5.3

Stable suspension of the bodies in dynamic potential wells.

Gorsky O., Dzenzersky V., Zeldina E.

Transmag Research Institute, 49005,Dnepropetrovsk, Piesarzhevsky 5 ,Ukraine
e-mail:gorsky@npkista.dp.ua

Abstract. Dynamic potential wells have been proposed in ninetieth. The main peculiarity of the dynamics revealed is next: stable suspension of bodies but weak dependencies on geometrical parameters. Counter flux short-circuit contours used as electrodynamical counterpart in creation of dynamic potential well do increase the sensibility of suspension of bodies to the geometrical parameters. The main features of the dynamics in such a system are extracted in the present work.

The dynamic potential well for the suspension of bodies was described in [1]. In proposed scheme we do intend to use normal flux short-circuit contours for the creation of repulsive force combined with attractive force of moving current coil to two wires with the constant current I_0. As it was carried out in [1] the suspension is stable in wide range of parameters for so arranged dynamic potential well but dependencies of dynamics characteristics on geometrical parameters are rather weak. In present work we are intended to investigate the suspension in dynamic potential well with counter flux short-circuit contours previously described in [1] as counterpart of electrodynamical repulsive force keeping in mind to increase the dependencies of dynamical characteristics on geometrical parameters. The proposed scheme of dynamic potential well in the present work is depicted in Fig.1. Let us consider a magnet (current coil) 1 moving with velocity V. The magnet is spaced under a discrete structure of short-circuit contours 2 arranged along two wires 3 with the constant current I_0.

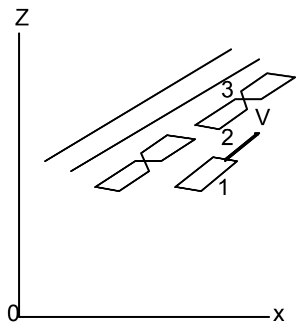


Fig.1 The arrangement of short-circuit counter flux contours and dynamic potential well organisation

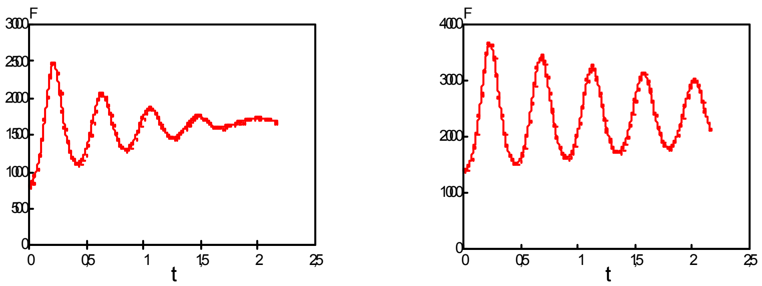
Vertical oscillations of the magnet are governed by the equation

$$m\ddot{z} = -mg + I_0 I_1 \frac{dM_{01}(z+h_0)}{dz} - \alpha I_0 \sum_{i=1}^{n} I_i \frac{dM_{0i}(z)}{dz}$$

There m and z is the mass and co-ordinate of the magnet, h_0 is a distance between the current line and the discrete structure, M_{ijj} is the mutual inductance of contours, I_i is the current induced in short-circuit contours, n is a number of contours. The transitional process in the discrete structure is governed by the equation

$$L_i \frac{dI_i}{dt} + \sum_{i=1}^{n} I_i \frac{dM_{0i}}{dt} + R_i I_i = -I_0 \frac{dM_{0i}}{dt}$$

