Experiment research on coupling effects of low frequency pulse magnetic field on common shielding materials

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Abstract: Cold-rolled steel plate, galvanized sheet iron, pure iron plate, aluminum plate, copper plate materials are common used in engineering as electromagnetic shielding materials. Because of the different physical properties, the materials show different coupling properties to the electromagnetic radiation field with different components. The coupling effects of low frequency pulse magnetic field of the materials are researched in this paper, the coupling rules are obtained, and the effects of thickness, permeability, conductivity, shielding size and field source parameters on the coupling rules are analyzed. The research results provide basis and reference for the engineering application.

Keywords: low frequency pulse magnetic field; shielding material; coupling effects; experiment research

Cold rolled steel, galvanized iron, pure iron plate, aluminum plate, copper plate material are common used in engineering and electronic equipment as electromagnetic shielding materials , which are mainly used for making shielding cavity of electromagnetic shielding room and equipment. Referencs [1-3] how the research work of the shielding performance of metal shielding materials on low frequency magnetic field. However, the above researches are mainly based on single frequency continuous wave or fast edge narrow pulse magnetic field, and some research results are got based on numerical simulation, lacking of experiment data. Based on this situation, this paper carries out the experiment research on the coupling effects of the shielding bodies, which are made of the above five metal materials, of low frequency pulse magnetic field. Some coupling rules of low frequency pulse magnetic field are obtained, which can provide basis and reference for shielding performance evaluation of shielding body, material selection of electromagnetic shielding protection design and engineering electromagnetic pulse protection.

1. Research methods and approaches.

According to the actual use mode of shielding body, the five metal materials are made for shielding body model which are tested in low frequency pulse magnetic field. The results are obtained by measuring the distribution and variation of the internal and external fields of the shield model. According to the existing research results and theoretical analysis, the effect of small-sized holes on the coupling effects in low frequency magnetic field is small. Therefore, the shield models are mainly made by riveting method. The shielding bodies of pure iron plate, copper plate and aluminum plate are fixed by riveting method, while the shielding bodies of cold rolled steel plate and galvanized iron plate are welded and fixed by carbon dioxide gas shielded welding method. The specific dimensions of the tested models are shown in table 1.

According to GB 12190 - 2006 method for measuring shielding effectiveness of electromagnetic shielding room, the amplitude and waveform changes of magnetic induction intensity of pulse magnetic field at the same measuring point before and after the existence of shielding body are tested, as well as the distribution characteristics of field strength at different positions are compared and analyzed to determine the coupling rules of low frequency pulse magnetic field.Considering the eddy current magnetic field effect and the low magnetic resistance pathway distribution features, the field intensity distribution and its variation rules against wave central region, central region, shield the internal wall inside and outside.

2 test conditions

2.1 low frequency pulse magnetic field simulation test system.

The low frequency pulse magnetic field simulation test system is used for generating the low frequency pulse magnetic field required by the test, which is mainly composed of a high-voltage energy storage capacitor, a high-voltage discharge switch, a magnetic field simulation solenoid and related control equipment. The pulse magnetic field is generated by the spiral pipe, and the test area is positioned in the solenoid. The basic principle of the system is shown in figure 1. RLC series discharge circuit is used to discharge large solenoid through high voltage energy storage capacitor to form pulse current, so as to generate pulse magnetic field in the solenoid. The circuit parameters such as r, l and c in the simulation system can be adjusted to generate pulse magnetic field with different characteristic parameters.

2.2 low frequency pulse magnetic field measurement system.

The pulse magnetic field measurement system consists two sets of measuring devices, which are tested by electromagnetic induction principle and hall effect principle respectively. Electromagnetic induction principle measurement system is composed of pulse magnetic field sensor, electro-optical converter (optical transmitter), electro-optical converter (optical receiver), digital oscilloscope and signal transmission fiber. The system can effectively suppress the interference of strong electromagnetic field to the measuring system, and can test the pulse magnetic field form 100 Hz to 1 MHz. The physical photos of each component of the system are shown in figure 2.

