

Centrifugal Z-pinch

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Abstract - The author considers the reasons which cause the necessity of changing configuration of a discharge camera of plasma focus installation. The new construction with non-cylindrical Z-pinch installations is offered. The author forwards a proposal about the cardinal change of formation and gas discharge process in the offered working camera, expected growth of thermonuclear efficiency coefficient and reducing the neutron scaling saturation in mega-joule installations.

Key words: non-cylindrical Z-pinch, plasma focus, inverse pinch, shear, S-pinch, theta-pinch, inertial-magnetic fusion, plasma vortex, retention time, thermonuclear efficiency coefficient.

1. Introduction

Research units plasma focus is a challenge, due to the high - thermonuclear parameters working temperature and density of the plasma reaches a relatively simple and compact technical means. Classic setup with plasma focus are executed in two variants - with Filippov configuration of electrodes or meyerovskoy. Note that the creator of the plasma focus option NV Filippov together with NG Makeev and TI Philippi created a plasma source of penetrating radiation that combines dignity meyerovskoy configuration - long heating with the advantages of the scheme Filippov - the rapid development of cumulation [1].

A distinctive feature of the installation - the diameter of the working part of the anode larger than the diameter of the cylindrical insulator. At movement of the plasma from the smaller diameter to a larger - from an insulator to the equator of the anode, there is a stabilization of plasma instabilities in systems with a reverse pinch. It is interesting that when the plasma is like in the reverse Z-pinch, ie when moving from a small diameter to a larger no restrictions on the configuration of the pinch because of the so-called aspect ratio. In the cylindrical Z-pinch ratio of length to diameter of the pinch - aspect ratio - can not be more than 10. Otherwise, it will fall apart MHD instabilities. Inverse Z-pinch configuration such restrictions do not.

The considered installation with "combined" configuration - not exotic: with spherical electrodes produces a plasma focus VNIIEF (Sarov) and VNIIA them. N.L.Duhova.

As in any noncylindrical Z-pinch getting fusion plasma parameters is not achieved throughout the volume of the working gas. First, as you know created noncylindrical current-plasma sheath (TPO). Subsequently, the sudden collapse of the funnel TPO occurs leakage of plasma from the top of the funnel with pinching the flowing plasma. Resulting in a compact pinch plasma column was called plasma focus. Although the Z-pinch is by definition the electrode

high-current gas discharge self-contracting, it is important to note that the resulting plasma focus is not in contact with the electrodes. As in all the pinches the lifetime of the plasma focus does not exceed the discharge time of the capacitor bank.

2. Problematic characteristics of the plasma focus

Splitting into two plasma of volume allows to make cumulation of energy in a smaller volume of plasma focus with a large volume of TPO. There is a kind of plasma gun where the projectile acts plasma focus. However, the first experiments on small low-power plants was obtained the mass of ejected "shell" - the plasma focus, only a few tenths of a percent of the total mass of gas in the discharge chamber [2]. Modern installation is not much left in the effectiveness of cumulation. So developers and experimenters say focus energy content of about 10% battery power [3].

Theorists mention the plasmoid is already emerging in the second compression of the plasma, predicted only 3% of the input energy to focus on the energy of the battery [4].

Because of the lack of rotational motion of plasma particles in a plasma focus, TPO these plants is inherent in filamentation. Alternatively, the problem is solved by creating a front of the main discharge plasma low (Fusion standards) performance [5].

However, if it was possible to get a wide TPO in the plasma focus, then decided to issue filamentation due to intermixing of concentric plasma layers with their different ways crossed plasma filaments, and - like the Tokamak - would add an effective mechanism for suppression of plasma instabilities in the form of - the shear.

In addition to the presentation - increasing the size capacity and invest in the area megajoule energy values of the capacitor bank is accompanied by saturation of the scaling of the neutron - neutron flux lack of growth with an increase in the input energy in a pinch in areas megajoule.

3. Comparison of the plasma focus with existing systems

The proposed system is not developed by Pioneer, so it makes sense to compare it with existing ones. For example, despite the fact that the theta-pinch as a plasma focus source of pulsed electrical discharge all acts tazha capacitor bank, the plasma confinement time in the theta pinch many times more. So the characteristic retention time for the plasma focus 10^{-8} - 10^{-7} s., While the theta pinch is about 10^{-5} s.

Such growth energy confinement time in the plasma due to the theta pinch the ring and not the cylindrical - as in the plasma focus, the configuration formed in the plasma pinch tight bunch. Closed the circular track to allow movement of the plasma particles undergo large segments than in the linear portion of the plasma focus.

