

# The Plasma Compression Fusion Device—Enabling Nuclear Fusion Ignition

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**Abstract**—The plasma compression fusion device (PCFD) generates the energy gain by plasma compression-induced nuclear fusion. This concept has the capability of maximizing the product of plasma pressure and energy confinement time to maximize the energy gain, and thus give rise to fusion ignition conditions. The preferred embodiment of this original concept uses a hollow cross-duct configuration of circular cross section in which the concentrated magnetic energy flux from two pairs of opposing curved-headed counter-spinning conical structures (possibly made from an alloy of tungsten with high capacitance) whose outer surfaces are electrically charged compresses a gaseous mixture of fusion fuel into a plasma, heated to extreme temperatures and pressures. The generated high-intensity electromagnetic (EM) radiation heats the plasma and the produced magnetic fields confine it in between the counter-spinning conical structures, named the dynamic fusors (four of them—smoothly curved apex sections opposing each other in pairs). The dynamic fusors can be assemblies of electrified grids and toroidal magnetic coils, arranged within a conical structure whose outer surface is electrically charged. The cross-duct inner surface surrounding the plasma core region is also electrically charged and vibrated in an accelerated mode to minimize the flux of plasma particles (including neutrals) from impacting the PCFD surfaces and initiating a plasma quench. The fusion fuel (preferably deuterium gas) is introduced into the plasma core through the counter-spinning conical structures, namely, injected through orifices in the dynamic fusor heads. There is envisioned another even more compact version of this concept, which uses accelerated vibration in a linear-duct configuration (using two counter-spinning dynamic fusors only) and would best be suited for fusion power generation on aircraft, or main battle tanks. The concept uses controlled motion of electrically charged matter through accelerated vibration and/or accelerated spin subjected to smooth, yet rapid acceleration transients, to generate extremely high-energy/high-intensity EM radiation (fields of high-energy photons) which not only confines the plasma but also greatly compresses it so as to produce a high power density plasma burn, leading to ignition. The PCFD concept can produce power in the gigawatt to terawatt range (and higher) with input power in the kilowatt to megawatt range and can possibly lead to ignition (self-sustained) plasma burn. Several important practical engineering and operational issues with operating a device such as the PCFD are discussed.

**Index Terms**—Acceleration control, frequency control, fusion power generation, fusion reactors, magnetic confinement,

magnetic fields, oscillators, piezoelectric devices, plasma confinement, plasma control.

## I. INTRODUCTION

**T**HERMONUCLEAR fusion involves the forcing together (unification) of light nuclei to form a heavier nucleus, which due to the mass defect occurs with generation of energy, as expressed in the ubiquitous ( $E = mc^2$ ) expression. Fusion occurs at extremely high temperatures, exceeding the core temperature of the Sun, which is approximately 10 million degrees Celsius. For example, the deuterium–tritium fusion reaction occurs at temperatures in excess of 175 million degrees Celsius and that of deuterium–deuterium (D-D) at approximately 232 million degrees Celsius.

At these extremely high temperatures and pressures, a gas will ionize and form a plasma (the fourth state of matter) that is an ensemble of an enormous number of electrons and positive ions ( $\geq 10^{20}/\text{m}^3$ ), which constantly interact with each other, exchanging energy. The three primary methods of confining plasma to make the ions fuse are gravitational confinement, inertial confinement, and magnetic confinement. To have fusion from gravitational confinement, stellar-sized masses are required; thus, we are left with inertial and magnetic confinement, as well as possible hybrids of the two. Inertial confinement fusion is produced with laser-driven implosions or with electric fields (electrostatic), whereas magnetic confinement fusion is generated with extremely high magnetic induction in configurations such as tokamaks, magnetic mirrors, magnetic cusps, pinches, and magnetized targets [1].

All these methods of plasma confinement have grave issues, ranging from extremely large size (commensurate to that of an aircraft carrier) and plasma instabilities for tokamaks, to power losses and short confinement times for magnetic mirror/cusp machines. None of these confinement methods to date has been able to achieve break-even fusion reactions (in a steady-state operational mode), namely, the condition for the fusion power output to equal the power input, let alone achieve the ignition condition whereby a fusion plasma burn is self-sustained, without the need for external power input. For a fusion reaction to occur, in the case of the deuterium–tritium reaction, we need to abide by the Lawson criterion, namely,

$$nT\tau_E \geq 3 \times 10^{21} \text{ KeV} \cdot /\text{m}^3 \quad (1)$$

where  $n$  is the plasma density,  $T$  is the plasma temperature, and  $\tau_E$  is the energy confinement time. This expression drives the point that the higher the product of plasma pressure with plasma energy confinement time, the higher the energy gain of the fusion reaction. The equal sign in (1) represents the

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break-even condition, in other words, an energy gain of one, which is the condition under which the fusion power output equals the reactor power input.

