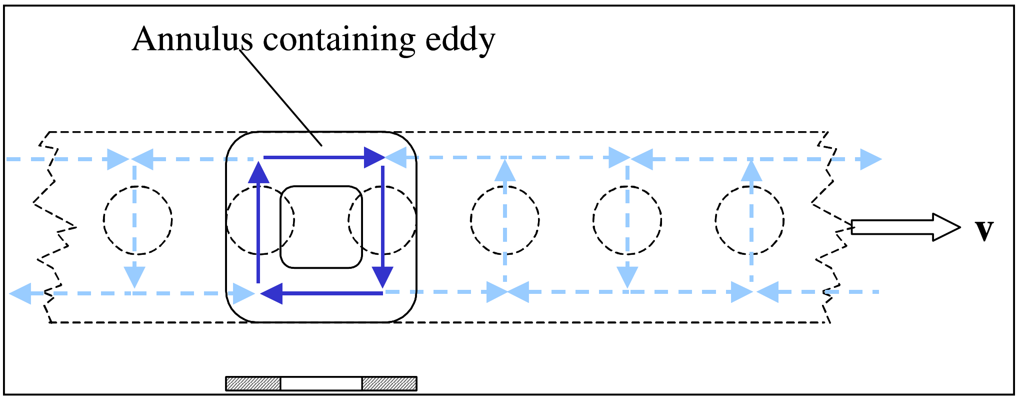

Figure 4. Annulus position after a half cycle.

At a cyclic frequency where the inductive impedance is much greater than the resistance the phase shift between induced emf and current will approach 90°. Under this condition the eddy current loops will be shifted to a new position a half cycle later than that shown in figure 2. This is seen in figure 5 which also shows the new positions of their effective magnetic dipoles.

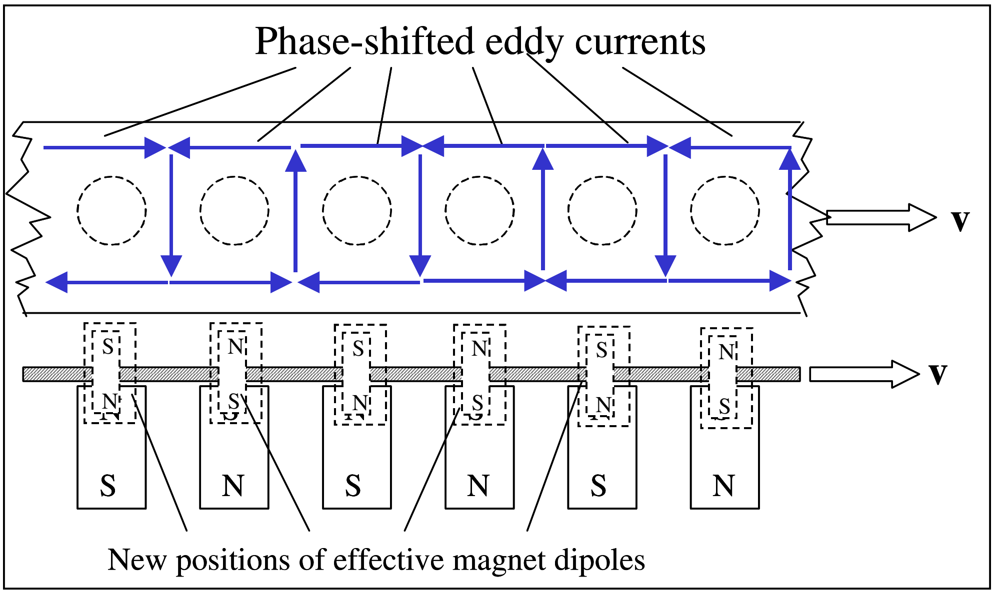

Figure 5. Phase shifted eddy currents

It is now seen that the eddy current dipoles are positioned directly above the permanent magnets and therefore do not endure any longitudinal force. The load on the mechanical drive has disappeared, yet there is still power dissipation within the strip. The next question is where does that anomalous power come from?