In other matters discharge duration theta pinch is also limited by the time of discharge of the capacitor bank.

In this regard, the system stands out magnetic inertial fusion, once worked out GPI [6]. Discarding all the technical details, it may be likened to all pinches fusion systems with inertial confinement. The course is similar to the process - in the early going pulse heating, and further expansion of free-heated plasma and reacted after removal of energy supply. The system inertia magnetic fusion in the shelling IOFAN thermonuclear target only one laser beam arises ordered plasmoid, which through its induced currents essentially pinch, there is some time and after

switching off the heat source - the laser.

To achieve a similar effect with the self-existence pinch plasmoid discharges the capacitor bank at existing pinch system is impossible. Even if short-circuit the solenoid theta pinch after the discharge will not create a system similar to the plasma focus with its most efficient performance of compression and heating of the plasma in the pinch.

The fact that, in the electrode discharge-type plasma focus is not in use arising from the rotation to wide extinction of plasma instabilities, does not mean that this method does not try to use other electrode discharges.

For example, create a twist in high-pinch plasma with the aid of electrically exploding wires [7].

Created by the twist and spiral slots at the ends of the electrodes in the high-current coaxial plasma gun [8].

However, such systems have not justified.

The fact is that given the classic Z-pinch system inherent insurmountable contradiction - something to heat and compress a rotating plasma is necessary to reduce the diameter of the vortex, and something to compression do not interfere with the centrifugal forces - the radius of rotation of the particles relative to the central axis of the apparatus need not to reduce, and it is better to increase.

In fact, the formula for the calculation of the centrifugal force, as well known, has the form:

$$F = \frac{mv^2}{r}$$

I remember the issue number 98 of the collection: the centrifugal force of inertia is inversely proportional to the radius of the circle - r, at which a material point moves.

Hence, for a sufficiently small radius, this force could achieve an arbitrarily large value. Why do particles lying near the poles of the earth, not come off and fly into space? The answer, of course, the following - the centrifugal force does not depend only on the radius, but the square of the linear velocity - v near the axis of rotation of the linear velocity is close to zero. And since it is included in the formula in the square, it determines the magnitude of the centrifugal force [9]. Unfortunately, earlier in the Z-pinch with rotating plasma clots and squares linear velocity only increase the radius subsided - at such a "globe" plasma is not confined. It should be recalled that the focus meyerovskogo type is a sort of railgun. Work on the railgun military will continue with any success in the plasma focus fusion programs. It was too tempting prospect. If artillery systems with the chemical fuel velocity of the projectile can not exceed the rate of the thermal motion of molecules exploded gunpowder, the railgun with light speed pulse prospects are almost limitless. Railgun-like catapults are large because of the great length of the straight line electrode system. The only option is to reduce the size of the transition to a system with a spiral motion of the projectile - Installation "Praschetron" Company HyperV Technologies Corp. [10]. With regard to the classical plasma pinch we can conclude the technical possibility of modernization. In fact, despite the small size of the plasmoid - plasma focus, the size of powerful plazmofokusnyh installations essential. Why waste energy on the parasitic inductance of the discharge chamber, if you can reduce the size of the discharge chamber by the spiral motion of the plasma particles along the electrodes when heated? As, for example, the device [11].

4. Formulation of the problem

It is well known that the installation of a cylindrical Z-pinch appeared only after Academician L.A. Artsimovich proposed to replace the porcelain side wall of the cylindrical Z-pinch on copper. Due to the greater thermal conductivity of copper relative porcelain intended to reduce the impurities from the side wall into the plasma. In fact, this constructive course radically changed the course of the configuration and development of the gas discharge. Summarizing all the above has been given the task - to change the map of the installation constructive plasma focus is to:

1. A plasmoid had an annular shape;
2. The relative growth of volume of volume with respect to the annular clot TPO offset by a paradoxical use of plasma rotation - leave wide, and the centrifugal forces of the enemy to draw compression mechanism for compression of the plasma.

5. The solution of this problem

Driving the newly developed installation it is illustrated in **Fig. 1**.

