UDC 533.9

ALPHA – PARTICLE CONFINEMENT CONTROL AND ALFVEN WAVE-PARTICLE INTERACTION

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Two important physics effects are found in the interaction of the particle with the electromagnetic field of Alfven type wave in the toroidal magnetic trap: the increase/decrease of the radial deviation of the particle under the effect of the switching on/off of the time dependent part of the electromagnetic perturbation.

1. Introduction

Confinement of the "hot" alpha–particles, removal of the "cold" alpha-particles and screening the bulk plasma from the impurity ions with the high charge number Z released from the wall, divertor and target materials are the subject of the study of the modern fusion reactor physics. Different methods are known to enhance the confinement of the "hot" alpha–particles, this is the optimization of the magnetic configuration, especially (see, for instance [1]). For the removal of "cold" alpha-particles there are proposed different approaches which are connected with the externally applied magnetic field perturbations, the use of isolated drift resonances (drift islands) and overlapping of adjacent resonance (stochasticity) [2-5]. For the screening plasma from the penetration of impurity ions different types of divertors are developed and optimized. The control of particle motion with the use of electromagnetic waves is also possible [6,7].

In this paper we consider the methods, which use the "wave – particle" interaction to control the test particles of different energy range. The selectivity of this effect concerning the energy W and mass M of particles is realized.

2. Transit Orbit under the Helical Field Change

As it is known [4] the passing particles, which satisfy the resonance condition with, the externally applied perturbation magnetic field (namely $i^* = m/n$) can be transported across the magnetic surfaces with the use of such physics effect -"drift island motion". This mechanism is rather effective to remove the "cold" alpha-particles from the plasma core of the reactor. However it is demonstrated [4] that this mechanism is possible for the passing particles. The trapped particles should escape due to the drift motion in the inhomogeneous magnetic field. Transit particles (which transform the state from the helically trapped into the blocked and back) should be the subject of study.

Here we consider the effect of the slowly changed helical magnetic field on the "cold" alpha-particles ($W = 350$ keV) with the transit orbits. There is taken the magnetic configuration with $l = 3$ torsatron-type helical winding with the drift-optimized properties [1].

In the case when the amplitude of the helical field does not change in time the transit particle does not come out from the confinement volume (Fig.1).

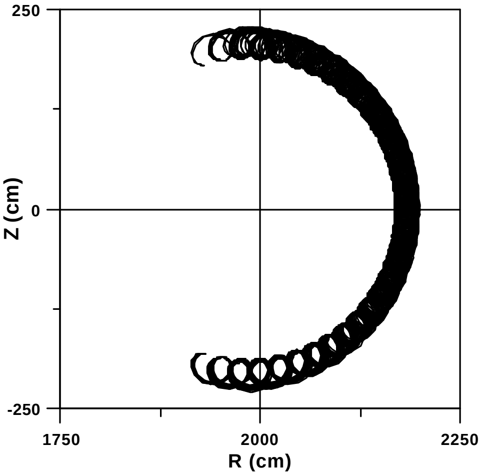

Fig.1. The trajectory of the transit "cold" alpha-particle in the vertical plane of reactor scale configuration

The transit character of the trajectory one can see from the dependence of the velocity pitch $V_{\parallel}/V$ on the time t (Fig.2.).

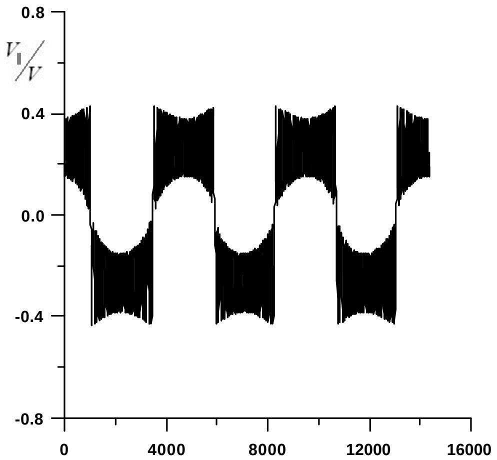

Fig.2.The dependence of $V_{\parallel}/V$ on the time t

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The radial variable “oscillates” but the maximum value does not increase in time (Fig.3).

