

# On a New Reaction-less Mechanism for Thrust Production and the Explanation of the Working of the EmDrive

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## Abstract

In this paper, we proposed a totally new mechanism for thrust production, to explain the working of the two reaction-less drives. Namely the EmDrive invented by Roger Shawyer, and the Cannae drive invented by Guido Fetta. The explanation based on a postulated potential or viable momentum deduced from the relativistic momentum energy relation. We assumed that by selectively adding energy to one object of a binary system made of two objects connected by a rigid mass-less rod, a viable momentum would be possessed by this object. We claimed that this will be the inverse of the momentum energy relation. We used the relativistic equivalence of mass and energy to show that the mass of the object where the energy is added will increase. This increase in mass will change the position of the center of mass of the binary system. We postulated that the claimed potential momentum will manifest as a true observable momentum in the direction of center of mass change. The added energy will be absorbed by the object's atoms and manifest as a kinetic energy. And according to the equivalence of all inertial frames of reference dictated by the special theory of relativity the system will be accelerating.

## 1 Introduction

Two inventors a British Roger Shawyer, and an American Guido Fetta independently invented two devices, the EmDrive and the Cannae drive. The two devices as claimed by the two inventors produced directional thrust. The drive powered by electricity to generate microwaves using a magnetron, all kept in a perfectly sealed container, apparently in a complete contradiction to a well established law of physics, namely the law of conservation of momentum. Or to put it another way, the two devices defy Newton's third law of motion, which states that, for every action there is an equivalent reaction in the opposite direction. The EmDrive apparently seems to generate thrust, no matter how small, without radiating anything in the opposite direction.

Two different theories have been proposed by the two inventors, and they insist on their peculiar designing of the two drives, and everyone of the two claimed that the produced thrust is due to the unique design of his invention. But now we will see that the design of the functioning drive rely mainly on three factors. First the distribution of the mass of the drive. And the second factor is a high quality dielectric resonator well placed at a proper location. And the third factor is an efficient continuous supply of energy in the form of microwave radiation to the dielectric resonator.

We considered the testing done by the NASA's Eagle-works team led by Harold White to the two drives and their announcement that they detected a thrust. We considered this announcement to be a confirmation of the production of a directional thrust. And now we add the Eagle-works team's peer reviewed paper by the American Institute of the Aeronautics and Astronautics (AIAA) [1]. Therefore an explanation is needed. The explanation depends on exploiting the mass energy relation discovered by the great physicist Albert Einstein, and the dependence of the kinetic energy of an object with a certain mass on the state of the total energy of that object. An object at rest according to special relativity possesses an energy  $E_o = mc^2$  where  $m$  is its mass and  $c$  is the speed of light. The energy  $E_o$  is known as the rest energy possessed by a mass  $m$  even when it is at rest. This kind of energy wouldn't be found in Newtonian mechanics. The rest energy hints at an internal structure of matter where the speed of light plays a major role. Special relativity when first proposed by Albert Einstein, micro-particles were not even thought of. But when Paul Dirac applied it for the electron it fits perfectly, which we take as an evidence that the theory of relativity has something to do with the true nature of matter internally. In fact Paul Dirac in his Nobel Prize lecture said: "It is found that an electron which seems to us to be moving slowly, must actually have a very high frequency oscillatory motion of small amplitude superposed on the regular motion which appears to us. As a result of this oscillatory motion, the velocity of the electron at any time equals the velocity of light." [2]. We can claim that the conclusions of Dirac about electrons must equally be true for protons and neutrons, though more difficult to prove, and generally we can say that all particles of matter have some peculiar internal motion with the speed of light. If this claim is correct, then an internal momentum could be assumed to exist for a particle, even when the particle is at rest externally. Now by increasing the total energy of the particle we increase the internal momentum, and as we can show in Section.2 this can be stated differently to introduce a new type of momentum, the potential momentum. The previous discussion about Dirac's speculation is only to show that, effects considered impossible using Newtonian mechanics, may absolutely be possible using the theory of relativity.

