Research and Practice on Magnetic Shielding Characteristics of Mechanical Watch Shield Materials

Wang Lei
Qingdao Institute of Technology    266300

Abstract. Through the study of the magnetic shielding theory of the cylinder, the actual anti-magnetic performance of the movement of the mechanical watch under the strong DC magnetic field is compared, and finally we learned the influence dimension and magnetic permeability of the magnetic shielding performance. Through the test, the performance test results of the antimagnetic shield of electric iron, martensitic stainless steel, permalloy, etc., verify that the magnetic shielding performance is different under a strong DC magnetic field. For example, Mo alloy has a high initial permeability, but is not as stable as electrical iron and martensite.

1. Introduction
After the parts of the mechanical watch are magnetized under a strong magnetic field, the analysis of the escapement speed control parts is mainly focused on the frequency cycle after magnetization and the direct influence of magnetization. In daily life, everywhere has the magnetic field. For example, the magnetic field strength in the telephone receiver is only 800-3200A/m, but the impact on the travel time of the watch is very huge, and may even cause the mechanical watch to stop moving. In the anti-magnetic performance, when the technical research of the watch develops into the engineering environment of defense, navigation and aerospace, the anti-magnetic performance of the mechanical watch has reached the realm of the original watch.

2. Frequency Cycle Analysis of Escapement Speed Regulation of Mechanical Watches
In general, for the mechanical watch to pass the requirements for anti-magnetic performance, the method adopted is to use the weak magnetic force of the magnetic resistance as much as possible, and the magnetic field affecting the mechanical watch is divided into a DC magnetic field and an AC magnetic field. The anti-magnetic nature of mechanical watches, the former means that the direction of the magnetic field does not change with time. The effect of current on the magnetization of mechanical watches is obvious to all. The most effective method of using a magnetic shield is to study the strength of different magnetic shield materials on the DC magnetic field to reduce the influence of the mechanical movement. In addition to the non-magnetic materials, the latter is to alternate the demagnetization and magnetization of the balance spring. The effect is very small, and it is mainly used for anti-magnetic properties in a strong DC magnetic field environment.

3. Experiment Method
Conducting comparative tests, through the test method of anti-magnetic properties of mechanical watches, we studied two kinds of material: permalloy and electrician pure iron, found that the most sensitive place of permalloy is anti-magnetic shielding performance, in the verification test of magnetic field, in line with the anti-magnetic watch technology of China's light industry. The standard
is equivalent to the international standard for mechanical watch movements, using martensitic stainless steel. As a test for this Alio to prepare the same size of the magnetic shield, due to the difference in antimagnetic properties before and after heat treatment, the corresponding standard requirements can be obtained.

Use the instantaneous differential tester according to the requirements, the qualification criterion for anti-magnetic performance is the movement in the test magnetic field, to ensure that the test will not stop when the test, the remaining effect will not exceed 30s / D, test the intensity can be gradually increased. After leaving the magnetic field for 5 minutes, the maximum antimagnetic magnetic field strength of the shield is finally obtained.

Fig.1 Shielding of magnetic bypass provided by high permeability materials

It can be seen that there are more magnetic field component of the shielded flow shunt, and the performance of the shielding and the calculation method of the equivalent circuit are all beneficial to the shielding effect. According to this principle, the equivalent circuit is used, the parallel resistance is used to carry out the magnetic resistance of the shielding material and the magnetic resistance of the shielding body space, and the shunting of the magnetic field is calculated according to the circuit analysis method, and the corresponding shielding effect is calculated according to the shielding effect. The resulting formula is:

$$H_i = H_0 R S$$

The strength of the magnetic field in the shielding body is divided into the magnetic field strength outside the shielding body and the magnetic resistance of the shielding body. After calculation, the probability of relative magnetic permeability of the magnetic circuit length can be obtained [1].

Table 1. Theoretical and practical comparison of magnetic shielding effectiveness of mechanical watches

| Magnetic shielding material | Relative magnetic permeability | Saturation magnetization M/T | Maximum magnetic field strength H / (A.M-1) |
|----------------------------|-------------------------------|-----------------------------|--------------------------------------------|
| Martensitic Stainless Steel| 5805                          | 1.35                        | 58000                                      |
| Permalloy                   | 156088                        | 0.79                        | 42000                                      |
|                            | 7694                          | 0.85                        | 45000                                      |

In the actual anti-magnetic test, the strength comparison of the anti-magnetic magnetic field is carried out. After the calculation results and the comparison values are studied, it is found that when the shielding thickness reaches a certain performance without shielding, the theoretical shielding effectiveness can be calculated. The higher the magnetic permeability, the deeper the shielding material and the effectiveness of the shielding is higher. According to the relative magnetic permeability of the material, the actual shielding effectiveness is calculated, and the difference analysis is carried out. The calculation formula of the diameter cylindrical magnetic shield and the
thickness of the anti-magnetic shielding cover are used, and the maximum strength of the anti-magnetic shielding cover is compared according to different materials. It is found that the difference between permalloy, martensitic stainless steel and electrical pure iron can reach 100 times, while the difference in heat treatment of permalloy is 2600 times [2], which means that the thickness of the shield is effective in the space where distance protection occurs better.