Hall effect principle measurement system is mainly composed of hall magnetic field test probe, shielded transmission cable, hall probe power supply, 24 - bit acquisition card and computer, which can test the pulse magnetic field from DC to 60 kHz.

The coil sensor is more flexible to use and the sensor uses optical fiber to transmit signals, which has stronger anti-interference ability. So, the test process mainly uses coil sensor, hall sensor is mainly used to calibrate the coil sensor.

The test scene of low frequency pulse magnetic field is shown in figure 3.

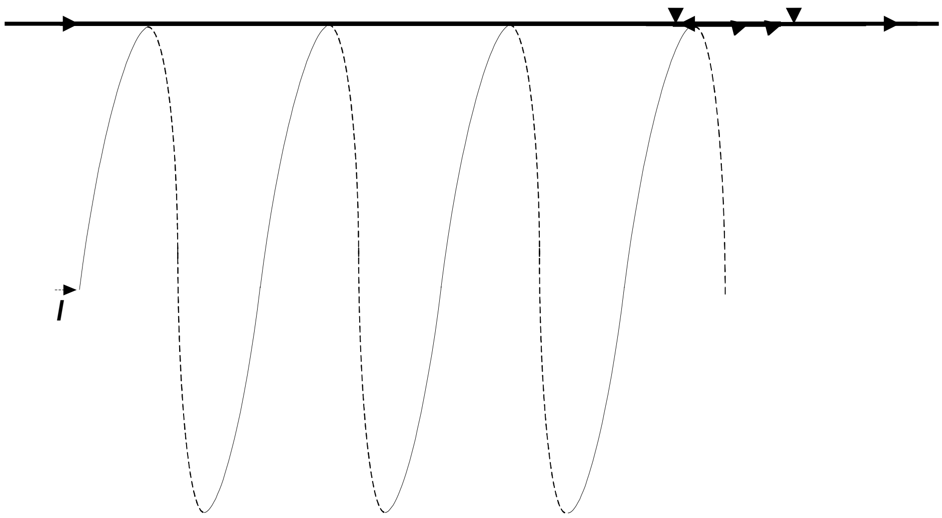

Fig. 2 schematic diagram of coupling effect test process of low frequency pulsed magnetic field to shield

3. Measurement results and analysis.

During the test, the key parts of each shield model specimen were tested, and the typical waveforms of the measured magnetic field source field and the center point inside the shield are shown in fig. 4. Some typical results are given below based on material properties.

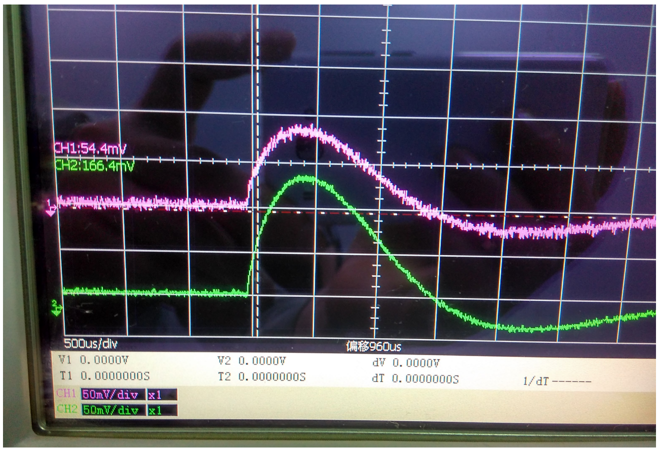

Fig. 4 typical waveforms of the magnetic field source field and the center point inside the shield

3.1 the change rule of the field strength and difference of the shielding body in the center of the surface of the wave surface.