## 2 The potential momentum combined with the change of center of mass

Consider an observer at certain inertial frame of reference. If an object of mass  $m$  is at rest with respect to this observer, then its energy can be given as:

$$E_o = mc^2$$

This is the well known rest energy possessed by the object even when it is at rest externally. Now if we set the object in motion by any means, pushing or pulling it for example, then the object will move with a velocity  $v$ . Now the new energy of this object will be:

$$E = \frac{mc^2}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Now we may conclude that, an object in motion has a higher content of energy as judged by an observer still at rest. In this case the conservation of momentum can be verified with ease. But what will be the case if we add energy directly to this object's rest mass?!. For example by heating it or storing microwaves inside it or by any other means. We claim that a body with energy greater than its rest energy possesses a viable velocity that could manifest under suitable conditions as a true observable velocity.

Here we would like to introduce and define a new term using the relativistic momentum energy relation. The relativistic momentum energy relation is a well known equation which can be written in the following form:

$$p = \sqrt{\frac{E^2 - E_o^2}{c^2}} \quad (1)$$

Where  $p = \gamma mv$  is the momentum of the particular object,  $E_o$  is its rest energy,  $E = \gamma E_o$  is its total energy,  $c$  is the speed of light, and  $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ .

By contemplating Eq.1 we conclude that, if an object of mass  $m$  given a momentum  $p$  by pushing or pulling it, or by any other means, then its internal energy will increase and will be related to this momentum as in Eq.1. Now we claim that the inverse of this situation is also possible, and according to Eq.1 for an object which is at rest in a particular inertial frame, if we increase the internal energy of it by any means, there will be a viable momentum, or a potential momentum which could be manifested as a true observed momentum, under suitable conditions. For this case we can write:

$$E = E_o + \Delta E$$

Where  $\Delta E$  in this particular case, is the energy added to the rest energy of an object without moving it. We knew of various means by which to increase

the internal energy of an object of mass  $m$ , for example by heating it, or as in a capacitor by charging it, and as in the dielectric resonator by supplying it with sufficient electromagnetic waves.

Now there are two main cases in which an additional energy is added to a particular object of a certain mass. The first when the energy is added to a homogeneous object with a regular geometrical shape where its center of mass coincides with its geometrical center. The best example is the sphere. In this case the potential momentum wouldn't manifest, because the center of mass will remain at its same position and will not be affected. The second case is when we have two objects with masses  $m_1$  and  $m_2$ . These two objects are of regular shapes connected by a mass-less rod. Let  $m_1 = m_2$ , and the center of mass will lie exactly in the middle between  $m_1$  and  $m_2$ . Now if we add energy  $\Delta E$  selectively to the object with mass  $m_2$  alone, two things will happen simultaneously. First the object will possess a potential or viable momentum, that would manifest under suitable conditions. Secondly the mass of this object will change from  $m_2$  to  $m_2 + \Delta m$  using Einstein's mass energy relation, where  $\Delta m = \frac{\Delta E}{c^2}$ . This increase in mass will change the position of the center of mass of the system. The center of mass will move towards the object where the energy is added, as we will discuss in details in Sec.3.

### 3 The two postulates

#### 3.1 The first postulate (viable or potential momentum)

It is about the viable or potential momentum possessed by an object discussed in Sec.2, and can be stated as:

If an energy  $\Delta E$  stored by any means in an object of mass  $m$  which is at rest in a particular inertial frame of reference, as judged by an observer in this frame, then this object will acquire a directionless viable or potential momentum given by Eq.1 that could manifest as true observed momentum under suitable conditions. This stems from our claim that for a body of mass  $m$  to move with respect to an observer at a particular inertial frame of reference, its energy must be greater than its rest energy. And what we considered above is just the inverse of this case. And this will be my first postulate.

#### 3.2 The second postulate (center of mass change would allow the potential momentum to manifest)

Consider a system composed of two objects with masses  $m_1$  and  $m_2$ , connected by a rigid mass-less rod as in Fig.1. Now if we add energy selectively to one of the two objects say that with mass  $m_2$ , the mass in this case will increase from  $m_2$  to  $m_2 + \Delta m$ , where  $\Delta m = \frac{\Delta E}{c^2}$  deduced from the famous Einstein's mass energy relation. Accordingly the center of mass of the system will shift from its original location to a new one towards the object with mass  $m_2$  as in Fig.1.