For the D-D reaction, which is the reaction of choice for the present concept, the triple product,  $nT\tau_E \geq 10^{23}$  KeV·s/m<sup>3</sup>, since the temperatures required for fusion in the D-D reaction are far higher than those required for fusion in the deuterium–tritium reaction.

An important fact for magnetic confinement-induced fusion is that if the strength of the magnetic field is doubled (i.e., double the magnetic induction  $B$  in units of tesla), the linear size of the reactor is reduced by half, given other fusion parameters are held constant. Hence, being able to generate high magnetic induction (magnetic flux density) is extremely important in developing a compact fusion device [1].

There are two expressions that convey the importance of having high magnetic field induction, when it comes to plasma magnetic confinement for fusion, namely,

$$\text{Energy Gain} \sim B^3 \quad (2)$$

and

$$\text{Fusion Power Density} \sim P^2 \sim B^4 \quad (3)$$

where  $P$  is the plasma pressure and  $B$  is the magnetic induction or magnetic flux density, given the condition that the ratio of plasma pressure and magnetic field pressure is on the order of unity.

At present, there are few envisioned fusion reactors/devices that come in a small, compact package (ranging from 0.3 to 2 m in diameter) and use different versions of plasma magnetic confinement. Three such devices are the Lockheed Martin (LM) Skunk Works compact fusion reactor (CFR), the EMC<sup>2</sup> Polywell fusion concept, and the Princeton field-reversed configuration (PFRC) machine [2]–[4].

The LM-CFR uses a magnetic mirror configuration in which the toroidal magnetic coils featuring variable current generate magnetic field oscillations which heat a confined plasma. The Polywell device uses a hybrid plasma confinement and heating scheme using both inertial electrostatic confinement and magnetic confinement within a polyhedral biconic mirror cusp geometry.

The PFRC uses a unique radio frequency (RF) heating scheme to induce rotating magnetic fields to confine plasma. These devices feature short plasma confinement times, possible plasma instabilities with scaling of size, and their ability of achieving the break-even fusion condition, let alone a self-sustained plasma burn leading to ignition remains doubtful.

The key to fusion seems to rest with the achievement of extremely high magnetic fields, possibly exceeding 30 T, which are not even high-temperature REBCO-type superconducting magnets, which can be readily generated at present. However, it is herein argued that extremely high  $B$ -fields can be generated by controlled motion of electrically charged matter, through accelerated spin and/or accelerated vibration, subjected to rapid (yet smooth) acceleration transients.

## II. ENABLEMENT OF CONCEPT

As depicted in Fig. 1., the preferred embodiment of this original concept [plasma compression fusion device (PCFD)]

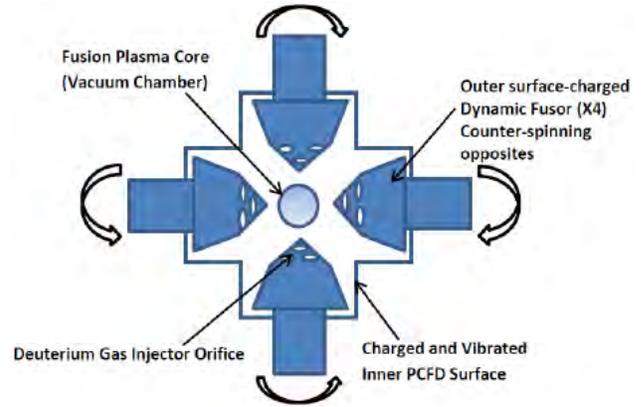


Fig. 1. PCFD cross-duct configuration (side view).

uses a hollow cross-duct configuration of circular cross section in which the concentrated magnetic energy flux from two pairs of opposing curved-headed counter-spinning conical structures (possibly made from an alloy of tungsten with high capacitance) whose outer surfaces are electrically charged compresses a gaseous mixture of fusion fuel into a plasma, heated to extreme temperatures and pressures.