For the actual shielding effectiveness, not the relative magnetic permeability of the air and the theoretical shielding effectiveness, the relative magnetic permeability of the air is used, the main theoretical calculation is performed on the size-matched movement, and the ratio of the internal storage of the shield to the actual shielding effectiveness is close. In the actual test, the theoretical shielding effect of permalloy and martensitic stainless steel and electrical pure iron should be the relative magnetic permeability of the mechanical movement.

Under the strong DC magnetic field, it has been proved by experiments that after the magnetic permeability of permalloy is heated, the magnetic shielding performance is lower than that of electric iron and martensitic stainless steel, and it is easy to be unstable in the case of impact. Therefore, it is not suitable for use in a strong DC magnetic field environment as a magnetic shield material for watches.

The theoretical shielding effectiveness of permalloy differs from the actual results. The main reason is that the saturation magnetization of permalloy is small, and it is saturated with a strong DC magnetic field, which is lower than the actual shielding effectiveness of permalloy under a strong DC magnetic field.[3].

4. Theory Conclusion
After testing, it was found that the permalloy in the strong DC magnetic field was mainly affected by external conditions. Due to the saturation and magnetization of the permalloy, in addition to the first magnetic permeability, the performance of magnetic shielding. Below martensite and pure iron, saturation will occur under the action of strong DC magnetic field. The parameters of the corresponding soft magnetic material can be referred to. The intensity of saturation magnetization is an important factor to measure the anti-magnetic effect, which satisfies the strong DC magnetic field. Under the premise of anti-magnetic requirements, the test of the anti-magnetic performance of strong DC magnetic field is carried out.

5. Case Analysis
The anti-magnetic performance of a brand watch repair and after-sale watch through the use of cylindrical magnetic shielding theory, compared the actual anti-magnetic performance of the steering rudder mechanical watch under the strong DC magnetic field, the main factor affecting the anti-magnetic shielding performance is the magnetic material of the shield material. The conductivity and size, which leads to the inadequacy of walking time or even stopping. The escapement speed control system parts (mainly the hairspring) will directly affect its frequency cycle. After being magnetized under a strong magnetic field, although the magnetic field strength is not large the influence is final stoppage.

Since the magnetism of the magnet is derived from a current, the magnetic field has the radiation characteristics of the wave particles. Its true appearance is a special material that cannot be seen or touched. The magnetic field is not composed of atoms or molecules. The magnetic field exists around the magnet. The interaction between the magnets is carried out by using the magnetic field as the medium, but the magnetic field exists objectively. Therefore, negative charge is a point object with excess electrons. Current is the motion of charge. The real field source of magnetic field is moving charge, current, magnet or changing space around electric field, electron (with unit negative charge) and two magnet protons (with unit Positive charge). The ultimate component of charge can be formed without contact, and the magnetic field is generated by changes in the motion charge or electric field [4].

From the point of view of modern physics, the magnetic field generated by moving electrons or
moving protons produces a moving charge that forms a special form of matter. In the maintenance, in order to solve the anti-magnetic problem, two kinds of media with different magnetic permeability are placed in the magnetic field, then the magnitude and direction of the magnetic induction are changed, and a cover made of ferromagnetic material is used in the watch. The component is tested for anti-magnetic interference, a cavity made of a soft magnetic material such as permalloy or iron-aluminum alloy with a large magnetic permeability in the cavity in the casing is used to prevent interference from external magnetic fields. In electronic equipment, the components that radiate the magnetic field are covered, and a magnetic shield is added to the outside of the electron beam focusing portion of the oscilloscope tube or the picture tube to isolate it from the external magnetic field, and the magnetic field is abruptly changed at their interface. When the magnetic induction line enters the iron from the air, this method is called magnetic shielding, and the parts that need to be anti-interference are placed inside, and can also be placed in an external magnetic field. It can play the role of magnetic shielding. Make it not interfere with other parts. The magnetic permeability $\mu$ of the casing is higher than the magnetic permeability $\mu$ of the air.

Put a piece of soft iron into the magnetic field. This soft iron generates a magnetic field due to magnetization. The shielded iron shell uses this phenomenon. Inside the soft iron, while outside the iron block, the magnetic lines of force are attracted to the iron. The shells come out and cancel each other out, preventing the components of the radiated magnetic field in the cover from interfering with the two magnetic field directions of the outer parts of the cover. As a result, the distribution of the magnetic lines of force becomes a magnetically shielded state, protecting the interference of the device inside the cover from the external magnetic field.