Now we claim that, this change of center of mass, will give a direction to the postulated viable or potential momentum, and allow it to manifest as a true observable momentum, in the direction of change of center of mass. The energy  $\Delta E$  will manifest as a kinetic energy for the system. This is an effect which is equivalent to an external pull in the direction of the center of mass change. And this will be my second postulate,

## 4 The EmDrive or the Phantom's Pull Drive

Consider the figure below. A perfectly homogeneous disc of mass  $m_1$  attached to the left end of a rigid rod with a negligible mass from its exact center. Situated at point  $x_1$  along the  $x$  axis. At the right end also attached a perfectly homogeneous short cylinder of mass  $m_2$  composed of a number of dielectric resonator discs of high Q value with a suitable mechanism to supply microwaves efficiently to the dielectric discs. This cylinder is situated at point  $x_2$ . The short cylinder is made of aluminum to work as a resonant cavity with minimum mass. The system have to be designed such that the center of mass of it must lie on the axis of the cylindrical rod. Also the source of the electricity have to be kept exactly at the center of mass of the drive. Now the center of mass of this system can be given as:

$$y_1 = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2} \quad (2)$$

Now let the microwaves be supplied to the dielectric resonators. A certain amount of electromagnetic energy is stored in the form of standing waves. And these standing waves are confined to the dielectric. Now this energy in principle and according to the special theory of relativity's mass energy relation is equivalent to a mass  $\Delta m$  which will be added to  $m_2$  and one can write:

$$\Delta m = \frac{\Delta E}{c^2} \quad (3)$$

Where  $\Delta E$  is energy possessed by the photons of the microwaves confined to the dielectric resonators. Now the addition of this mass to  $m_2$  will change the center of mass of the system towards the right end. The new center of mass will be:

$$y_2 = \frac{m_1 x_1 + (m_2 + \Delta m) x_2}{m_1 + (m_2 + \Delta m)} \quad (4)$$

Note that in the figure the distance between  $y_1$  and  $y_2$  is exaggerated for the purpose of explanation. Actually this distance is extremely small. But no matter how small is the distance, the center of mass has shifted. And according to our postulate this would allow the viable or the potential momentum to manifest in the direction of the center of mass change. The situation is similar to an external pull applied in the direction of center of mass change. Because the energy of

the microwave photons stored in the dielectric resonator will be absorbed by it and converted to kinetic energy. And so one can write for  $v$ :

$$\Delta mc^2 = \frac{1}{2}m_tv^2 \quad (5)$$

Where  $m_t$  is the total mass of the system. In our case  $m_t = m_1 + m_2$  . Now solving equation (4) for  $\Delta m$  we can write :

$$\Delta m = \frac{1}{2} \frac{m_tv^2}{c^2} \quad (6)$$

And solving it for  $v$  we get :

$$v = c \times \sqrt{\frac{2\Delta m}{m_t}} \quad (7)$$

Equation (6) shows clearly that the velocity by which the system moves depends on the square root of  $\Delta m$  . Therefore to increase the efficiency of the system one have to increase this quantity. But the velocity is inversely proportional to  $\sqrt{m_t}$  which means that the lighter the drive the more the value of the velocity will be. Needless to say this system which we have discussed above is nothing but either the EmDrive or Cannae drive. But more simple and many times efficient. Because now we can concentrate on how to make it lighter. And how to increase the value of  $\Delta m$  . Because to make this drive more efficient we have to create a lighter dielectrics with higher Q values, and reduce the size of magnetrons, or find an alternate way for supplying microwaves. If we achieve these goals then a highly efficient small drives can be designed. And by integrating a large number of these light and small drives, a powerful drive can be constructed.

In a total agreement with the drive discussed above, both EmDrive and Cannae drive use a dielectric resonator. In both drives the observed thrust is towards the end near the dielectric. There is no need for the large resonant cavity of any shape in EmDrive. A relatively smaller resonant cavity should be restricted to the end of the drive where the dielectric resonator is attached. And we need just an efficient mechanism for supplying microwaves to the dielectric. And all the requirements for that have to be attached to the dielectric end. At the other end only we need to attache an object with ordinary mass  $m_1$  where  $m_1 \geq m_2$  . This is the condition for a greater value of  $\Delta y = y_2 - y_1$  . Where  $\Delta y$  is the distance traveled by the center of mass. The maximum value of  $\Delta y$  can be achieved when  $m_1 = m_2$  . On the other hand the Cannae drive could be made more efficient by placing the dielectric exactly at the end and not near the middle as in the actual drive. Also in the Cannae drive the distribution of mass is bad, therefore the mass at the other end is not sufficient to fulfill the above mentioned condition for  $\Delta y$  . In cases where a thrust was claimed even without inserting a dielectric, when using high power. This may be due to uneven absorption of microwaves by the cavity wall. Because absorption can also increase the total energy. In fact we need to perform experiments where a