The PCFD uses controlled motion of electrically charged matter through accelerated vibration and/or accelerated spin subjected to smooth, yet rapid acceleration–deceleration–acceleration transients, to generate extremely high-energy/high-intensity electromagnetic (EM) fields which not only confine the plasma but also greatly compress it (by inducing a high-energy negative potential well) so as to produce a high power density plasma burn, leading to ignition.

The generated high-intensity EM radiation heats the plasma and the produced magnetic fields confine it in between the counter-spinning conical structures, named the dynamic fusors (four of them—smoothly curved apex sections opposing each other in pairs). It is important that the cross-duct inner surface surrounding the plasma core region is electrically charged and vibrated to prevent the plasma particles from impacting the walls and initiating a plasma quench. Vibration can be achieved by passing an electrical current through piezoelectric films such as lead zirconate titanate (PZT) imbedded in the PCFD duct inner walls. The PCFD device is housed in a Faraday cage for reasons of personnel safety.

A 10–15-cm-thick boron carbide (or tungsten alloy) shielding which acts as the Faraday cage can also incorporate the cooling channels for the thermal conversion cycle, as well as provide the needed structural support and integrity to withstand the fusion-induced neutron bombardment.

Plasma instabilities would be minimized and possibly suppressed by the shearing flows generated by the counter-spinning dynamic fusors. The flow shearing would tear apart the vortical eddies responsible for the onset of turbulence within the plasma, which is regarded as the main source of plasma instabilities in a fusion reaction [7]–[9]. Fig. 2 shows an even more compact version of the concept, which uses vibration in a linear-duct configuration, featuring two

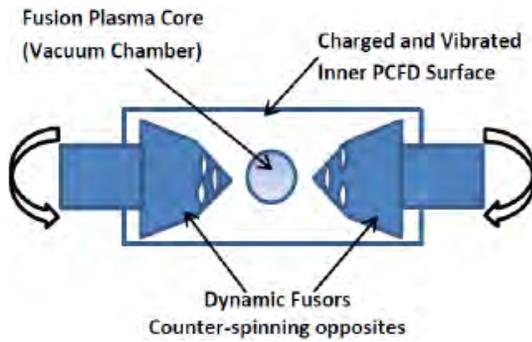


Fig. 2. PCFD linear-duct configuration (side view).

counter-spinning dynamic fusors only, and would best be suited for fusion power generation on aircraft, or main battle tanks.

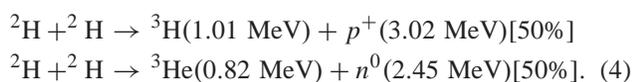
For both configurations, the fusion power output is extracted through conformal heat exchangers (not shown) which are flush with the PCFD outer walls and carry the neutron-produced heat to a thermoelectric generator through a cooling fluid, such as water or poly-alpha olefin (PAO).

The fusion fuel (preferably deuterium gas) is introduced into the plasma core through the counter-spinning conical structures, namely, injected through orifices in the dynamic fusor heads. Deuterium (heavy hydrogen) can be abundantly extracted from sea-water, hence the “virtually limitless” fuel source idea that makes this concept extremely beneficial.

The neutronic gaseous fusion fuel can be deuterium–tritium, D-D, or possibly a deuterium–xenon mixture. This later reaction can produce Xenon-129 with the release of two fast (highly energetic) neutrons which would greatly amplify the power output; however, PCFD wall degradation and enhanced radioactivity effects need to be considered from both an operational and a safety perspective.

Aneutronic fuel can be proton–boron11 (for fusion at more than  $10\times$  the fusion temperature of the neutronic fuel). In this case, there will be no neutrons released, hence no radioactivity dangers arise. For this hydrogen–boron fuel, there is a one in one thousand chance of a Gamma-ray channel being formed, which in case of full operational status of the device would demand great caution. Direct energy conversion is used in extracting fusion power from the PCFD, because the products of this aneutronic fuel are three alpha particles (three helium-4 particles), and hence a direct conversion of these charged particles through a hi-tech transformer is made viable. The main issue with the use of aneutronic fuel is that it demands a fusion temperature of 2 billion degrees Celsius (and higher), an almost  $10\times$  increase over neutronic fuel, such as the preferred deuterium gas.