The variation rules of the center position of the inn and outer surfaces of the wave-front surface are shown in table 2, with the increase time of 300 subtle and the pulse width being 1.2 milliseconds. As can be seen from table 2, the overall amplitude of the center of the wave-front surface is small due to reflection, eddy current cancellation and other reasons. with the increase of the magnetic field strength, the overall amplitude rises slowly and is relatively stable. especially for the L1 shield with the thickness of the wave-front surface of 2mm, the amplitude of the center of the wave-front surface hardly changes.

As shown in fig. 5, the variation of the magnetic field components in the wave-front face of the four types of shielding bodies is shown in the figure. as can be seen from the figure, the magnetic field components in the wave-front face of the three types of ferromagnetic shielding bodies gradually increase with the increase of the magnetic field strength, the growth rate gradually decreases, and finally, the trend of decrease. In terms of material thickness and permeability, the absolute value of ferromagnetic material component with high permeability is significantly higher than that of steel plate material, while the magnetic flux increases with the increase of thickness in the same material. The above characteristics can just explain the positive correlation between permeability and thickness and shielding performance, while the decrease of the total component in the wave-front shell is related to the approximate magnetic saturation state of the shielding body, which is described in detail in another paper. Because the magnetic permeability of the aluminum plate shield is basically the same as that of the air, the difference between the magnetic field of the inner and outer surfaces of the wave-front surface of the aluminum plate shield is relatively stable, and the magnetic field component lost in the wave-front surface shell is basically unchanged.

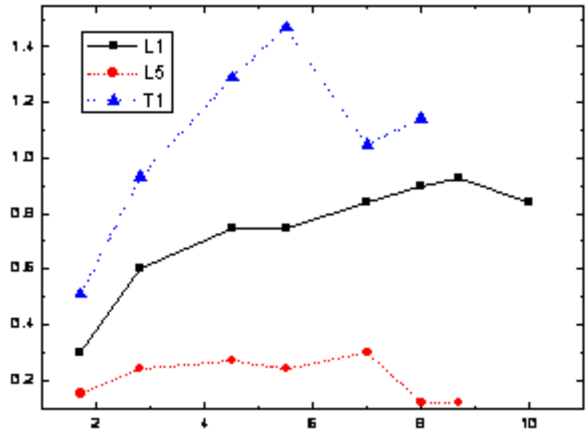

Fig. 5 variation law of magnetic induction intensity inside the wave-front surface

3.2 the variation of magnetic field intensity on the shield face.

Under the action of S2 field source 2.8 mT magnetic field, the change law of the field strength of the outer surface of the wave-front surface of several shield models from the center to the periphery is shown in table 3 below. for the convenience of explanation of the change law, the unit in table is mV. The position of each measuring point is shown in figure 6.

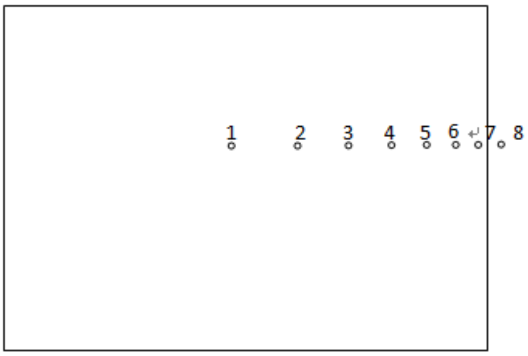

Fig. 6 distribution of field strength measurement points on the wave-front surface of the shield

It can be seen from the table that the change law of G1 shield's wave-front surface is the process of decreasing first and then increasing. in the table (- 5 / + 4) indicates the bidirectional waveform of negative first and positive second. the amplitude of G5 shield's central region is relatively stable, and increases greatly at the edge of the shield. G2 small shield shows the trend of steadily increasing outward from the central region. L1 is similar to G5. The common point of the four shielding bodies is that the magnetic field at the edge of the shielding body is several times larger than the field strength at the center point, namely 3.4 times, 9.4 times, 9.5 times and 7 times respectively, the larger the size of the shielding body, the larger the magnetic field difference at the center and the edge, the higher the magnetic permeability, the higher the field strength at the center area of the wave-front surface, and the visible magnetic field distribution rule is obviously influenced by the size and the magnetic permeability of the shielding body, which is related to the eddy current strength formed by the pulse magnetic field. The distribution law of magnetic field on the surface of a single steel plate is basically the same as that of the field strength on the wave-front surface of the shield, which also verifies the reliability of the test results.

