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Dynamic Interaction of Rotating Imbalanced Masses in Vacuum

Annotation

The article presents experimental research results of disk interaction, rotating closely in vacuum, which are not mechanically connected. It was ascertained that at high angular velocities interacting forces between the disks occur, resulting in disk precession and elastic deformation (surface spiral twist) during their conjoint rotation. Meanwhile, a power transfer from the rotating disk to the originally fixed disk occurs, resulting in its rotation, as well as in mutual braking and disk heating during their simultaneous rotation.

Contents

1. Experimental equipment

In our experiments we used a device (Fig. 1) which comprised two direct-current motors D-14FT2s (1 and 2), having electromagnetic brakes, mounted on steel plates 3 and 4 with the thickness of 18 mm.

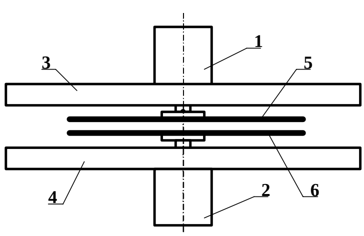


Fig.1. Basic diagram of device for mass-dynamic effect research

The disks (5 and 6) had their diameters of 165 mm and their thickness of 0.9 mm, they were made of aluminum alloy AMg3M (in several cases we used a solid cardboard disk), and they were firmly fixed on the flanges of the motor rotors. The motors were connected to DC power supply B5-48, located outside the chamber in order to maintain a set steady voltage. A separate power supply was used to activate or desactivate the motor electromagnetic brakes.

The distance between the disks was set by parallel movement of electric motor fixing plates on four steel columns, with subsequent rigid fixation. The distance from the disks to the plates was not less than 20 mm. Alongside with that, in our experiments we set both a deliberate distortion of the disk axes relative to their electric motor axes, which created a variable quadrupole moment while the discs were rotating, and the highest possible disk parallelism and dynamic balance were provided. The initial gap between the disks was set from 1 to 6 mm and more. The possibility of mechanical contact during the disk rotation, taking into account their imbalance, was excluded.

The device was installed and rigidly fixed in a vacuum chamber with its inner diameter of 300 mm and its wall thickness of 15 mm (Fig. 2). The air from the chamber was pumped by a vacuum forepump up to residual pressure of about 1 Pa.

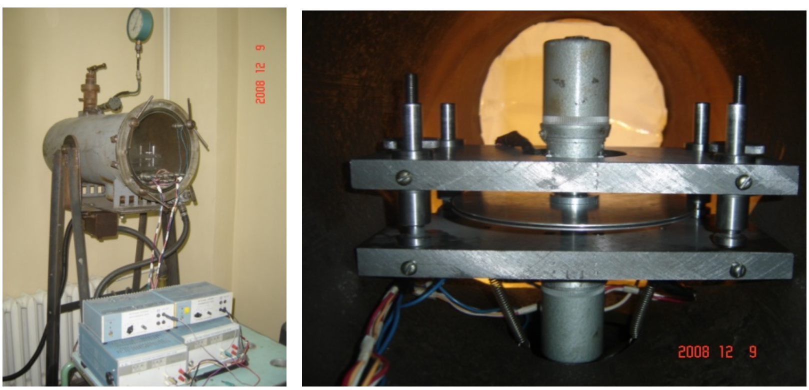
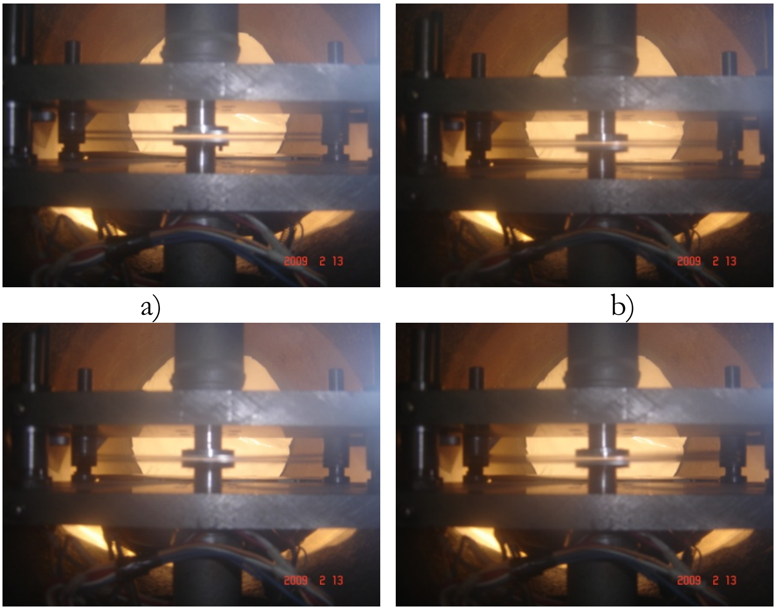