The PCFD will use deuterium ( $^2\text{H}$ ) gas as the fusion fuel of choice, yielding the reactions



Thus, it is feasible to use both direct (electrical) and indirect (thermal) energy conversion using deuterium gas, which is highly desirable from an operational viewpoint.

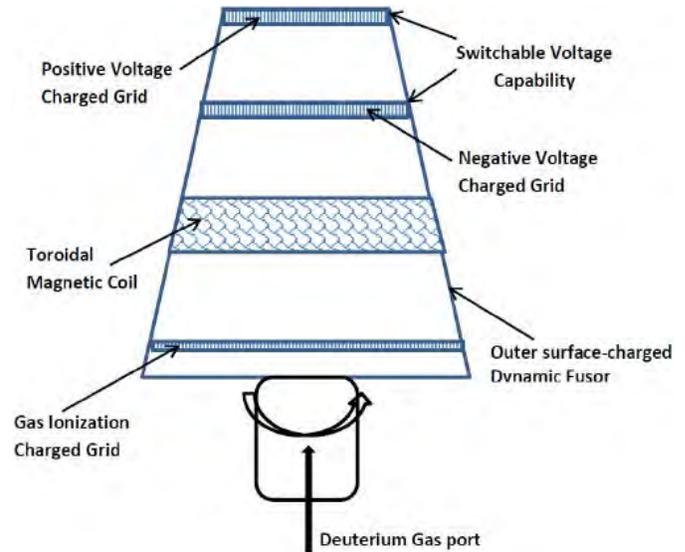


Fig. 3. Alternative dynamic fusor (cross-sectional side view).

As shown in Fig. 3, the dynamic fusors can be assemblies of electrified grids and toroidal magnetic coils, arranged within a conical structure whose outer surface is electrically charged. The electrical grids are used to ionize the deuterium gas (or other fusion fuel in gaseous form) and are kept at different oppositely charged voltages so as to electrostatically accelerate either electrons or ions into the fusion plasma core, depending on the desired physical effect, in a manner similar to ion thrusters. The direction of the dynamic fusor spin is such that the generated magnetic flux always points toward the plasma core.

The dynamic fusors can act as particle accelerators for electrons that are closely bound to the magnetic field lines of the inner toroidal coil, as well as to the magnetic field lines of the conical structure, once they exit the dynamic fusor. These electrons are electrostatically accelerated through a set of two grids exhibiting a potential difference into the plasma core, forming a deep (high-energy) negative potential well. This negative potential well greatly accelerates the positively charged ions toward it, and as the ions keep recirculating around the well, they undergo fusion. A high-temperature, high-pressure plasma core results from the impingement of gas dynamic vortical plumes, which exhibit high viscous heating, as well as the intense collisions of electrons and positively charged ions which make up these plumes. To heat the plasma at the extreme temperatures that fusion requires, the electrically charged dynamic fusors (outer surfaces only) generate high EM radiation by virtue of their accelerating spin. The inner surfaces of the dynamic fusors are well-insulated against electrical charge migration, possibly with silicon carbide (or boron nitride, boron carbide) liners. An alloy of tungsten with high capacitance, to hold an electric charge of a least 1 C, is the material of choice for the dynamic fusors, which can also be dome-like in geometry. The dynamic fusor is mounted on a hollow shaft (deuterium gas conduit) which is coupled to a variable power dc induction motor and can be accelerated–decelerated–accelerated in spin, through a digital controller. The PCFD must be vacuum-pumped for fusion power to be

effectively produced. An ultrahigh vacuum on the order of  $10^{-5}$  torr is desirable, yet a lower quality vacuum may be used, given operational constraints on the device.

### III. HIGH-ENERGY ELECTROMAGNETIC FLUX GENERATION

As discussed in two recent articles by the inventor [5], [6], for conditions of accelerated vibration or accelerated spin of an electrically charged object/system, we can write for the maximum EM energy flux (time rate of change in EM energy transfer per unit surface area)

$$S_{\max} = f_G(\sigma^2/\epsilon_0)[(R_v\nu^2)t_{\text{op}}] \quad (5)$$

where  $f_G$  is the charged system geometric shape factor (equal to 1 for a disk configuration),  $\sigma$  is the surface charge density,  $\epsilon_0$  is the electrical permittivity of free space,  $R_v$  is the vibration (harmonic oscillation) amplitude,  $\nu$  is the angular frequency of vibration in hertz, and, similarly in the case of axial spin,  $R_v$  is the effective system radius, while  $\nu$  represents the angular frequency of spin, and  $t_{\text{op}}$  is the operational time for which the electrically charged system is operated at maximum acceleration ( $R_v\nu^2$ ). This closed-form formulation is the result of the synthesis of classical EM field theory with the physics of simple harmonic motion.

