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The Hummingbird System: A Theoretical Propulsion Mechanical Device

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ABSTRACT

A propulsion mechanical device is a type of system that is claimed to produce net external thrust by using just the motion of internal components. Despite recent efforts to develop such a device, only a scientifically sound proposal would be an option to develop practical systems in the future. This review presents a theoretical propulsion mechanical device, called the Hummingbird System, which is summarized in several concepts to describe its performance. These concepts include the Basic Model to explain the generation of thrust, the Continuous Model to allow a constant generation of thrust, the Basic Unit to compensate the torque and direct the thrust, and a proposal to cluster several Basic Units to displace an object in space. Some potential applications of the Hummingbird System are also discussed, suggesting its use in naval, artificial satellite, and spacecraft propulsion systems. The ultimate aim of this review is to encourage the design and development of novel propulsion devices that are based on the Hummingbird System. The theoretical concepts that are described in this review remain to be confirmed in practice.

KEYWORDS: *aerospace, naval, propulsion, satellite, spacecraft*

NOMENCLATURE

A	Time between peaks of ΣFY
Fc	Centrifugal force
Fk	Tension on the rod of length L
FR	Resulting force or net thrust
FX	Force generated by the model on the horizontal plane
FY	Force generated by the model on the vertical plane
ΣFY	Total force generated by the model on the vertical plane
g	Gravitational acceleration
L	Length of the rod
n	Number of pairs of rods of length L
m	Mass
M	Mass of the model
Q	Bearing
r	Radius
v	Tangential velocity
W	Weight of the model
w	Weight of the mass m
α	Angle relative to the vertical plane
β	Angle relative to the reference level
τ	Torque

1.0 INTRODUCTION

A propulsion mechanical device is defined as a type of system that is claimed to generate net external thrust by using only the motion of internal components [1]. There have been many attempts to develop feasible propulsion mechanical devices; however, such a system remains unavailable. Millis and Thomas [2] reviewed several propulsion mechanical device proposals in the framework of the NASA Breakthrough Propulsion Physics Project, classifying them into two main categories: thrusters and gyroscopic devices and concluding that their ostensible creation of net thrust was attributable to misinterpretations of normal mechanical effects. In their opinion, the oscillation thrusters were misinterpretations of differential friction, whereas the gyroscopic devices misinterpreted torques as linear thrust. Thus, only a scientifically sound proposal is an option for developing practical propulsion mechanical devices in the future.

The aim of this review is to present a theoretical proposal for a propulsion mechanical device, named the Hummingbird System, the purpose of which is to serve as the basis for the design and development of feasible propulsion devices. The main concepts of the Hummingbird System that are described here include the Basic Model to explain the generation of thrust, the Continuous Model to allow a constant generation of thrust, the Basic Unit to compensate the torque and direct the thrust, and a proposal to group several Basic Units to move an object in space. Some potential applications of the Hummingbird System are also discussed. The explanation of the performance and potential applications of the Hummingbird System follows standard laws of physics [3]. This paper focuses on the main force components that act during the operation of the system.

2.0 BASIC MODEL

The generation of thrust in the Hummingbird System centers on the Basic Model (**Figure 1**), a theoretical model in which the centrifugal force that is applied to symmetrically distributed pairs of masses generates a total force on the vertical plane, called *ΣFY*. The Basic Model consists of a motor with the capacity to regulate the number of revolutions, an axle that is attached to said motor, and a rod that measures *QQ'*, attached to the other end of the axle. At points *Q* and *Q'*, there are bearings that are attached to two rods that measure *L* and *L' (L=L')*, respectively. At the ends of these rods, there are two masses *m* and *m' (m=m')*, respectively. **Figure 1** shows that each rod of length *L* and *L'* can move 90º from position *a* to position *b*.