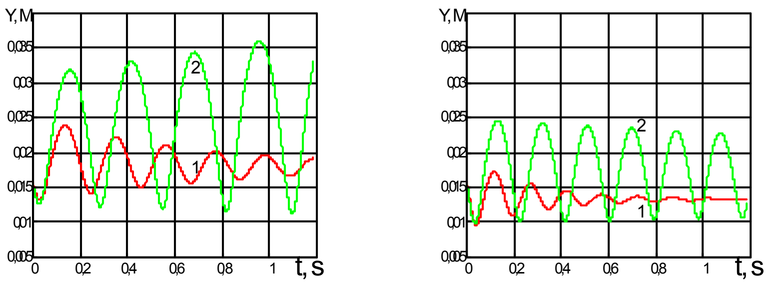
There L_i, R_i are self-inductance and resistance of contours. With initial conditions $I_i(0) = 0, z(0) = z_0, \dot{z}(0) = 0$, the system was numerically integrated in the wide range of the parameters. The dynamics in short-circuit counter flux contours case is much more complex as compare to short-circuit normal flux contours. The increase of the velocity and stable suspension is in strong dependencies on the sizes of counter flux contours and moving magnet. This was the aim of the present work to show that only in the case of counter flux contours as compare to normal flux contours it is possible. Of course, the fact may be positive or negative in real suspension case. As positive we get more parameters to control stable suspension. As negative this fact might limit the region of stable suspension. In the present work we don't investigate the possibility of extension of region of suspension. To begin with we propose time series of repulsive electrodynamical forces between moving magnet and short-circuit contours in the case of counter flux (Fig.2). As one can see variety of behavior for repulsive forces is at hand. In this case the length (1 m for both halves) and width (0.3 m) of short-circuit contours were fixed. We report results for repulsive force because this dependence does reveal in the case of electrodynamical levitation as well.



a **b**

Fig.2. Typical time series of repulsive forces acting on moving magnet (current coil). Curves are figured out for V=60m/s. Curves a, b –for counter flux short-circuit contours with different lengths of magnet along direction of motion l=0.8m (a), *l*=1.2m (b).

Contrary to normal flux dynamical potential well the system with counter flux contours very easy responds when a change of length of moving magnet takes place. Such behavior of repulsive force would result in dynamics being developed. This indeed one might see in time series of oscillations of suspended current coil (Fig.3). In Fig.3 we report typical time series of vertical oscillations for different velocities of moving magnet.



a **b**

Fig.3 The time series of oscillations for different velocities of moving magnet and fixed lengths of short-circuit contours. Curve a -for l=0.8 m, V=50 m/s curve, b is for V=60 m/s, 1-normal flux short-circuit contours, 2-counter flux short-circuit contours.

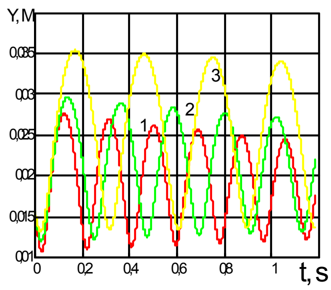


Fig.4 Time series of oscillations of moving current coil with different lengths. V=60 m/s, 1-l=0.8 m, 2-l=1,2 m, 3-l=1,4 m.