Furthermore, for the case of rapid time rates of change in accelerated vibration/spin (rapid acceleration transients) of the charged system, given that the time differential of acceleration is nonzero, we obtain

$$S_{\max} = f_G(\sigma^2/\epsilon_0)[(R_v\nu^3)t_{\text{op}}^2]. \quad (6)$$

This formulation shows that even with moderate vibrational/spin frequencies in a rapidly accelerating mode, the EM energy flux is greatly amplified (cubic frequency profile). Moreover, this shows the extensive capabilities of a high-energy/high-frequency EM field generator, when used to heat plasma within the confines of the PCFD.

If we consider adding to the equation representing simple harmonic motion an “energy/momentum-pumping” (negative damping) term ( $bv$ ), endemic of system acceleration, where  $b$  is a constant and  $v$  is ( $dx/dt$ ), namely, the speed of a vibrating mass ( $m$ ), it can be shown that the maximum of the total energy ( $E_T$ ) of the vibrating system can be written as

$$E_T \approx mR_v^2\Omega^2[\exp(2\Omega t)] \quad (7)$$

where  $\Omega$  is the angular frequency of vibration, under the condition  $[(b/2m) \gg \Omega_0$  (natural frequency of vibration)]. Because the EM energy flux is directly proportional to  $E_T$ , we observe that there will be an exponential growth in energy flux with accelerating vibration, especially under the condition of rapid acceleration transients.

Considering a classical Newtonian second law expression using the Lorentz (EM) force, we can relate the vibrating mass ( $m$ ) with its vibrating charge ( $Q$ ), in that  $m$  becomes directly proportional to the square of the ratio ( $Q/\Omega$ ). Coupling this relation with (7) yields

$$S_{\max} \approx (Q^2/\epsilon_0)(R_v^2/R_s^5)\Omega[\exp(2\Omega t)]. \quad (8)$$

This equation represents the maximum EM flux that can be achieved by accelerated vibration under the aforementioned condition and applies to a spherical geometry (radius  $R_s$ ) for a vibrating mass ( $m$ ) of corresponding charge ( $Q$ ). Note that the vibration in the electrically charged PCFD device inner walls must be monitored so that it does not greatly exceed the natural vibration frequency of its component materials, because this can generate an exponential growth in the EM flux and may have deleterious effects on the plasma core, as well as on the structural integrity and operational safety of the device.

Moreover, due to the conical geometry of the counter-spinning dynamic fusors, the plasma fluid will assume the shape of vortex structures. Considering the free force vortex expression of ( $\text{curl } v = A_v v$ ), where  $v$  is the plasma fluid velocity and  $A_v$  is a constant, which under certain conditions can be far greater than 1, we can write ( $B$  is directly proportional to  $v$ )

$$B/R_v \sim \text{curl} B = A_v B \quad (9)$$

where  $R_v$  is the effective vortex radius, so that as  $R_v$  goes to zero,  $A_v$  becomes a  $B$ -field amplification factor which mathematically can go to infinity. Physically, this expresses the great amplification of the magnetic induction  $B$ -fields of the vortical plasma structures in the PCFD plasma core.

### IV. POSSIBLE OPERATIONAL ISSUES WITH THE PCFD DESIGN

There are several important practical engineering and operating issues with operating a device such as the PCFD.

First, the deuterium–tritium triple product given in (1) will be much higher, by at least two orders of magnitude, for the D–D reaction envisioned as the PCFD fusion reaction of choice. This is due to the fact that the plasma physics presented herein is oversimplistic, with little if any consideration of plasma transport or instabilities which degrade the achievable triple product.

Further (future) theoretical research would have to be performed to give consideration to the impact of the extremely high neutron flux anticipated in the D–D reaction (even though this will peak at lower energy than for deuterium–tritium) and even proton–boron fusion is not without neutron issues due to the byproducts and  $B$  isotope production.