The eddy current loops occur at a phase when the emf drive is near zero, but because of the finite conductivity there must remain a small circular E field as a "voltage drop" around the loop. Put another way, within the strip there will be an E field obeying $\mathbf{E}=\mathbf{J}\sigma$ where $\mathbf{J}$ is the eddy current density and σ is the conductivity. If that circular E field exists within the strip, it must also exist outside the surface of the disc where it can couple to the permanent magnets. Note that although this closed E field is cyclic within the moving frame of the strip, and is in phase with the eddy currents, in the fixed reference frame of the permanent magnets it is static. Each permanent magnet endures a DC closed E field. Such a closed static E field is unrecognised in contemporary physics, but holds the key for extracting power from the atomic dipoles responsible for magnetism. Its presence is easily seen from the phasor diagram relating current and voltage in a LR circuit, figure 6. Note this relates to the cyclic parameters in the moving frame.

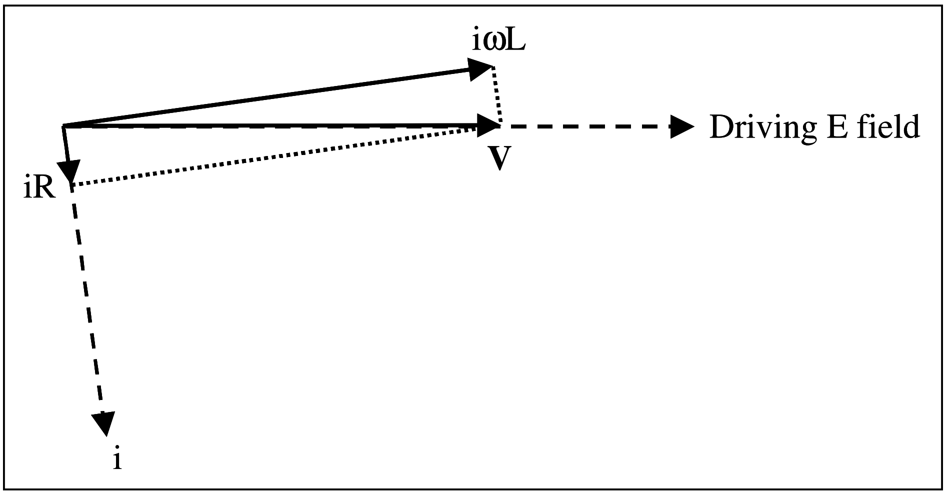

Figure 6. Phasor diagram

The driving **E=v×B** field supplies the voltage V and it is seen that the current and the iR voltage drop both lag by nearly 90°.

Extracting energy from atomic dipoles has been shown to occur within cyclic systems where that energy is clawed back in the next half cycle, the net energy gain over a full cycle being zero. There the closed E field around the magnet came from a changing (cyclic) magnetic field, and it was recognized that to gain net energy a static (DC) closed E field was required. It seems the eddy current disc can supply that condition. There the iR electric field is cyclic within the disc, but becomes static when seen from the fixed reference frame. It should be possible to use this rectification effect in other systems to achieve overunity.

One can get an idea on how a magnet can supply energy by considering an electron as a spinning sphere of negative charge. This is shown in figure 7 with a motor driving the spin. The presence of a circular closed static E field supplies force to the volume charge creating a retarding torque to the motor, hence the motor has to deliver mechanical power to the shaft, the retarding torque tries to slow down the spin. In the quantum world that can't happen, hence the quantum motor keeps the spin going and that quantum dynamo supplies the energy.

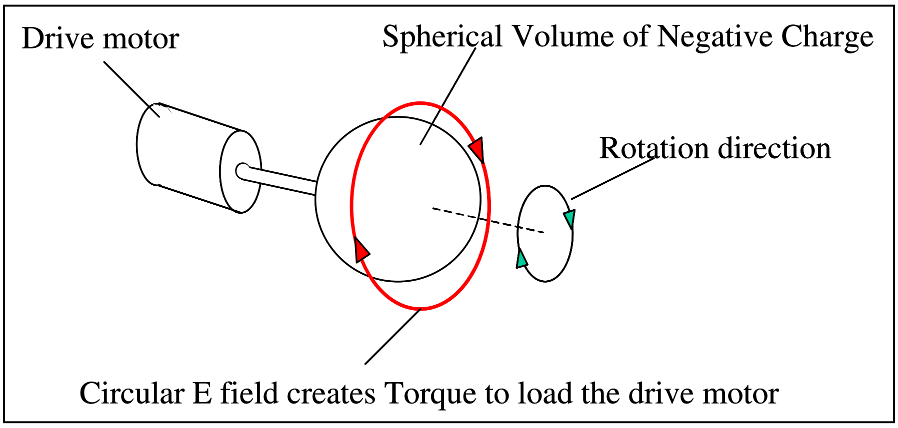

Figure 7. Spinning Charge Model of Electron