As for the fluctuation phenomenon of L1 surface magnetic field, the reason is complex, which is not only related to the shield size, but also related to G1 internal steel pipe keel structure. This phenomenon is not related to the research content of this topic, and will not be considered for the time being.

3.3 the influence of shielding body on external radiation field.

The effect of shielding body on external radiation field is illustrated with copper shield. The field distribution at different distances of the shielding body was tested under the effect of 2.8mT strength magnetic field, and the specific test position was shown in fig.5. Among them, 1# is close to the shielding body; 2# is located 10cm from the side; 3# position is 20cm from the side; The position is 30cm from the side. 5# position is 50cm from the side; 6# is located 60cm from the side; The position is 80cm from the side. The location is 100cm from the side. The measured actual magnetic field peak results are shown in figure 6 and table 4.

It can be seen from the test results that under the action of the pulse magnetic field with rise time of 300 μ s, the magnetic field gradually decreases to a stable empty field value in the radial direction of the south side, which is mainly due to the eddy current effect of the copper shield facing the wave to the low-frequency magnetic field, so that the magnetic field near the side is enhanced, and the farther the distance is, the smaller the influence of the superposition magnetic field of the eddy current effect is, the closer the test results are to the real empty field. In the axial direction of the wave-front surface, in the range of 0 ~ 100 cm, the further away from the wave-front surface, the stronger the magnetic field, and the magnetic field value is basically stable at 2.78 mt when the distance is more than 80 cm. That is, the measured magnetic field value of the 1m copper shield can represent the true value only when it is at least 80 cm away from the wave-front surface. This is mainly due to the change of the magnetic field distribution caused by the reflection of the shield on the low frequency magnetic field. At the same time, it can be seen from the table that the law of different characteristic parameters under the action of pulse field source is basically the same.

3.4 the relationship between shielding effect and pulse magnetic field intensity.

The magnetic field intensity and its variation in the cent of the eight shields under the action of a field source （s1）with a rise time of 300 mu s and a pulse width of 1.2ms are shown in table 5.

Combining the shielding model parameters and shielding effectiveness data, it can be seen from fig. 9 that the shielding effectiveness of the center of the shielding body has the following rules: first, the shielding effectiveness of the shielding body under the action of low-frequency pulse magnetic field is low as a whole, the L2 cold rolled steel plate model with the thickness of 2mm of the shell is not more than 30 db at most, and the D1 galvanized iron plate model with the thickness of 0.75 mm of the shell is less than 15 db at most. Second, the shielding effectiveness of the shield as a whole with the increase of the magnetic field strength gradually decreased, high permeability of pure iron shield change amplitude is larger, the amount of change is about 15 db, this phenomenon is related to the phenomenon of magnetic saturation. Third, shielding effectiveness is directly related to material permeability and shielding shell thickness. for example, t1 pure iron plate with shell thickness of 1 mm has higher permeability, and its shielding effectiveness is similar to that of L2 cold rolled steel plate with shell thickness of 2 mm, the maximum value is about 25 db. because of thickness difference, the shielding effectiveness of L2 cold rolled steel plate with shell thickness of 2 mm and D1 galvanized iron plate with shell thickness of 0.75 mm differs by more than 15 db. Fourth, the shielding performance of non-ferromagnetic aluminum plate and brass plate shielding body is relatively stable.