For the D–D reaction, which is the reaction of choice for our present concept, the triple product,  $nT\tau_E \geq 10^{23}$  KeV s/m<sup>3</sup>, because the temperatures required for fusion in the D–D reaction are far higher than those required for fusion in the deuterium–tritium reaction [10]. As far as the plasma instabilities (magnetohydrodynamic, interchange, kink, etc.) within the PCFD device are concerned, it is possible that such instabilities would be minimized and possibly suppressed by the shearing flows generated by the counter-spinning dynamic fusors. The induced flow shearing would tear apart the vortical eddies responsible for the onset of turbulence within the plasma, which is regarded as the main source of plasma instabilities in a fusion reaction [7]–[9]. It is important to note that this observation would have to be experimentally verified in an actual working PCFD device, because plasma

instabilities represent phenomena of immense complexity, for which theoretical expectations are insufficient with regard to conclusive concept validation. Plasma heating would also play an important role in the verification process, because this drives plasma density and temperature gradients.

Moreover, the PCFD geometrical configuration can give rise to high beta-factors, namely, the ratio of the plasma pressure to the magnetic pressure can be high, possibly on the order of unity. As discussed in [7], high beta can diminish the possibility of the onset of plasma instabilities and in this manner control their existence. The PCFD device can optimally control gradients in plasma densities and temperatures, thereby controlling and minimizing plasma instabilities. This theoretical argument must, however, be tested experimentally, because plasma instabilities are highly complex entities, whose optimal control proves to be a highly controversial subject.

Another possible issue with the PCFD is the extremely high  $B$ -fields anticipated in operating it. Even though such high-intensity EM fields have been shown to be theoretically feasible [5], [6], experimental verification is necessary for proof of concept.

If indeed the controlled motion of electrically charged matter (from solid to plasma) under accelerated spin and/or accelerated vibration and subjected to rapid acceleration transients can produce the theoretically anticipated high-energy EM fields necessary for optimal PCFD operation, then another major problem can arise, namely, possible structural failure of the device due to the strength of material limits imposed by the generated  $B$ -fields.

This is a problem of utmost importance for safety and survivability of the device and its practical operation and must be addressed at the highest levels, if the PCFD fusion-generating abilities are to be realized. However, the ability of the PCFD device to produce extremely high magnetic fields can shape the plasma core in a configuration conducive to a high possibility of self-sustained plasma burn fusion [11].

Furthermore, the PCFD device is operated in a transient, far-from-equilibrium mode, which in the case of the D-D reaction can give rise to fast neutrons and fast protons, a fact which would optimally control fusion energy production [12]. The impact of the high-speed neutrons with the walls of the enclosure which houses the dynamic fusors can be mitigated by the high EM radiation generated by the accelerated vibration of the electrified inner PCFD surfaces (enclosure), because fields of photons carry both energy and momentum. This is not to say that particle flux (including neutrals) will not impact the PCFD surfaces; however, such interactions can be minimized, as explained at the end of this section.

It is quite possible that to maintain the extremely high temperatures (in excess of 232 million degree Celsius) for the D-D fusion to occur, RF heating will be of great necessity to be incorporated within the PCFD design. At the present time, only EM heating of the plasma is provided by the dynamic fusors and the vibrating electrified inner surfaces of the PCFD cross-ducts; however, RF heating may be necessary for establishing and maintaining a burning plasma core.

Once a burning plasma state has been achieved, the PCFD transient operation may become steady-state by the cou-

pling of additional RF heating with additional fuel injection into the plasma core. The optimal RF heating method for utilization would be electron cyclotron resonance heating (ECRH), which uses RF waves of  $>100$ -GHz frequencies for plasma heating. RF waves of this frequency can be produced by gyrotrons (novel unconventional technology) and couple optimally with the plasma from an absorption (of heat) perspective. It may be possible to use 5-GHz radio waves, produced by a klystron; however, these waves may not be able to penetrate the plasma edge and thus offer optimal heating.

One aspect of the PCFD reactor design that is critical for future investigation is the large particle and heat flux to the reactor wall, especially because the smaller the system is made, the higher this impact will be. Moreover, the neutron loading, even for a gigawatt and terawatt system (such as the proposed PCFD reactor), will be extremely large on the reactor walls, something that tokamaks and stellarators often have to contend with.