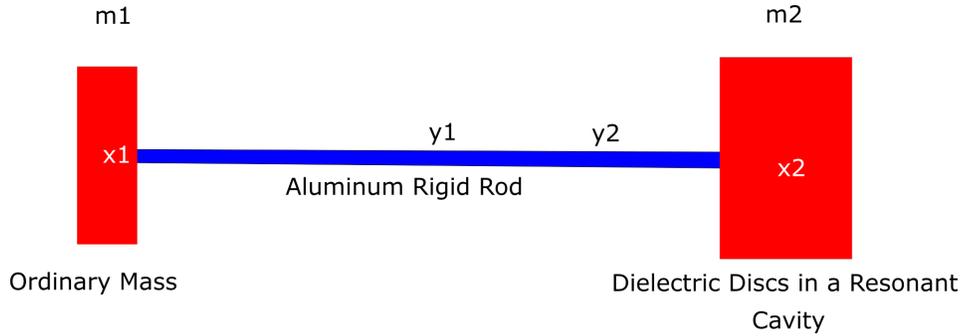


Figure 1: Showing the ideal design of an EmDrive for producing maximum thrust by concentrating on the basic principle behind its working.  $m_1$  is an ordinary mass connected by aluminum rod to the mass  $m_2$  composed of a suitable number of dielectric resonator discs inside a sealed aluminum resonant cavity.  $y_1$  is the center of mass of the system before the addition of the microwaves and  $y_2$  is the new center of mass after the addition of the microwaves photons.  $x_1$  and  $x_2$  are the coordinates of the centers of the two masses  $m_1$  and  $m_2$  respectively. Note that the figure is not drawn to scale, the distance  $\Delta y = y_2 - y_1$  is exaggerated for the explanation sake.

good microwave absorber is attached instead of the dielectric resonator. And we need experiments with more energetic photons like ordinary light or even ultraviolet radiation. The truncated shape if proved essential for the working of the drive, then may be this particular shape will direct and concentrate the microwaves towards the end where the dielectric is situated, therefore efficiently and swiftly loading the dielectric with microwaves.

This drive works on something that is missing in Newton's mechanics. Namely the energy possessed by any mass even when it is at rest. Also the difference in energy when the body is at rest and when it is moving. Then exploiting this we can create motion by directly increasing the total energy of one part of a system, as described above. Nothing like this is encountered in Newton's mechanics. Therefore this drive mustn't be expected to obey the conservation of external momentum in its strict form. Because in Newton's mechanics we deal only with differences between external quantities and interactions.

Now let us again return to the working of this drive. After supplying microwave photons to the dielectric resonator and the system moves as described. Let the magnetron be turned off. The system will be moving by inertia with a constant velocity. For an observer moving with the drive's inertial frame of reference the drive is at rest with no additional energy. Because the energy of the microwave photons has been absorbed and consumed by the dielectric and converted to kinetic energy as judged by an observer at rest at the first frame. For an observer in the second frame moving with the drive the system now is at rest according to equivalence of inertial frames dictated by special relativity. By adding microwave photons to the dielectric the process will be repeated in the

third frame of reference, and so forth for higher inertial frames. The process will be repeated again and again, from one inertial frame of reference to another. And always an observer moving with the drive will claim to be at rest with the drive for a short period of time, and the dielectric is ready to take energy again. For an observer at rest in the first frame the drive is accelerating continuously. This is also true for an observer traveling by the drive, the drive is accelerating continuously. In fact this acceleration can only be limited by special relativity's rule for an object with rest mass, where the speed of light is the limit. This is a new and a profound way of obtaining a reaction-less thrust, based on relativity mechanics.

As mentioned by the two inventors and by NASA scientists the applications of this drive can only be limited by our imagination. From highly efficient spacecrafts to a vertical take off and landing of planes, to flying cars. And even highly efficient motors and dynamos. No limit to this extraordinary drive. Only we have to be more imaginative.