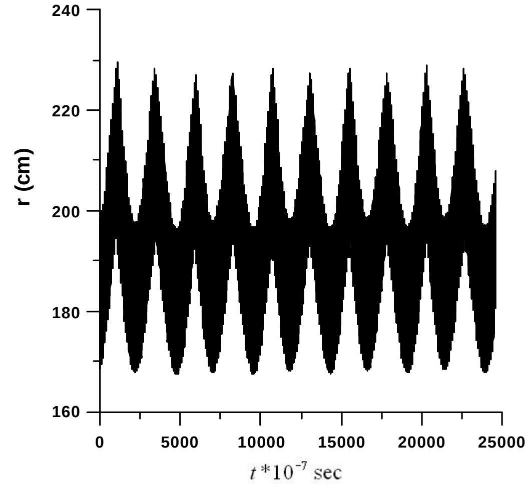

Fig.3.The radial variable of the transit particle versus the time

When the amplitude of the helical field changes in time (Fig.4) the properties of the transit particle change considerably (Fig. 5-7).

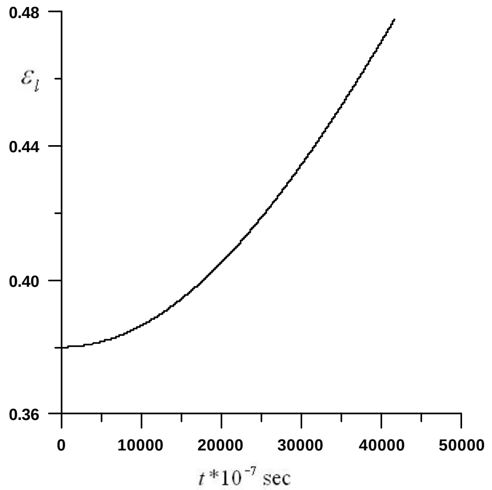

Fig.4.The change of the amplitude of the helical field in time

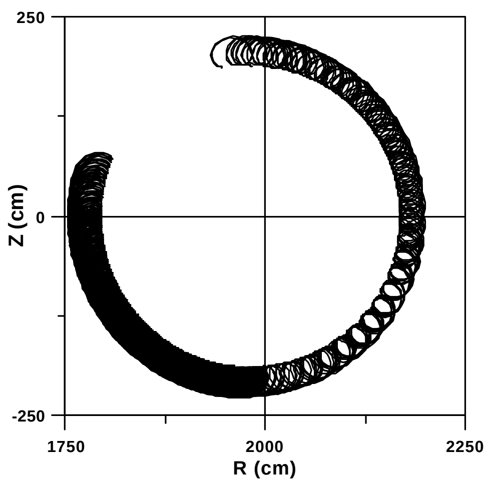

Fig.5.The trajectory of the transit particle under the change of the helical field amplitude

This is not the full trajectory but the part of the trajectory, which shows that particle becomes the helically trapped one.

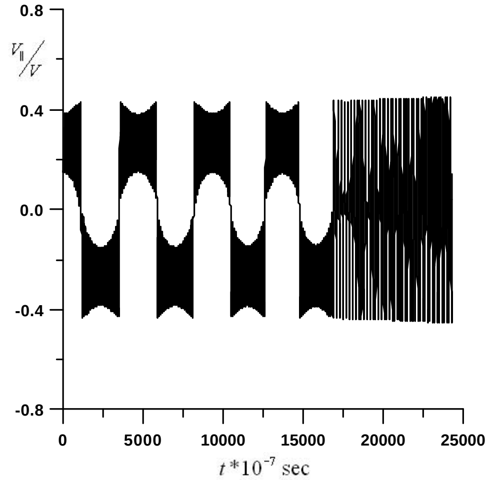

Fig.6. The dependence of $V_\parallel / V$ on the time t of the transit particle under the change of the helical field amplitude

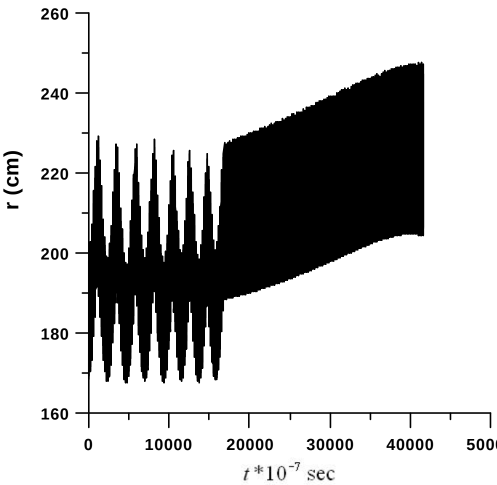

Fig.7. The radial variable of the transit particle versus the time under the change of the helical field amplitude

This figure demonstrates the effect: the particle becomes helically trapped and escapes from the confinement volume.