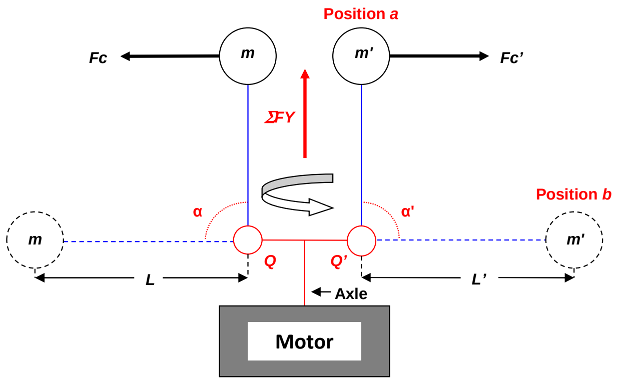

Figure 1: The Basic Model of the Hummingbird System. *ΣFY*= total force generated by the model on the vertical plane. *Fc* and *Fc'*= centrifugal forces. *L* and *L'*= length of the rods. *m* and *m'*= masses. *Q* and *Q'*= bearings. α and α'= angle relative to the vertical plane.

The Basic Model has three phases of operation. In *Phase I*, the motor accelerates to rotate the axle until it reaches a constant revolution period and constant angular velocity. Angular velocity causes the centrifugal forces *Fc* and *Fc'* to act on the masses *m* and *m'*, respectively. In this phase, the rods, which measure *L* and *L'*, and their corresponding masses *m* and *m'*, are in position *a*. Let us suppose that there are some safety mechanisms that do not allow the rods to move when they are in position *a* during the first phase. In *Phase II*, the safety devices are unblocked, allowing forces *Fc* and *Fc'* to act on the masses *m* and *m'*, which simultaneously move rods of length *L* and *L'* from position *a* to position *b*. Finally, in *Phase III*, the Basic Model reaches equilibrium again when the rods of length *L* and *L'*, and their corresponding masses *m* and *m'*, are in position *b*.

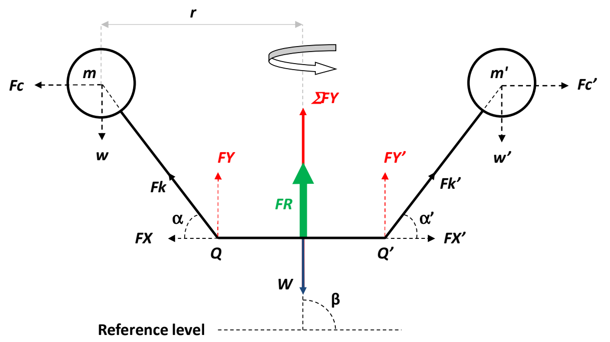

Figure 2: Forces acting on the Basic Model during *Phase II*. *Fc* and *Fc'*= centrifugal forces. *Fk* and *Fk'*= tensions on the rods of length *L* and *L'*. *FX* and *FX'*= forces generated by the model on the horizontal plane. *FY* and *FY'*= forces generated by the model on the vertical plane. *ΣFY*= total force generated by the model on the vertical plane. *M*= total mass of the Basic Model. *m* and *m'*= masses. *Q* and *Q'*= bearings. *r*= radius. *W*= weight of the Basic Model. *w* and *w'*=weight of masses *m* and *m'*. α= angle relative to the vertical plane. β= angle relative to the reference level.

During *Phase II*, the centrifugal forces that act on the masses *m* and *m'* increase the tension on the rods of length *L* and *L'*, respectively. The tension on each rod has a horizontal and vertical component. In the Basic Model, the horizontal components cancel each other, because they are opposing, whereas the vertical components, which act in the same direction, are combined. The combination of these vertical components that is generated by the model is called *ΣFY*. **Figure 2** shows the distribution of forces on the horizontal and vertical planes when the Basic Model is in *Phase II*. Given that the model is symmetrical, the analysis of **Equations 1** to **5** is restricted to bearing *Q*, rod of length *L*, and mass *m*.

