Linear Induction Accelerators. An Alternative Consideration

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Abstract

"Linear induction acceleration", if it is identified with the "acceleration by the curl (vortex) electric field", would have a place only in a Bouwers "magnetic solenoid". The placing a secondary in this device puts it in the class of arrangements with an particles acceleration by means of a charges field between a secondary ends and amplifies roughly by an order of the curl voltage effectivity. Usually one counts that the variation of the magnetic field in the ferromagnetis core of a linear induction accelerator is a primecause of appearence of accelerating voltage. But the same variation arises if you apply voltage to the accelerating gap from outer source, when without doubt the acceleration is caused by this voltage. The core serves in this case for inductive voltage generation and high impedance formation which limits current load of accelerating voltage source.

Introduction

The term "linear induction accelerator" was introduced by N.S.Christofilos [1]. Its principle of action was explained in [1] by a picture like Fug. 1. The explanation was needed due to absence in distingtion to betatron case of clearity and obviousness of curl field interaction with accelerated particles. But instead of a testimony in [1] it is simply said ". . . the change of field in magnetic core induces an axial electric field". Like this in [2, p. 11] it is written ". . . the curl electric filds is exited, which is used for charged particles acceleration" and in [3, p. 56] ". . . curl electrical field is exited, which accelerates the electrones".

But from Fig. 1. it very hard to discern where the curl field acts on electrones, because on their way through gap acts on the secondary voltage of a transformer consisted of the core 1, primary turn 2 and secondary composed of outer 5 and inner 6 tubes together with the end discs. In the electrical engineering the field between the ends of the secondary loop does not identified with the curl field. If you like to speak about the field you must have in mind a field of electric charges on the ends of a secondary. In case of rectangular form of primary and secondary voltages the field has no difference from that created for example by a condenser 3 voltage if it is connected by a switch 2 (point b) to gap for a short moment. In this condition of accelerating device its action has no difference from the case of feeding through primary turn. In the core a growing magnetic flow is caused and electromotive force is induced, action towards applied voltage U_c and providing a moderate magnification of current i_2 from condenser 3 to secondary loop $i_2 = U_c \cdot \int dt/L$. The role of a core is only the inductance L enlargement.

The place and role of curl field

It is natural to put a quation where is the curl field in this description. Of course it is not elapsed, it exists until there is the magnetic field changing

$$d\Phi/dt = U = S(dB/dt) = S(dH/dt) = Sa(di/dt) \qquad (1)$$

These processes will continue until the condenser voltage does not change considerably. Crossing the gap particles will be influensed by the outer voltage. But will they gain corresponding to this voltage energy depends on power of the curl field permeability into a tube 6. At thickness of tube 6 smaller than skinlayer thickness the curl field will touch the particles. Only at considerably large wall thickness the particles gain a full acceleration, wich is to one order more that in Bouwers magnetitic solenoid [4]. The reason is secondary loop (tubes 5, 6 and discs on Fig. 1) transforms into acceleratingg voltage a voltage El throughout the whole length l of a curl field line meanwile in magnetic solenoid (Fig. 3) with the particles interacts only a part corresponding to a length of a projection on a particles orbit.

On Fig. 1 the accelerating gap is far from the core and the refore the curl field lines don't reach a gap. The real sections of Astron [1] and of many other installations of this type have a form, represented in Fig. 2. Here one part the curl field lines is shorted by the outer tube like the secondary loop of a transformer and stimulate its secondary voltage. On Fig. 2 in convential form we show charges on the ends of this loop. Namely the field of these charges accelerates the particles. The remaining part of the curl field lines is shorted about the core and those of them with touch the particles give acceleration. But this part is small, its role is likely the role of dispersion inductance of secondary winding. It is useful to note similarity of this device to cylindrical resonator. The exitation of the axial quasipotencial field of large

continuation is reached hire with the smaller current in a primary loop.

Nontransformer accelerating arrangements

In a case of applying the accelerating voltage directly to the gap (position "b" of the key 2 in Fig. 1) the tube 6 fulfils during a skineffect time a role of "metallis isolator" preventing a short circuit of the condenser 3. But important is a fact of a preventing due to a skineffect an electric field penetration in the inner cavity and forming in the gap of unipolar electric field. Fig. 4 explains a manner of forming a monopol action /5/. On the way between the graunded plates 1 and 2 the particles do not receive energy from the graunded source 4 because created by means of ring 3 electrical fields 3 have opposite direction. For the short time it is possible to remove this by means of closing one of the gaps by a tube 5 having thickness which exceeds a skinlayer one. The source current in the tube will rise as $i = \frac{U}{L} t$ t and only its tolerated value limits an interval of effective work of this skinelectromonopol [5]. Circulating around the tube marnetic frow generates in is electromotive force of selfinduction $E = L \cdot di/dt$, which slows down current growing. The increasing this effect reached easily by means outer tube 6 which concentrates a magnetic flow in the vicinity of tube 5. Still more inductive impedance growing is reached with the help of the ferromagnetic core between tubes 5 and 6.

In ckinelectromonopol form was made the represonted in Fig. 5 accelerating device of the arrangement ERA injector [2, p. 162]. In this practically realized device there is no place for curl field along the particles way and there is no place for inductive exitation the core maggnetic field (by a loop).