Due to the highly complex state that is represented by a burning plasma, the PCFD reactor would need a highly sophisticated feedback control system, to sustain this fickle state of matter. Therefore, because experiment trumps theory every time, a phased approach based on careful experimental studies needs to be considered in making the PCFD design a viable reality for producing cost-effective fusion power, especially at ignition conditions.

The generation of very high  $B$ -fields on the order of 1000 T and above is amply discussed in [5] and [6]; these high magnetic induction values can be obtained by the accelerated spin and/or accelerated vibration of electrically charged matter subjected to rapid, yet smooth acceleration–deceleration–acceleration transients. Indeed, in case this charged matter is a plasma, it can be readily observed that the  $v^2$  term in (5) is directly proportional to the plasma oscillation frequency and thus directly proportional to the plasma density. Therefore, high  $B$ -field values can be obtained by increasing both the angular frequency of spin/vibration of the dynamic fusors and the plasma density. The only limiting factor in the case of the PCFD design and fabrication is that the structural integrity of the fusion device can be compromised by  $B$ -fields exceeding 1000 T.

Of notable importance is also the fact that for optimal operation of the PCFD system, we use the accelerated spin of the dynamic fusors in conjunction with the accelerated vibration of the PCFD electrically charged inner duct surface (see Figs. 1 and 2). This greatly limits the loss cones of particle flux out of the plasma core, because such PCFD operation would produce high-intensity EM radiation, namely, intense fields of high-energy photons oriented into the core which would greatly minimize particle contact with the PCFD surfaces, including high-energy neutral particles (photons are uncharged). The only time that particle contact with the PCFD surfaces may occur is during the deceleration mode of the acceleration–deceleration–acceleration transient; however, such adverse effects can be counteracted with enhanced reactor shielding, as well as other safety precautions herein not discussed.

To properly understand the plasma physics of the PCFD device (hence, properly judge its fusion ignition capabilities), it is necessary to consider future studies involving the Monte Carlo simulations of many-particle nonlinear dynamics which is a necessary effort to be undertaken for PCFD validation and verification in conjunction with experimental work. Such studies would also result in preliminary  $B$ -field mappings of the fusion plasma core and guide future experimental research to be undertaken. No such unclassified data exist at this point in time for the PCFD effort.

## V. CONCLUSION—FEASIBILITY OF PCFD CONCEPT

Using physics explained in two recently published peer-reviewed articles by Pias [5], [6], we can write the maximum of magnetic field induction ( $B$ ) for one of the dynamic fusors as a function of the angular frequency of spin of the dynamic fusor ( $\omega$ ) as

$$B_{\text{MAX}} \approx \mu_0 \sigma R_\omega \omega^3 t_{\text{op}}^2 \quad (10)$$

where  $\mu_0$  is the magnetic permeability of free space (on the order of)  $O(10^{-6})$ ,  $\sigma$  is the surface charge density of the dynamic fusor,  $R_\omega$  is the effective spin radius of the dynamic fusor, and  $t_{\text{op}}$  is the operational time at maximum acceleration of spin.

For the condition of  $\mu_0 \sigma R_\omega t_{\text{op}}^2 \sim O(1)$ , that is order of unity, we obtain  $B_{\text{MAX}} \sim \omega^3$ , in other words, the maximum magnetic flux density scales with the cube of the angular spin frequency of the dynamic fusor.

Because laboratory experiments (performed by the author's team—unpublished work) have taken disk-shaped objects of (less than) 10 cm in diameter and spun them at 10000 rad/s (100000 rpm), with no apparent failure resulting from centrifugal loading, we can safely conclude that given the hardness of tungsten from which the dynamic fusor is manufactured, it is possible to have values of  $\omega$  on the order of  $10^4$  rad/s. This means that a value for  $B_{\text{MAX}}$  on the order of  $10^6$  T (and much higher) is achievable by accelerated spin of the surface-charged dynamic fusor, with a time differential of acceleration not equal to zero (smooth, yet rapid spin acceleration—no abrupt/jerking motion required).

Taking into consideration (2), the energy gain of the fusion reaction is on the order of  $10^{18}$ , meaning that the possibility of fusion ignition, that is, self-sustained plasma burn, is highly feasible, under the aforementioned conditions. As a result of this simple analysis, it is important to note that the present concept can produce power in the gigawatt to terawatt range (and higher) with the input power in the kilowatt to megawatt range and possibly lead to ignition plasma burn, that is, self-sustained plasma burn without need for external input power.

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