During *Phase II*, the main forces that act upon the mass *m*, are the centrifugal force and its own weight. The following equation represents the centrifugal force:

$$Fc = \frac{mv^2}{r} \quad \textbf{(1)}$$

where *Fc* is the centrifugal force, *m* is the mass, *v* is the tangential velocity, and *r* is the radius. Note that the radius varies, depending on the angle α that rod of length *L* forms with rod *QQ'*.

The weight of the mass *m* is defined as:

$$w = m\ g\ sin\beta \quad \textbf{(2)}$$

where w is the weight of *m*, *m* is the mass, *g* is the gravitational acceleration, and β is the angle relative to the reference level.

During *Phase II*, the tension on the rod of length *L* depends on the centrifugal force and the weight of *m*—*i.e.*:

$$Fk = Fc\ cos\alpha - w\ sin\alpha \quad \textbf{(3)}$$

where *Fk* is the tension on the rod of length *L*, *Fc* is the centrifugal force, w is the weight of *m*, and α is the angle that is created by the rod of length *L* with the rod *QQ'*.

During *Phase II*, the tension on the rod is broken down into its horizontal and vertical components. Their values are:

$$FX = Fk\ cos\alpha \tag{4}$$

and

$$FY = Fk\ sin\alpha \tag{5}$$

where *FX* and *FY* are the horizontal and vertical components of force in bearing *Q*, respectively, *Fk* represents the tension on the rod of length *L*, and α is the angle that is created by the rod of length *L* with the rod *QQ'*.

In the Basic Model, the values of *FX* and *FX'* are equal and therefore cancel each other out. Thus, on the horizontal plane, the forces of the model are balanced.

Components *FY* and *FY'* have the same direction, which causes the total force that is generated by the model on the vertical plane to be equivalent to the sum of the values. A Hummingbird System can have as many pairs of rods of length *L* that operate in *Phase II* as necessary. To calculate the total force, it is considered that:

$$\Sigma FY = n\ (FY + FY') \tag{6}$$

where *ΣFY* is the total force that is generated by the model on the vertical plane, *n* is the number of pairs of rods of length *L* and *L'* in the model, and *FY* and *FY'* are the vertical components of the tensions on the rods of length *L* and *L'* during *Phase II*, respectively.

Assuming that the model is perpendicular to a reference level in an environment with a substantial gravitational acceleration (*e.g.*, Earth's surface), the forces that act on the vertical plane constitute the total force that is generated by the model *ΣFY* and its own weight.

The weight of the Basic Model is defined as:

$$W = M\ g\ sin\beta \tag{7}$$

where *W* is the weight of the model, *M* is the mass of the model, *g* is the gravitational acceleration, and β is the inclination of the model with regard to the reference level.

Thus, the resulting force or net thrust that the Basic Model has in an environment with gravitational acceleration is:

$$FR = \Sigma FY - W \tag{8}$$

where *FR* is the resulting force or net thrust on the vertical plane, *ΣFY* is the total force that is generated by the model on the vertical plane, and *W* is the weight of the model

In **Equations 2** and **7**, the inclination of the model with regard to the reference level β will influence the resulting force *FR*. Thus, if β is greater than 0º and less than 180º, the weight will have a negative effect on the resulting force *FR*. If β is 0º or 180º, the weight does not have any effect on the resulting force *FR*, and only *ΣFY* acts as the net thrust. Finally, if β is greater than 180º and less than 360º, the weight contributes to increasing the resulting force *FR*, with 270º being the optimal inclination for this to occur.