Fig.2. Overall l view of experimental equipment and device in vacuum chamber

2. Experimental research results

In the first series of experiments, the feeding voltage was supplied to both electric motors simultaneously. It is ascertained that if the initial gap between the disks is 1-3 mm (Fig. 3a) and the simultaneous voltage supply is 30 V on both electric motors to rotate them in opposite direction (counter rotation), they are initially accelerated up to a maximum speed of approximately 100-120 1/s (Fig.3b). Then periodical vibration of one of the disks (Fig. 3c), or simultaneous vibration of both disks occurs. (Fig.3d). Disks vibration frequency is approximately 10-20 1/s. During the vibration the disk rotation speed dramatically falls by approximately 2 times (50-60 1/s).



a) b)

c) d)

Fig.3. Disk high-amplitude vibration excitation during simultaneous counter rotation in vacuum chamber

During this process, a considerable disk surface bending is observed, i.e. their elastic deformation (Fig. 4). The vibration of one disk is chaotic relatively to the other. The gap between the disk surfaces in different zones is a time-varying parameter.

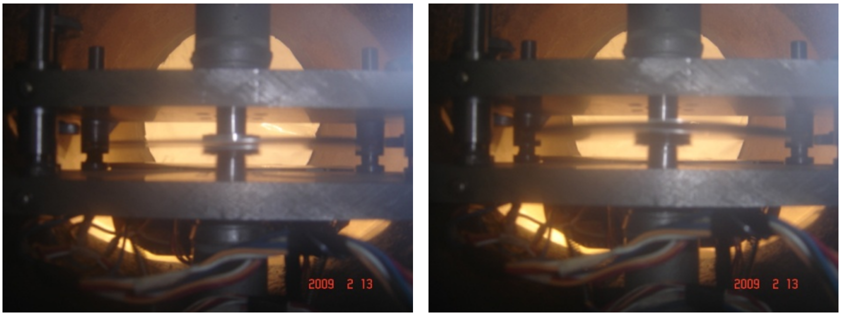


Fig.4. Disk surface bending during high-amplitude vibration

In this case a mechanical contact between the disks did not occur even if the initial gap between the disks was 1 mm. The disks repelled from each other, which can be seen in the photographs, and each disk was rotating in its own direction. When the vibration stopped the disk rotation speed increased again. The process repeated with certain periodicity.

At some moments the disk chaotic vibrations became relatively stable – the disk spiral twist, rotating with a frequency of 1-3 1/s (Fig. 5).

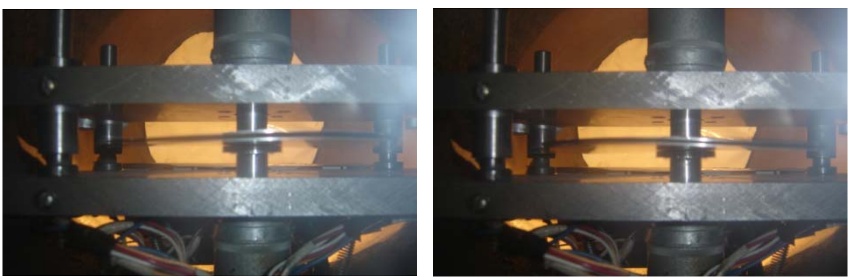


Fig.5. Disks surface bending and twisting during simultaneous counter rotation in vacuum

In this case, a synchronous distortion of both disk planes occurred. As it can be seen in the photographs and in a slow video of this process, the distorted disk surfaces are almost equidistant. That is, spiral surfaced disks, rotating in opposite directions at a speed of 90-100 1/s, flow around each other without any mechanical contact, a wave of the disk mechanical elastic deformation moves along the surface at the same angular velocity as the disk angular velocity. And the rotation of the spiral twist is in the direction of the disk rotation, which had a higher rotation frequency.