## 5 Perpetual Motion Machine, or Unlimited Clean Energy ?!

With all the denial of the two inventors of the extraordinary drives. That their drives couldn't act as a perpetual motion machines. In fact yes a drive constructed as discussed above is nothing but a perpetual motion machine of the first kind. because as it is well known that any device with a thrust to power ratio greater than the photon rocket will operate as a perpetual motion machine of the first kind. And for the EmDrive this was proved by the NASA's Eagleworks scientists to be the case. By conducting direct experiments on the drive. They found a thrust more than thousand times greater than that of the photon rocket. In fact this number can be increased after knowing the mechanism by which it works. Now as history informs us. When a good experiment contradicts a theory, accept the result and check the theory. This may not prove the theory is wrong. But may point to the limitations of the theory, or may be we ignored something.

Now this fact can be exploited to generate limitless energy. Imagine a dynamo constructed such that two drives of equal power, connected to a rigid disc attached to a rigid axle where a magnet is attached. Surrounding the magnet is a fixed coil made of copper arranged as usual to generate electricity once the magnet start rotating. By activating the two drives the magnet start rotating and electricity will be produced. But the two drives velocity will increase steadily. And at some point the electricity produced will exceed the input. Now we can feed the drives from the electricity produced by the dynamo. But the drive continue to accelerate and at some point we need to do something to decelerate this motion.

Yes the dynamo discussed above will apparently contradict the first law of thermodynamics. But works in perfect agreement with special theory of

relativity. And again we need to say that the first law of thermodynamics has been derived on the basics of Newton's mechanics. But this drive works on the basics of special theory of relativity. Special relativity can be replaced by Newton's mechanics at low velocities as compared to light velocity. This works finely when we consider only the external interactions and we neglect the internal properties of matter. We can't reduce to nothing the rest energy which is absent in Newton's mechanics, we can't reduce it as a low velocity approximation. The rest energy is there even when the body is at rest. Newton's mechanics deals with external interactions between objects, and energy differences between different states. While special relativity hints at internal properties of matter of which we knew still a little, and perhaps one day we would be able to conserve the first law of thermodynamics even in this case, provided we knew the exact physical meaning of the rest energy, or the total energy.

## 6 The Serrano Field Effect Thruster

The SFE Thruster, or Serrano Field Effect Thruster works by applying an electric field to a dielectric with a high dielectric constant. In fact this is equivalent to add a certain potential energy to the dielectric. But adding potential energy is same as adding a mass equivalent to this energy according Einstein's mass energy relation. Now to improve the working of this drive, we have to construct it in the same way explained in Fig.1. The dielectrics must be in place of  $m_2$  attached to a second ordinary mass  $m_1$  through a rigid light rod, where  $m_1 = m_2$ . Therefore using the same logic used for explaining the working of the EmDrive, we assume that the potential energy increases the mass of the dielectric. This increase in mass changes the center of mass of the system, at the same time the potential energy would change to a kinetic energy to restore the drive to the original position of the center of mass, in a new inertial frame of reference. The system now will move in the same way as that explained in Fig.1 and will be accelerating.

## 7 Conclusion

So as discussed above we are on a verge of an extraordinary breakthrough for producing unlimited clean and cheap energy. Therefore sufficient funding for further research must be given to physicists and engineers working to improve this new kind of a reaction-less thrust producing drive. Also large companies like Boeing, Lockheed, and others, must participate to accelerate the improvement of this drive. Because this is a drive that can revolutionize our concept about transportation. And makes the fiction a reality. Perhaps this application of the special relativity will prove to be the most important of all the applications of the theory. As far as clean, cheap and efficient energy production is concerned.

Finally this is a suggestion for building an efficient version of the EmDrive. If the total mass of the current EmDrive is 7kg. Then we can build a drive where

$m_1 = 4 \text{ kg}$  , and about 2kg made of a suitable number of dielectric resonators discs and only 1kg or less for the aluminum cavity resonator to encase the dielectric resonators end only with the magnetron. This way we will allow the resonating photons in the cavity to increase the value of  $\Delta m$  . The two ends have to be connected by an aluminum rod to minimize the weight. The maximum number of dielectric resonators discs for maximum thrust have to be found experimentally, so if NASA's Eagle-works scientists are interested, they may try to construct and test this version.

## References

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