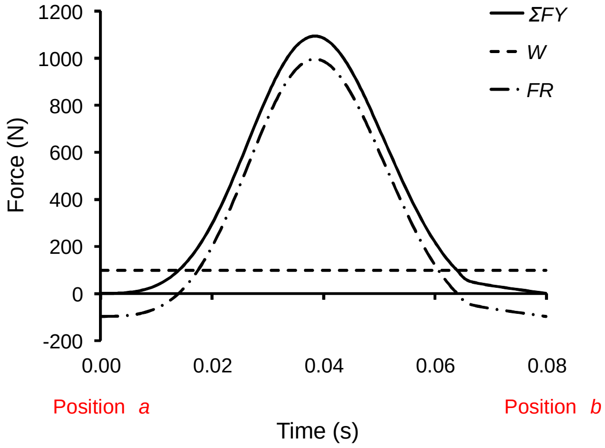

Figure 3: Example of the forces acting on the vertical plane over time during *Phase II* in an environment with gravity, when the inclination of the model is perpendicular to the reference level (β=90º). *ΣFY*= total force generated by the Basic Model on the vertical plane. *FR*= resulting force or net thrust. *W*= weight of the Basic Model. Based on the conditions of Appendix A.

The main force components that act on the Basic Model during *Phase II* are depicted in **Figure 3**. This example is based on the conditions of Appendix A. In this representation, the total forces on the vertical plane *ΣFY* are greater than the weight *W* of the Basic Model, allowing a net thrust *FR* to be generated during a single *Phase II* operation. Thus, at least theoretically, it is possible to develop a model that produces a net thrust to displace the system on the vertical plane.

3.0 CONTINUOUS MODEL

The constant generation of thrust in the Hummingbird System is based on the Continuous Model. As explained, the Basic Model is able to generate a force *ΣFY* on the vertical plane in a single *Phase II* operation. However, for an object to be displaced with constant force and acceleration, it is necessary to repeat *Phase II* in continuous cycles of operation.

In the Basic Model, the system is balanced once position *b* has been reached; thus, to repeat *Phase II*, the rods must be placed in position *a* again. To achieve this, the Continuous Model is proposed, in which the rods of length *L* and *L'* return to position *a* to complete a circle around the axis of the bearings *Q* and *Q'*, respectively. **Figure 4** shows an example of bearing *Q'* in a Continuous Model. In this example, the bearing is attached to 14 rods of length *L* (L_1' to L_{14}') with their respective masses (m_1' to m_{14}'), where the displacement of each rod by means of bearing *Q'* is independent. In **Figure 4**, the rod with mass m_1' is at rest in position *a* before the safety device is opened and *Phase II* is started; the rod with mass m_2' is in *Phase II*, in which the vertical force component FY_2' of the tension on the rod of length L_2' is generated; and the rod with mass m_3' is in position *b*. To complement this concept, **Figure 5** shows a Continuous Model with a pair of bearings. **Figure 5** only displays the rods that are in

Phase II; it is assumed that the other rods are in the grey area, moving from position *b* to position *a* to restart the cycle.

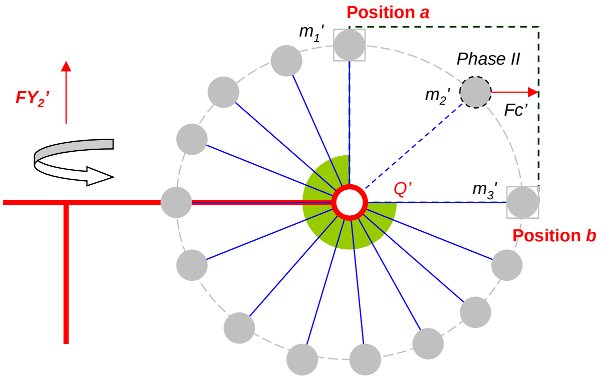

Figure 4: Example of bearing *Q'* with 14 rods in a Continuous Model. m_1', m_2', and m_3'= masses. *Fc'*= centrifugal force. FY_2'= vertical component of the tension on the rod of length L_2' and mass m_2'.