If the disks were deliberately imbalanced (a small disk axes distortion and the rotors axes of electric motors distortion were set), which caused their intense vibration, the above-described effect of the disks interaction (vibration excitation, and then flexural wave occurrence) was observed when the gaps between them were up to 3 mm. In experiments under the same conditions, but in the absence of vacuum (standard pressure in the chamber) these effects did not occur. The strong disk vibration was not excited, and a flexural wave was not observed even when initially set gap between the disks was less than 1 mm.

When one of the electric motors (rotating in vacuum) was switched off, and its disk was stopped, the second electric motor started spinning up to a maximum frequency of approximately 180-200 1/s. When the first electric motor was switched on, the rotating frequency of the second electric motor decreased again. The rotation frequency of both disks was approximately 90-100 1/s. Thereby, during experimental recurrence, it was experimentally ascertained that during conjoint rotation in vacuum a sufficiently strong mutual disk braking was observed.

It was ascertained that in that case during continuous (2-3 minutes), simultaneous, contactless rotation and interaction, the disks are heated to the temperature of 65-70 ºC. When the device worked continuously (5-7 minutes), the temperature of the disk heating was up to 80-90 ºC. The disk temperature was measured 1-2 minutes after the disks had been stopped and the vacuum chamber had been opened.

While the feeding voltage of 30 V was supplied simultaneously to both electric motors to rotate their disks in the same direction, after complete spinning only a strong vibration of both disks was observed. The distortion of the disk plane bending was not observed.

The electric motor rotation frequency was also significantly less than the maximum frequency. In the process of simultaneous rotation the disks were heated to the temperature of 50-60 ºC. When the power supply of one of the electric motors was switched off, the second electric motor spun up to the maximum frequency. When the motor was switched on again, all the effects recurred completely.

If one of the electric motors was switched off and braked, then after the voltage of 30 V was supplied to the second electric motor and after its complete spinning, a slight disk vibration began, and then a slight fixed disk vibration was periodically excited. When the fixed disk vibration was excited, there was a visible decrease in the rotating disk frequency. However, no disk heating even after continuous work was observed.

Thereby, as a result of experimental recurrence, it was ascertained that disc heating occurs only in the case of simultaneous disc rotation in vacuum. The disc heating is the consequence of disc contactless interaction and mutual contactless braking.

In the second series of experiments, the voltage was supplied to only one of the electric motors, while the second one was switched off and braked.

It was experimentally ascertained that if in vacuum a (driven) electric motor was switched off, and braked, when the second (driving) motor was supplied with the voltage of 30V and completely spun, the forced rotation of the first disk with its electric motor rotor began. It was revealed that the effect of excitation of forced rotation and rotation frequency, with other conditions remaining the same, depends on the degree of the disk dynamic balance.

The experiments showed that, with a sufficient high degree of the disks dynamic balance and the absence of disc vibration at a maximum spin, the forced rotation of the driven disk, when the disk gap was more than 2-3 mm, was not excited.

If the gap between disks was 1.0-1.5 mm and the driving disk was completely spun, a slow driven disk turning with a frequency of less than 0.05 1/s was observed. When the driving disk vibration occurred, a driven disk began rotating with a frequency of 5-10 1/s. If the driving disk vibration increased, the driven disc frequency increased up to 20-30 1/s.

At the same time it was ascertained that with a relatively small disk dynamic imbalance the forced disk rotation was excited with the disks gap up to 3 mm. The forced rotation frequency, with other conditions remaining the same, depends on the initial gap between the disks, the less it is, the higher is the rotation speed. When the gap between the disks was more than 4 mm even strong disk vibration did not result in forced rotation excitation of the driven disk.