In practice, it is extremely difficult to achieve complete shielding. Therefore, it is necessary to use a material with a high magnetic permeability, and the watch needs a cover material that can resist the magnetic force and make the magnetic field pass through. There are always some magnetic fields that leak into the shield or out of the shield. Its accuracy will not decrease at all. The external magnetic field and the magnetized soft iron produce the same direction of the new magnetic field. In general, the smaller the magnetic resistance of the shield is, the better the shielding effect is, and the material that can cover the external magnetic field, such as permalloy, silicon steel sheet, etc., when the shielding requirement is high. It is also possible to use multiple layers of shielding. It can be seen that the outer magnetic field can be shielded by making the cover with special materials, so that the internal parts are not affected by the external magnetic field, so that the iron parts inside the watch will not be magnetized. This phenomenon is called magnetic shielding in physics.

If the watch is placed near the magnet, the joints should be as small as possible, and not too thin. The structural design of the shield is handled according to the above principle of magnetic shielding. Especially when the hairspring is magnetized, the movement in the mechanical watch is made of steel, and the steel movement is magnetized. For example, when the power transformer needs to be shielded, it must not be placed near the magnet because it cannot be anti-magnetic, and the magnetic line is largely deviated from the normal, so it contracts strongly. Therefore, most of the magnetic field lines pass through the walls of the casing, and the magnetic induction lines are few. This achieves the purpose of magnetic shielding. Although very expensive, it can be seen that the small magnetic needle will not be attracted by the magnet outside the ring, and the magnetic shielding inductance meter will stop immediately [6].

If in the low-frequency alternating magnetic field, even if the watch is placed near a strong magnetic field, as for the gold and silver watches with gold or silver as the outer casing, the magnetic shielding of the mechanical watch should achieve a good shielding effect, at the seam of the production. To be tight, put a small compass in a hoop without affecting the parts that are shielded inside. It provides a smooth magnetic circuit for the external disturbance magnetic field, which can protect the steel parts inside the watch. Interestingly, due to the influence of the magnetic force, it is important for the shielding body to design the shielding body. Reducing the air gap, the type of material chosen has a significant impact on its performance and cost, such as high magnetic permeability materials (Mumetal iron-nickel alloy), such as a nickel alloy with a high magnetic
permeability of 80%, with iron or steel the outer casing of the watch has a relatively thin thickness of 0.002-0.125 inches. Since the magnetic shielded casing has a small magnetic resistance, it must be a frequently used shielding material, which is originally iron which is easily magnetized. In order to prove this, when shielding is required, the magnetic lines of force are short-circuited through the iron shell, and the magnetic shielding materials are selected according to their respective characteristics. These alloys are typically used due to the effect of changing the direction of the low-frequency magnetic field, especially the magnetic saturation performance and permeability, choose the right material to meet the target requirements. In-depth understanding of the characteristics of various common shielding alloys, a full understanding of these very different performance, so that when magnetic shielding is required, a reasonable material is used to make the magnetic shield, especially when the magnetic field is reduced in a small space it can play its role.

6. Conclusion
The mechanical deformation of the mechanical watch's escapement speed parts under a strong magnetic field produces a frequency cycle. In the case of inaccurate walking, the anti-magnetic performance test can be carried out. Now in the field of defense, navigation and aerospace, whether it is engineering. The environment is also a civil environment. It has higher requirements for the anti-magnetic performance of mechanical watches. It is even required to meet the strong magnetic field environment under extreme conditions. Therefore, the most effective method is to use anti-magnetized materials and use magnetic shields. The method reduces the influence of the magnetic field on the mechanical movement and obtains the maximum antimagnetic magnetic field strength.

References
[1] Bao Xianyong, Li Bei, Zhang Ming, et al. Research on magnetic shielding characteristics of mechanical watch shield material [J]. Ordnance Materials Science and Engineering, 2010, (3): 32-34.
[2] Zhao Lei. A non-contact RF mechanical watch: China, CN201521076076.9[P]. 2016-06-22.
[3] Li Bei, Bao Xianyong, Chen Jie, et al. High-precision multi-function mechanical watch movement [Z]. Shenzhen FIYTA (Group) Co., Ltd. 2010.
[4] Zhong Xinyuan. Research on elastic alloy RC-1 for high stability antimagnetic watch spring [Z]. Chongqing Special Steel Factory.
[5] Wang Xiaoliang, Xu Ke, Yang Zheng, et al. TinyLoc: An indoor positioning algorithm for wearable devices with limited energy consumption[J]. Chinese Journal of Computers, 2017, (8): 1813-1828.
[6] Li Bei, Bao Xianyong, Chen Jie, et al. High-precision multi-function mechanical watch movement [Z]. Shenzhen FIYTA (Group) Co., Ltd. 2010.