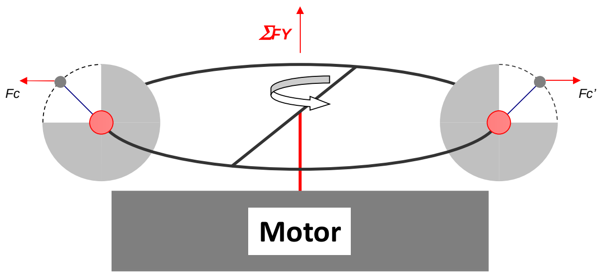

Figure 5: The Continuous Model of the Hummingbird System. *Fc* and *Fc'*= centrifugal forces. *ΣFY*= total force generated by the Continuous Model on the vertical plane.

The Continuous Model, then, allows consecutive *Phase II* cycles to be undertaken. The continuity is essential, because it is enabled to be a sequence of constant impulses, which could create uniform acceleration in the Hummingbird System during its performance. The example of **Figure 6** is based on the conditions of Appendix A. In **Figure 6**, *A* represents the time between the peaks of forces that are generated by the model on the vertical plane *ΣFY* that occur in three continuous cycles of *Phase II* operation. Let us suppose that the Hummingbird System is being used to displace an object in space. If *A* is very long, then the object would give brusque impulses at intervals that are the same as *A*. In contrast, if *A* is minimal, the displacement of the object would be more uniform and *A* could be so small as to be unnoticed, and the impulses would become imperceptible. As a consequence, forces on the vertical plane would become relatively constant, and thus, the acceleration of the object would also be constant.

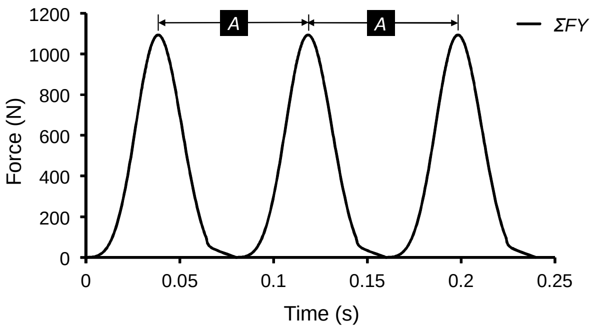

Figure 6: Example of the total force generated by the Continuous Model on the vertical plane *ΣFY* over time during three consecutive cycles of *Phase II*. *A*= time between *ΣFY* cycles. Based on the conditions of Appendix A.

It is important to note that the Hummingbird System allows the number of impulses to be reduced or increased, given that the release of the rods of length *L* and *L'* from position *a* can be controlled. Moreover, it is also possible to vary the magnitudes of force and acceleration by adjusting the number of motor revolutions. The models that are presented in this work are theoretical. To develop a practical propulsion mechanical device, depending on the requirements, we must establish the power of the motor, the optimal distance between *Q* and *Q'*, the number of pairs of bearings, and the optimal length of the rods *L* and *L'* and their masses *m* and *m'*, respectively—these are merely the most relevant factors that should be considered in the design.

4.0 BASIC UNIT

The compensation of the torque and direction of the thrust in the Hummingbird System is based on the Basic Unit. In accordance with Newton's law of action and reaction [3], torque must be counteracted or controlled before the Hummingbird System can be displaced in space. To this end, an opposite and equal force must be applied on the horizontal plane of the Continuous Model to counteract the effect of the motor and the action of the rods of length *L* and *L'* their respective masses *m* and *m'* during *Phase II*. Although many options could be proposed to counter the torque on the Continuous Model, the easiest alternative would be to attach another Continuous Model that operates at the same pace but spins in the opposite direction:

$$\tau_1 = \tau_2 \qquad \textbf{(9)}$$

where τ_1 and τ_2 are equal magnitudes of the torque of two Continuous Models that spin in opposite directions.