Thus, the force effect of the driving disk, rotating at a high speed, on mechanically contactless driven disk, resulting in its rotation in vacuum, was experimentally ascertained.

The value of torque, which was developed during this process, was sufficient to rotate the electric motor with the driven disk. The counteraction to this torque, to stop the forced driving disk rotation, required voltage supply to the driven motor, connected with it, which was equal to 0.2-0.8 of the voltage supplied to the electric motor of the driving disk, depending on the gap between the disks and the degree of their imbalance. When the voltage supply of the driving motor was 30 V, to stop the forced rotation of the driven motor with the gap between disks of 1.5 mm, the voltage supply of 12−18 V to the driven disc was required for counter-rotation, and when the gap between the disks was 3 mm, the voltage supply was 5-11 V. When the voltage supply of the driven electric motor was further increased, its disk started to rotate in its own direction (oppositely to the driving disk).

These experiments were carried out without vacuum (under the standard atmospheric pressure in the chamber). While the feeding voltage of the electric motors was the same, the disc rotating speed was lower. In this case, the disk vibration did not occur. The forced rotation of the driven disk was not excited virtually, even when the gap between the disks was less than 1 mm. Under these conditions, only a slow turning of the driven disc with the rotation frequency of less than 0.1-0.3 1/s was observed, i.e. significantly lower than in the case of the driven disk forced rotation in vacuum.

Thereby, as a result of experimental recurrence, it was ascertained that the forced rotation of the initially fixed disk is the consequence of its contactless force interaction with the rotating disk in vacuum. Under these conditions the initial disk precession or vibration preceded its forced rotation. In the absence of vacuum (in the presence of air in the chamber) the forced rotation of the initially fixed disk with a closely located disk, rotating at a high velocity was not virtually excited.

The disks were made of nonmagnetic material and, therefore, other known force interactions were excluded (Barnett effect, etc.).

As the driven disk in our experiments started rotating or its precession was observed, i.e. it received energy from the driving disk, and since the driving disk, with a stable fixed feeding voltage supply of its electric motor, was braked during the driven disk rotation, the driving disk transmitted the part of its rotational energy. The air environment opposed this process.

Conclusion

Proceeding from the analysis of the aforesaid experiment results we can ascertain the following:

1. It was experimentally ascertained that in vacuum the energy was transferred from one (driving) disk, rotating at a high angular velocity to the second initially fixed (driven) disk, which did not have a mechanical

contact with the first disc. At the beginning we observed a precession (or vibration) of the driven disk, then its rotation in the same direction as the driving disk rotated. It was ascertained that the initial disk precession or disk vibration is the necessary condition of the intensification of its forced rotation (when the motor is switched off).

2. It was experimentally ascertained that in vacuum the driving disk rotating at a high velocity has a significant force effect on the closely located driven disk which did not have a mechanical contact with the driving disc. The value of the torque, produced in this process, was sufficiently great not only to rotate the motor with the driven disk, but even to result in the rupture of the disk suspension. When the disk gaps were small, the counteraction to the torque required the voltage supply to the connected electric motor, which was equal to 0.3-0.8 of the voltage supplied to the driving disk electric motor, depending on the gap between the disks and the driving disk imbalance.

3. During a simultaneous high-velocity rotation of the closely located discs, contactless force interaction occurs, resulting in an intense vibration and simultaneous disk distortion, i.e. disk plane bendings, if the disk precession is impossible due to the rigid motor fastening to the electric motor flanges.

4. The force interaction and the disk mutual braking during a long-term contactless rotation in vacuum, result in a significant disc heating (by 50-70 °C). When only one disk rotated no heating was observed.

5. All the effects above mentioned occur when the disks rotate in vacuum. When the disks rotated at a standard atmospheric pressure in the chamber, the disk high-amplitude vibration do not occur, and the plane twist do not occur either. Furthermore, the forced rotation of one disk at a maximum velocity of the other disk rotation is not excited. A slight excitation effect of forced rotation with the frequency less than 0.05-0.1 1/s was observed in the air when the gap between the disks was less than 1 mm.