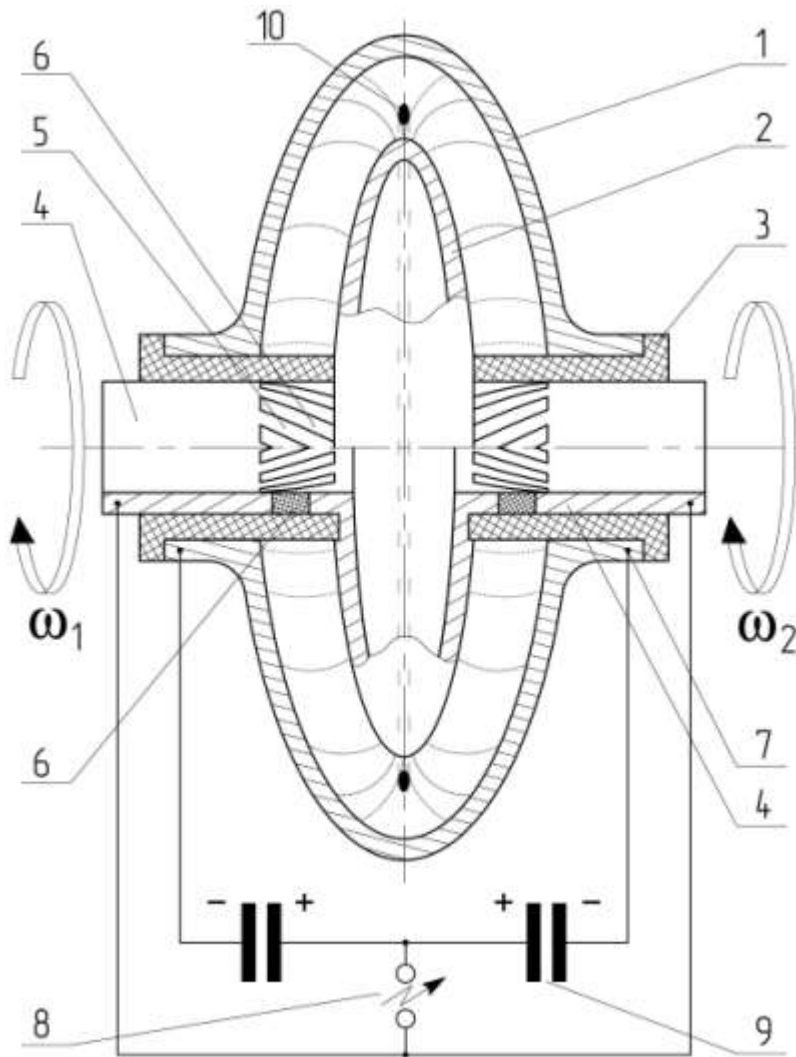


Fig. 1

The caption to Fig. 1:

1. The cathode;
2. The working part of the anode;
3. The cylindrical insulator between the electrodes;
4. The tube current lead of the anode;
5. unlocked electrically conductive coil of multi-start helix;
6. insulator adjacent turns of multi-start helix;
7. The current lead cathode;
8. gap;
9. High-low-inductive capacitor bank;
10. kvazitoroidalny plasma focus.

$\omega_1 = \omega_2$ - respectively, equal in magnitude and direction of angular rotation speed of the mirror plasma vortices.

The dashed lines show the cross section and the position of the current - plasma membranes during their movement from the corresponding cylindrical surface of the insulator to the perimeter of the anode.

The cathode material - stainless steel. The cathode consists of two mirror halves which are joined together vacuum-tight (not shown).

Anode material - Electrical copper.

Working electrode surface delineated using ellipsoids of rotation.

The material of the insulator between the electrodes is proposed to use a broker because of its high thermal conductivity [12]. It is assumed that the thus reduced amount of impurities from the insulator at the beginning of the discharge.

As materials for insulators filling spiral slots on the tube anode current leads, you can use PTFE or mica because of their high resistance to radiation exposure.

To keep the size of the device after assembly, the central axis can be positioned contracting pin with mirror - nuts and washers with the dielectric plates abutting ends of the current leads in the overall anode (not shown).

6. Estimated method of operating a centrifugal Z-pinch

After applying a voltage pulse from the source to the anode through a gap near the two insulators are formed two cylindrical plasma shell with a fibrous structure. Under the action of electrodynamic forces plasma membrane symmetrically away from insulators. Due to multiple-pulse current in the coils of the two lead-in wires of the anode shell gain to the existing axial additional movement - vraschatelnoe azimuth. Two multi-start helix acts in this case as two pulse inducers swirl plasma due to its external pulsing magnetic field. Due to this rotation of the fiber currents - plasma membranes are mixed to form a shear. Two vortex to spin in two parallel coaxial annular spaces between the electrodes. The diameters of the vortex always increasing - autoregulation configuration as in the reverse Z-pinch. Formed from two shock waves to the plasma membranes acquires torque. After a specified time currents - rotating plasma membrane under the influence of ponderomotive and centrifugal forces out his soles on the perimeter of the anode. Here are oppositely facing their side surfaces. The geometry of the chamber and inductance capacitor bank are chosen so that the