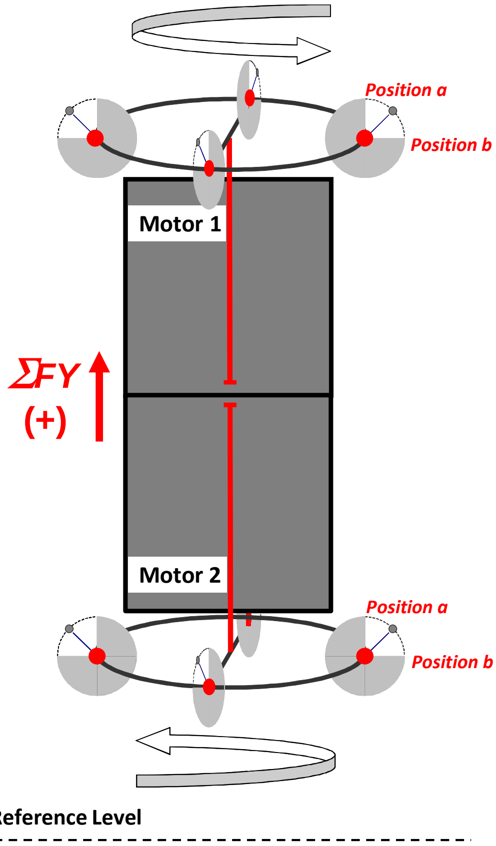

Figure 7: Example of a Basic Unit consisting of two Continuous Models spinning in opposite directions to counteract their torques. Each Continuous Model has two pairs of bearings in *Phase II*. The direction of the total forces generated by both Continuous Models on the vertical plane *ΣFY* is opposing the reference level (+).

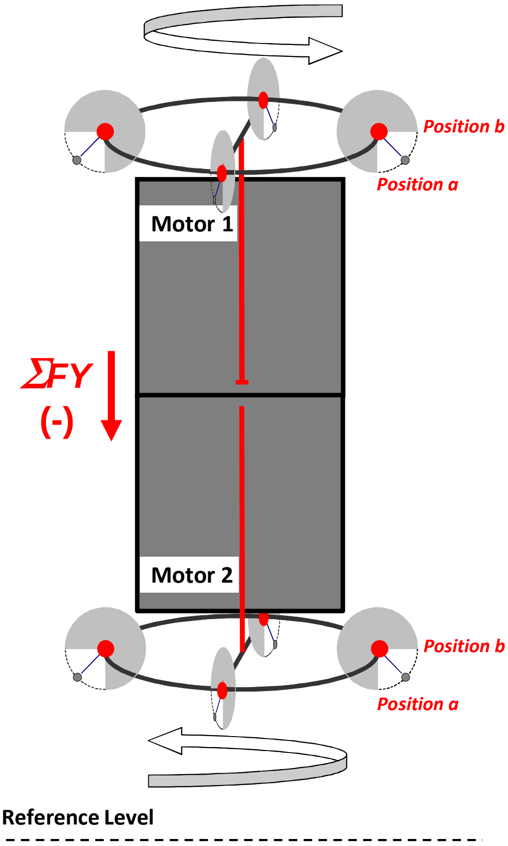

Figure 8: Example of a Basic Unit consisting of two Continuous Models spinning in opposite directions to counteract their torques. Each Continuous Model has two pairs of bearings in *Phase II*. The direction of the total forces generated by both Continuous Models on the vertical plane *ΣFY* points toward the reference level (-).

To illustrate this concept, **Figures 7** and **8** present examples of Basic Units. Each figure represents a Basic Unit, comprising two attached Continuous Models that spin in opposite directions to compensate their torques. Each Continuous Model has two pairs of bearings with four masses in the *Phase II* operation. The release positions of rods of length *L* and *L'* in both Basic Units allow a sum of forces on the vertical plane *ΣFY* that act in the same direction to be generated.

According to the release position of the rods of length *L* and *L'*, two alternatives are possible on the vertical plane with respect to a reference level. In **Figure 7**, the total force that is generated by the two Continuous Models on the vertical plane *ΣFY* opposes the reference level. This case is called positive (+). In **Figure 8**, the total force that is generated by the two Continuous Models on the vertical plane *ΣFY* points toward the reference level. This case is called negative (-).