As one can see the character of dependencies of oscillations for different lengths of moving magnet is different. For various lengths the different dynamical regimes are realised. Such dependencies are unavailable in the case of dynamical potential wells with normal flux contours. Contrary to the dynamical potential well with normal flux short-circuit contours and weak enough dependencies on geometrical parameters (particularly on length of moving magnet along direction of motion) in the case at hand we get new parameters to control dynamics. In normal flux potential well in high speed limit of motion a short-circuit contours have managed like perfect conductivity contours and vertical oscillations impossible to damp. In the case of counter flux contours one is free for choice of dynamics to realise. For example, to manage rigid dynamics one has to increase length in direction of motion and vice versa to decrease if one has to engage damping. The decrement of vertical oscillations is easy to vary. Beside this a frequency of vertical oscillations may be changed within large scale. In the case of counter flux short-circuit contours one has possibility to increase suspended mass (in some case we increase the suspended mass in 8-10 times as compare with normal flux suspension) and vary height of suspension. Drag force in this case depends on geometrical parameters too. These forces have very perplexed dependencies, which are extremely difficult to analyse. In real case of suspension of moving magnet this may be handicap to act. This question may be cleared up in long run of investigation of stability of motion in 3D suspension. In the present we must say that because of attraction of moving magnet to one of the coupled contours this may be serious problem for engine of any kind because of non-homogeneous power supply. In counter flux short-circuiting one have to manage with number of different geometrical parameters inaccessible for normal flux suspension or levitation There is another parameter which might be subjected to changing to control dynamics evolved. In electrodynamical levitation case or in dynamical potential well with normal flux contours such parameter is used to be unchangeable. This is height of suspension. Indeed, in counter flux short-circuit contours one has got yet one more parameter because both halves of contour may have been situated on a different height from moving magnet. So what a number of parameters one has to control dynamics, forces and motion. Let us enumerate these parameters: heights for different halves of short-circuit contours, lengths of both halves of short-circuit contours, variety of schemes of arrangement counter flux contours (different schemes of short-circuiting). Why we are considering dynamical potential wells? As we have mentioned previously [1] this is because of compatibility of this kind of suspension and many other well performed schemes such as: electromagnetic suspension with controlled electromagnet, controlled permanent magnet [2] and high temperature superconducting magnet suspension scheme. In [3] was proposed suspension scheme performing low temperature superconducting magnet and its frozen magnetic flux. In [1] we partially have carried out investigation on this subject. According to our investigations a branching of frozen flux in superconducting magnet reveals some interesting properties to be used to control dynamics. So there are a lot of schemes completely compatible for stable suspension to be realized. It is not clear at all what advantages of the suspension over well-performed electrodynamical levitation one might to wait. Indeed in our view different schemes of levitation and suspension is very difficult to compare. In the present work we don't report on dependencies of forces, dynamical characteristics on geometrical parameters. This is because of variety of dynamics, its sensitiveness to the changing of any kind. In Fig. 5 is shown the dependence of repulsive force upon distance between suspended current coil and short-circuiting contours arranged along direction of motion. This curve has been read in process of the dynamics evolved. The curve has smooth character as compare to analogous curve of dynamical potential well with normal-flux short-circuiting contours.

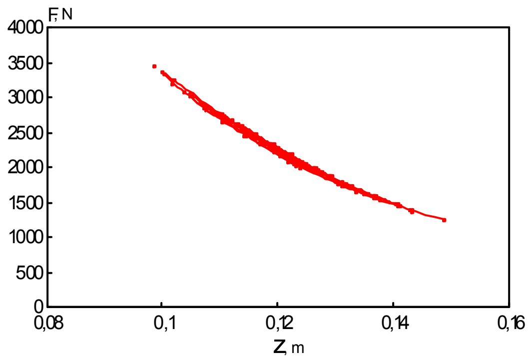


Fig.5 The dependence of repulsive force on distance between suspended current coil and short-circuiting contours arranged along direction of motion carried out in time series of dynamics evolved.

The question of lateral stability of the proposed dynamical potential well with counter flux contours is still open. Preliminary investigation does show that lateral stability may be assured in the case of normal flux contours. As we did underline in [1] the suspension of permanent magnet close to rim of rotating disc has been demonstrated in 1989. Contrary to electrodynamical levitation, which is impossible to realize using rotating disc (one might experience lateral instability, rotating moment acting on levitated magnet) in dynamical potential well one can get absolutely free suspension without any auxiliary device. In the case of counter flux counters we get one more branch of magnetic field. It is still unclear so far if this source of instability or stability.

Key words: magnetic suspension, dynamic potential well, dynamics, and counter flux contour

Reference

1.Gorsky Oleg, Dzenzersky Victor, Zeldina Ella Static and dynamic potential wells, counter flux electrodynamic levitation as possible alternative maglev systems. The 16 international conference on magnetically levitated systems and linear driver, Maglev'2000, Rio de Janeiro, Brazil ,2000,p.225-229.

2. Wang P-J.,Wang L-Y. Design and analysis of maglev systems based on combined propulsion and levitation hybrid technology, Proc.2 Int. Conf. –Electric Railway Systems, Berlin, vol.74,1999,pp.395-398.

3. H. Ohsaki Proposal and FEM analysis of superconductive magnetic gradient levitation, IEEE Transaction on magnetics, vol. 31, 6, 1995, pp.4199-4201.