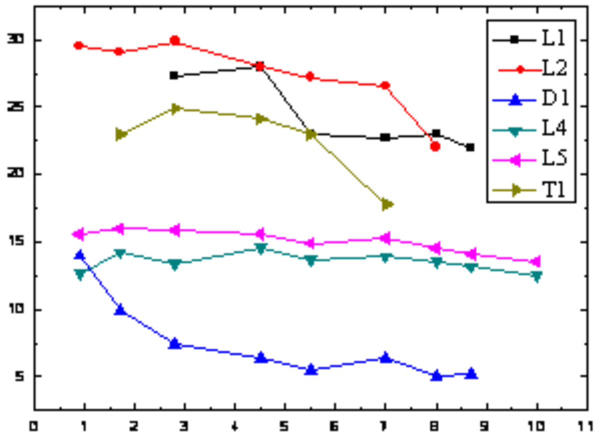

Table 5 shielding body model under the action of S1 field source shielding body center field strength values

3.5 comparison of shielding effectiveness under different characteristic parameter field source.

Model L1 (1m aluminum plate shield) is used to illustrate the relationship between shielding effectiveness and field source characteristic parameters. the shielding effectiveness data and variation law of L1 center position under the action of three characteristic parameters of magnetic field source are shown in table 6 and fig. 8. It can be seen from the test results that the higher the rising edge, the higher the shielding effectiveness. the shielding effectiveness under the three conditions are about 15 db, 17 db and 26.5 db respectively.

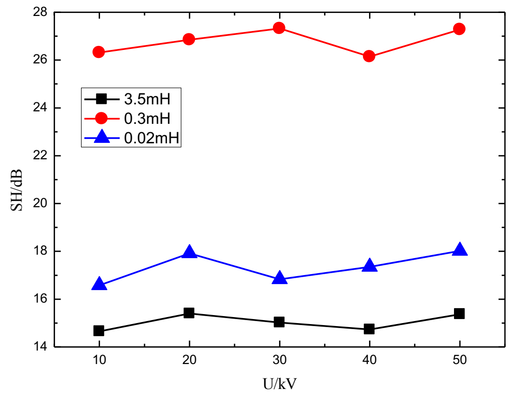

Fig. 8 variation trend of shielding effectiveness under magnetic field with different characteristic parameters

4 Conclusion

According to the above experimental research and theoretical analysis, we can get the coupling effect of common shield on low frequency pulse magnetic field:

(1) the shielding body can obviously affect the distribution of the space magnetic field around the shielding body. the field strength of the wave-front and back surface of the shielding body is obviously weakened. the change rule of the field strength is the same as that of the conductivity. the field strength near the outer surface of the side wall around the shielding body is obviously increased. the higher the permeability is, the larger the size of the shielding body is and the more obvious the increase is. The degree of influence is limited by the parameters (size, material, thickness, etc.) of the shield itself; In the process of using " specimen method" to test the shielding related characteristics in magnetic field environment, it is necessary to pay attention to the influence distance of shielding in the position of the empty field test probe.

(2) the shielding effectiveness of common shielding materials for low frequency pulsed magnetic field is not high. for pulsed magnetic field with rise time of 300 microseconds, the shielding effectiveness of cold rolled steel plate, aluminum plate, brass plate and galvanized iron sheet shielding body is about 14 db, 14 db, 10 db and 10 db, respectively. the change rule of shielding effectiveness is opposite to the rise time of pulsed magnetic field.

(3) the shielding effectiveness of the shield is greatly affected by the electromagnetic parameters of the shield material. from the test results, the larger the permeability and conductivity, the higher the shielding effectiveness of the shield. If that shield performance of the pure iron plate shielding body is lar than that of other shielding bodies, the shielding performance of the aluminum shield body is better than that of the brass shielding body.

(4) the stability of shielding performance is related to material electromagnetic parameters and field source strength. the shielding performance of aluminum plate and brass plate is stable, while that of cold rolled steel plate and galvanized iron sheet is obviously decreased, which is due to the difference of shielding mechanism between the two.

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