Therefore, the Basic Unit allows the torque of Continuous Models to be counteracted and the sum of their forces on the vertical plane *ΣFY* to be directed with respect to a reference level.

5.0 DISTRIBUTION OF BASIC UNITS

The intensity and direction of the net thrust must be controlled for the Hummingbird System to displace an object. This is feasible through the distribution of Basic Units in a cluster that enables the sum of forces *ΣFY* to be applied in the desired direction. Many distributions of Basic Units can be proposed, depending on the type of object and the direction in which it is intended to move. For instance, if the Hummingbird System is intended to move a vessel on the surface of the water, then a cluster of Basic Units with forces that act in two-dimensional directions would be sufficient, but if it is intended to move an object in space, then a distribution that allows the forces to act in three-dimensional directions is necessary. **Figure 9** is an example of a distribution of Basic Units to move an object in space. In this example, 10 Basic Units, composed of 20 Continuous Models with a pair of bearings each, are grouped in a circular order to permit displacement of the object in all three-dimensional directions. This example assumes that the net thrust in any direction in space is higher than the weight of the object in the gravitational environment in which it operates.

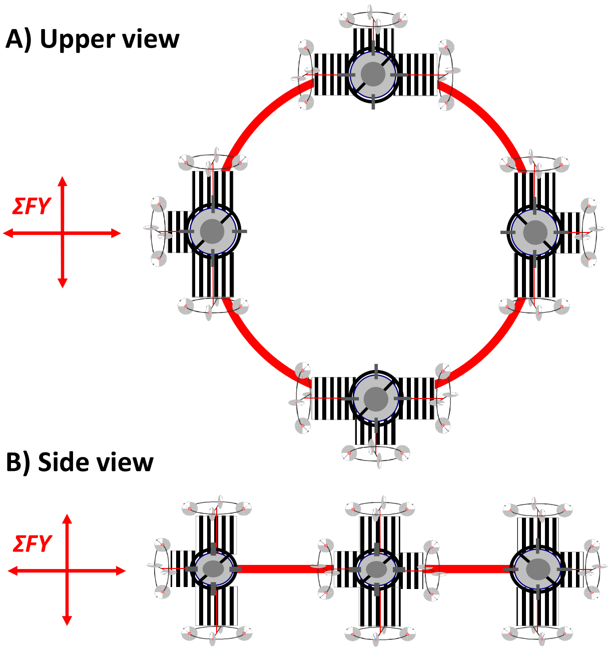

Figure 9: Upper (**A**) and side (**B**) views of a cluster of Basic Units consisting of 20 Continuous Models. Each Continuous Model has two pairs of bearings in *Phase II*. This cluster of Basic Units allows the sum of forces *ΣFY* to be applied in all three-dimensional directions.

6.0 APPLICATIONS

Several applications of the Hummingbird System can be proposed, assuming that the power that is required by the system to operate is provided.

The Hummingbird System produces net external thrust by using just the motion of its internal components. This characteristic, although unique, can create some disadvantages compared with the efficiency of other propulsion systems that benefit the environment in which they operate. For instance, one expects the Hummingbird System to be less efficient than the traction of a tire on a land transport or the propulsion of a propeller on a plane or a vessel. However, certain applications can be envisioned in such environments. An example is its use to displace submarines that are required to operate in silent running or stealth mode. In submarines, the propeller's cavitation is a major source of noise [4]. Here, the Hummingbird System could help develop silent propulsion systems that lie inside of the vessel without interaction with the seawater.