maximum current pulse coincides with the moment of the meeting surfaces of shells. Further there is a collapse of the wedge-shaped annular channel formed by the merger of spiral shells with vortex currents flowing out of the plasma toward the inner perimeter of the cathode. Vortex leakage leads to the accumulation of plasma. Pinching arising pinch, similar to the plasma focus, will be accompanied by the transfer of energy of the plasma to the resulting compact plasmoid. In the disclosed device, it will pinch quasitorus. This focused quasitorus plasma is a source of neutrons and X-rays. We can assume that some of the neutrons will have a thermonuclear nature - when undefeated configuration pinch quasitorus during its rotation, and of the neutron it will have a mechanism such as a beam, plus the target - when will decay quasitorus pinch configuration.

In addition, at the stage of designing the system can assume two variants of rotation of the plasma quasitorus:

1. plasma quasitorus rotated until there descended together two TPO - similar theta pinch: no more than the discharge time of the capacitor bank.

2. plasmoid formed rotates and after the discharge of the capacitor bank, like in inertial-magnetic synthesis. It is true on the one hand plasmoid is covered under a layer of cold plasma between the cathode and the inner equator.

7. Projected (at the design stage) centrifugal distinctive features of the Z-pinch

- Relatively plasma focus new installation has the disadvantage that the surface current density in the top of the funnel collapse TPO reduced.

- However, in contrast to the plasma focus with its cylindrical (linear trajectory) skumulirovannoy plasma toroidal shape (circular trajectory) form of plasma resulting in the accumulation of a new installation increases the trajectory of the focused particle and hence their retention time in the pinch.

- Also, on the other hand, we have the relative growth of volume levitating plasmoid during cumulation in the new installation as compared to the plasma focus. It is assumed that this is the key to resolve the issue of saturation neutron scaling in megajoule range.

- The new setting is saved effektinost pinch due to accumulation as a plasma focus, but added to increase the rotation of the plasma energy confinement time in the plasma, in the theta - pinch.

- Like the theta-pinch in a new installation centrifugal forces directed to compression of the plasma. Only centrifugal Z-pinch plasma by centrifugal force is dropped or solid wall installation or in the case of plasma quasitorus - by rotating the compressed gas layer. The theta-pinch outer order of the protruding magnetic field lines in vacuo. Experience has shown the ineffectiveness of the magnetic walls. Thus, in a new installation efficiency increased centrifugal forces.

- In contrast to the plasma focus and theta pinch centrifugal Z-pinch has mechanisms for repayment of plasma instabilities - reverse pinch and wide. Accordingly, we can expect increasing the efficiency of formation of cumulation. Besides broad issue closes filamentation.

- It should be noted appearance of centrifugal Z-pinch plasma self-cleaning properties. The fact that any Z-pinch, by definition, is a high-current discharge and an electrode therein contaminated plasma ions of the anode material, knock electrons from the cathode. The "classical" plasma focus - a copper ions. This dramatically reduces the temperature of the plasma due to the growth inhibitory (X-ray) radiation of electrons in collisions with copper ions. In this way not

currently considered fusion reactions involving lithium as a hydrogen bomb.

Consider the proposed scheme of Z-pinch by using centrifugal forces will operate to the same as the plasma pulse centrifuge. There will be a rejection of the effect of heavy ions of metal impurities on the periphery of the plasma to the cathode surface to clean deuterium plasma.

8. Conclusions

1. Review of new design allows you to change radically the geometry of the pinch with a view to the possibility of fundamentally new experiments in the solution of the problem - to increase the efficiency of fusion high current electrode pinch isotopes of hydrogen.

2. Plasma Focus in comparison with tokamaks, stellarators, fast pinch with liners, inertial confinement systems based on lasers or X-ignition targets have the advantage that they are under similar parameters thermonuclear plasma - compact and relatively simple. Although described new Installation is not at all plasma focus in the classical sense, nevertheless improvements introduced do not lead to a loss of compactness of the discharge chamber and to drastic complications. As a result - economic indicators of the feasibility of the new plant is also not beyond reasonable levels.

3. To find the optimal mode of the proposed pairs of pinch anode current leads should be made easily removable with different sizes multiple-screw spirals.

9. Note

Currently, the idea is at the stage of patenting in Rospatent - Application № 2015112392/07 (priority from April 7, 2015).

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