Passive magnetic bearings with permanent magnets

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1. Introduction

Currently, two main types of magnetic bearings are produced:

1) Active magnetic bearings, which principle of operation is based on the effect of attraction (magnetization) of an iron shaft to a coil (winding) when voltage is applied;
2) Magnetic bearings with an additional mechanical support which may consist of permanent magnets arranged in a special way, but such bearings are unstable in the longitudinal plane, therefore additional mechanical support is necessary.

These bearings cannot be considered as a replacement for existing mechanical bearings. Their applications are narrow and specific (gas centrifuges, suspension of turbine rotors, etc.). Engineers would like to get magnetic bearings that, in terms of their characteristics (design and maintenance), are as close as possible to existing mechanical bearings (minimum dimensions relative to loads, little or completely maintenance-free, wide temperature characteristics, lack of power systems, sensors, cooling, etc., lack of additional mechanical supports, lack of lubricants).

Bearings with such characteristics have not yet been created. There are a number of reasons for this:

1) Earnshaw's theorem;
2) The lack of research of the properties and characteristics of permanent magnets since 1970s;
3) Incorrect consideration of electromagnetic coil calculations as an analogy of a permanent magnet;
4) The absence of permanent magnets with high magnetic field induction until recently.

2. Ensuring of stable levitation

Irnshaw's theorem reports the impossibility of stable levitation on permanent magnets. This theorem considers the interaction of two monomagnets, but does not talk about the interaction of magnetic assemblies of permanent magnets. This means that we can try to create conditions for stable levitation using magnetic assemblies of permanent magnets.

If the shape of the magnetic field of a cubic permanent magnet is a ball (or tends to be a ball in any permanent magnet), therefore, when two spherical fields interact, they are unstable. Then, for stable levitation, one of the fields or both must be flat or, even better, one field must be concave.

Halbach array is notable for the fact that it allows to form a magnetic field on one side, and on the other side the magnetic field is very weak (or absent). We are interested in this assembly in another property: it demonstrates the possibility of redirecting the magnetic flux using permanent magnets.

By applying this property of permanent magnets, it is possible to obtain stable levitation on permanent magnets.

3. Horizontal stability

When two flat magnets interact, there is no horizontal stability (Fig. 1).

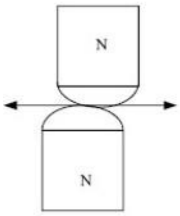
In order to create horizontal stability, the lower magnet must be modified to be not flat (Fig. 2). Since the strength of the magnetic flux decreases as a square of the distance, the shape of the upper magnet must be changed to reduce the air gap between the interacting magnets (Fig. 3).

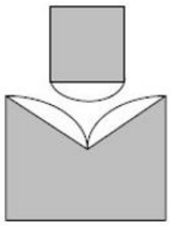
If we try to move the upper magnet relative to the lower one to the right or left, a force will arise that returns it to the center of this assembly. This is due to changing of the air gaps between the magnets: if the right decreases, then the left increases and vice versa. And since the strength of the magnetic flux varies as a square of the distance, when the air gaps on the right and left change, a returning force arises, acting until the moment of balancing.

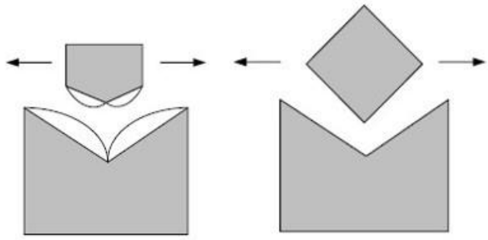
4. Vertical stability

It is necessary to form one concave shape instead of two fields (Fig. 4).

This can be done using the effect of redirecting the magnetic flux in an assembly of permanent magnets. To do this, instead of one monomagnet, we make an assembly of three magnets of the same size and configuration (Fig. 5) – a single magnetic field of the required configuration is obtained.

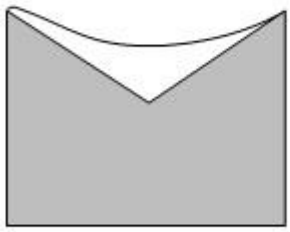






a) b)

Fig. 1 Fig. 2 Fig. 3



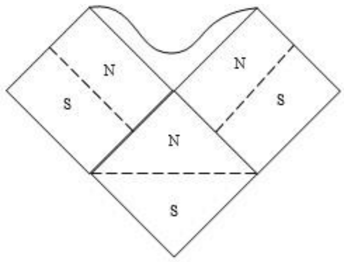


Fig. 4 Fig. 5

Explanation of this effect: each magnet has a direction of magnetization and it is directed from south to north. In a magnetic assembly, the magnetic fluxes of several magnets are combined. A single concave magnetic field is formed instead of two convex ones.

Based on the results of experiments, a patent was obtained for a passive permanent magnet magnetic bearing.

Solving the problem of stability of a passive bearing on permanent magnets, we also solved the problem of stability of magnetic levitation transport on permanent magnets.

References

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