Analogy with the accelerating resonator

Considered arrangement by the form of fulfilment represents working at the a very low frequency coaxial and cylindrical resonators. Of course the denomination "resonator" will be well founded in case its continuos work at a feeding frequency which coinsides with the self frequency oscillations. This from of oscillations will have place also in considered devices at shocks by short front pulses. But before the next pulse they will be vanished, the accumulation will be absent, works only inductive brunch, the feeding current will be large. But at accelerating a very particles current the effeciency will be acceptable. On the concept "resonator" were made like showed on Fig. 5 the permalloy loaded resonators for 2,8 MeV seven turn spiral accelerator of USSR Academy Sciences Radiotechnical Institute.

Conclusion

Returning after [5] to the alternative consideration the conception "induction acceleration" is justified one self by a possibility, as author hopes, to reach a new scientific and technical effects. For example, on the bases of the resonator analogy the author proposed a cavitron with the use of a polycylindrical resonators [6].

So far as the denomination "linear inductive accelerator" does not correspond to the physical processes it is a time to suggest a new one: L.F. resonator, cavitron, skinelectromanopol, endovibrator and other.

References

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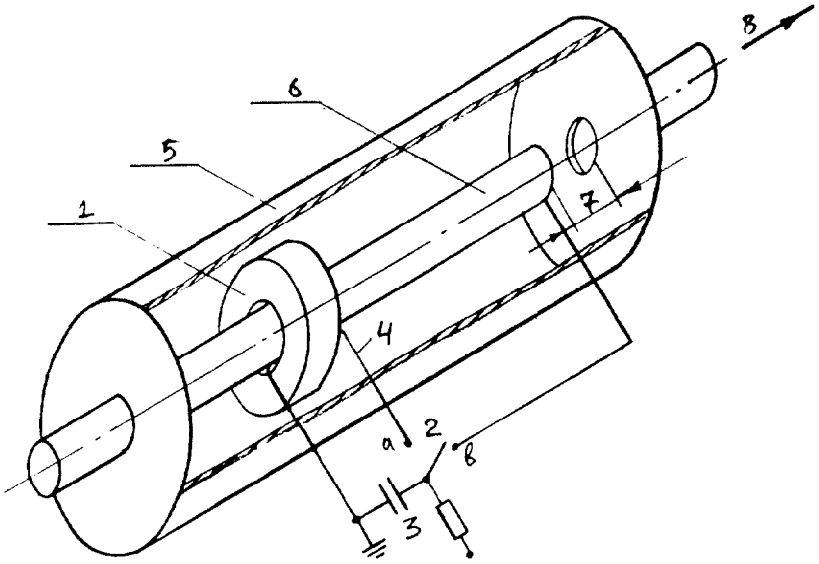

Fig. 1. Christofielos induction accelerator

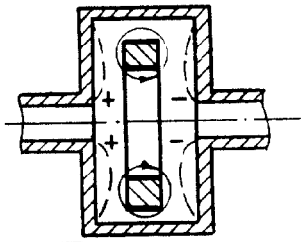

Fig. 2. Ashort section

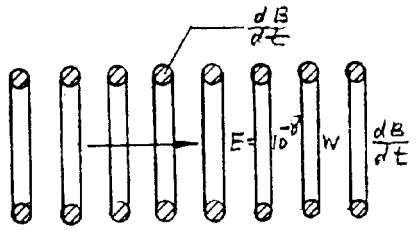

Fig. 3. A magnetic solenoid

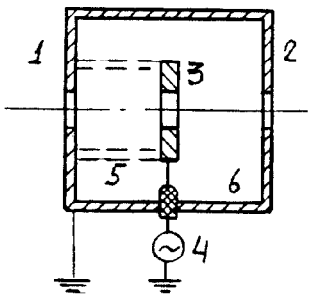

Fig. 4. A skinelectromonopol

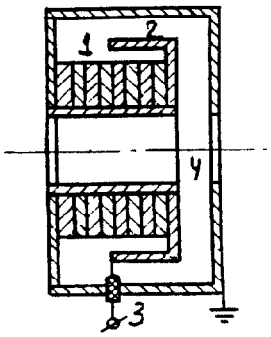

Fig. 5. An injector ERA accelerating device

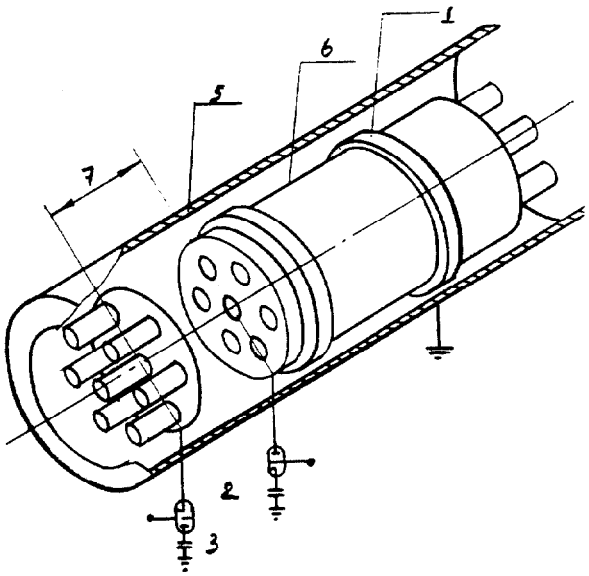

Fig. 6. A spiral accelerator permalloy resonator