3. Particle –Wave Resonance Conditions

The interaction of the Alfven-type magnetic perturbation with the “cold”-alpha particle is considered. The magnetic field perturbation is taken in the form [8]

$$d\mathbf{B} = \mathbf{rot}\,a\mathbf{B},$$

where $a = a_{nm}\sin(mq - nj + wt + d_p)$. Here m,n are the wave numbers, w and d_p are the frequency and the phase of the wave. Here is shown the process of the disruption of the resonance in the case when the frequency w is “switched off” (Figs.8-10). The resonance $i^* = 1/3$ is considered and the frequency value is taken $w = mV_\parallel$.

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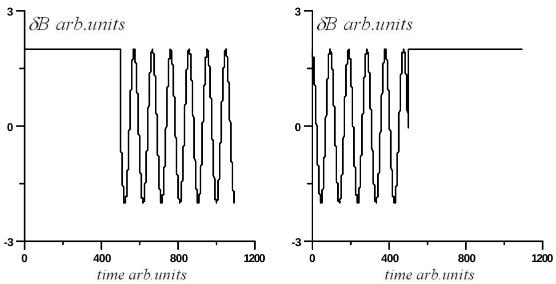

Fig.8. The electromagnetic field frequency switching on /off

Now it is possible to discuss some consequences of the combined effect of the magnetic resonance field and the electromagnetic field (the time dependent term). One can see the reduction of the radial deviation of the test particle after the switching off of the electromagnetic field (frequency switching off) (Fig.10).

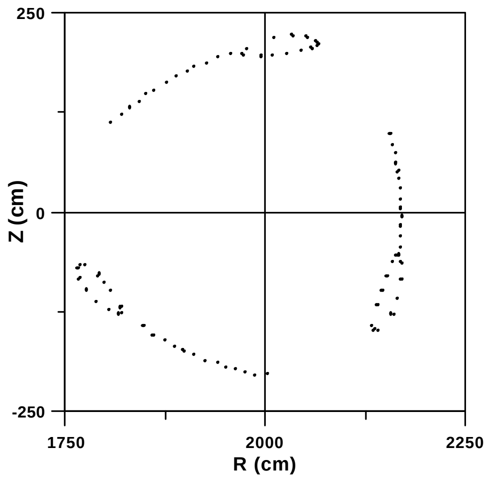

Fig.9. Disruption of the island structure during the motion of the particle after the electromagnetic field switching off

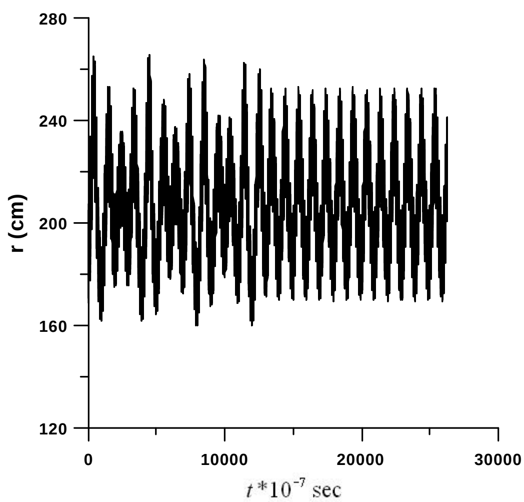

Fig.10. The radial variable versus time in the process of the disruption of the resonance

The radial variable increases if the electromagnetic field frequency is switched on (Fig.11). It means that this test particle can escape and be removed from the confinement volume.

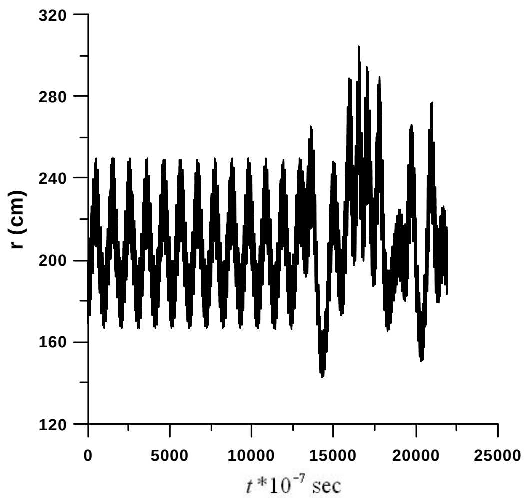

Fig.11. The radial variable versus the time in the case when the frequency is" switched on"

4. Conclusions

4.1. "Cold" alpha-particles with the transit orbits (transforming from the helically trapped ones into blocked ones and back) can be removed from the plasma core in the case of slowly changed helical field amplitude.

4.2. There exist the possibility to obtain the control of particle with the combined effect of the magnetic perturbations and electromagnetic wave launched by the external antenna when the switching on /off of the electromagnetic field is programmed in time.

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