The Hummingbird System has more advantages as a propulsion device for moving objects in outer space, where the ability to interact with the environment is negligible. Perhaps the immediate opportunity for its use would be as a propulsion device for artificial satellites, which require reliable and long-lasting propulsion systems for positioning and orbit control. Today, satellite propulsion systems are based on propellants, which limit the life of service when the reserve is exhausted [5]. Provided that a source of energy can be obtained, such as from solar panels, the Hummingbird System could operate as long as other components in a satellite, eliminating the lack of propulsion as the chief reason for its end of life. In addition, given the increased importance of active post-mission disposal of space structures [6], the Hummingbird System can also help in deorbiting satellites to keep Earth's orbit in an acceptable condition for the safe operation of future manned and unmanned missions.

In a more challenging approach, the Hummingbird System can be used as a propulsion device to displace a manned spacecraft. It is possible to foresee a combination of the Hummingbird System with other existing propulsion devices. For instance, one could use jet propulsion for a spacecraft to escape the gravitational pull of Earth, while the Hummingbird System could provide steady momentum once the craft is in outer space. However, the optimal case would be the development of an autonomous spacecraft in terms of power supply and production of net thrust, based on the Hummingbird System, to rise from the surface of Earth. Instantly, this achievement would have important implications. For example, the spacecraft could operate at least above Earth's gravity. Thus, such a spacecraft can leave Earth and land on any other celestial body with a mass equal to or less than Earth, such as the Moon or Mars, and return to Earth. That the Hummingbird System can provide a net thrust that exceeds Earth's gravity for a given period also means that the time to travel to other celestial bodies in the vicinity of the Solar System could be shortened substantially. In addition, it could reduce negative factors with regard to the health of the crew that are associated with space travel. For example, the lack of acceleration due to gravity induces a loss in muscle volume and lower bone mineral content [7], among other effects.

As an example, let us take travel to Mars. The average time between successive oppositions of Mars is approximately 2.13 years [8]. During the synodic period, the distance at close approach varies between roughly 54 and 103 million km. For practical reasons, let us consider an opposition between Earth and Mars of 80 million km. Assuming that an autonomous spacecraft covers half of the distance with acceleration near Earth's gravity (*e.g.*, 10 m/s^2), changes directions 180º at the halfway point, and then deaccelerates the remaining half of the distance at the same rate (*e.g.*, -10 m/s^2), the total distance between the two planets can be covered in less than three days (Appendix B provides the conditions of the example). Thus, assuming a power supply that allows the Hummingbird System to operate in a spacecraft during this period, this would represent a substantial reduction in travel time to Mars using current jet propulsion systems [9]. In addition to the advantage of decreasing travel time, the possibility of traveling to acceleration near Earth's gravity can benefit the crew by allowing them to forgo major differences in environmental conditions.

7.0 CONCLUSIONS

The Hummingbird System is an option for developing feasible propulsion mechanical devices. The Hummingbird System also has several potential applications in naval, artificial satellite, and spacecraft propulsion systems. The theoretical concepts that are presented in this review are intended to promote the design and development of practical propulsion mechanical devices that are based on the Hummingbird System.

APPENDICES

Appendix A

Conditions of the example:

- Masses *m* and *m'*: 0.1 kg
- Length of the rods *L* and *L'*: 0.1 m
- The model has only one pair of bearings (*Q* and *Q'*).
- The length of the rod *QQ'* and the length of the axle from the motor to said rod are not taken into account.
- Axle revolutions: 60 r.p.s.
- Mass of the model (*M*): 10 kg
- Inclination of the model (β): 90º
- Gravity (*g*): 9.8 m/s^2

Appendix B

Conditions of the example:

- Opposition of Mars: 80 million km
- Average acceleration of the spacecraft: 10 m/s^2
- Earth's surface gravity: 9.8 m/s^2
- Earth's mean radius: 6371 km
- Mars's surface gravity: 3.7 m/s^2
- Mars's mean radius: 3389 km

CONFLICTS OF INTERESTS

The author has no conflicts of interest to declare. The Hummingbird System is not patented, allowing the research and development of practical propulsion mechanical devices that are based on this concept.

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