Design and Experimental Study of Rail Degaussing System Based on Permanent Magnet

Yongkang Li[1] and Yaowen Zhang[2]*
[1]*China Railway ERYUAN Engineering Group CO., LTD, Chengdu, China*
[2]*School of Physical Science and Technology, Southwest Jiaotong University, Chengdu, China*

Keywords: Rail Degaussing, Permanent Magnet, Electrified Railway, Abnormal Magnetic Signal.

Abstract: In order to eliminate the abnormal magnetic signal of electrified railway rail, a permanent magnet degaussing array for rail was designed based on the mechanism of permanent magnet degaussing method. A permanent magnet degaussing device suitable for rail was developed by degaussing array, and its function was verified. The test results showed that the permanent magnet degaussing device can reduce the abnormal magnetic signal of rail surface amplitude of 100Gs to less than 5Gs, which was lower than the automatic over-phase induction threshold of locomotive 36Gs, indicating that the function of the degaussing device meet the requirements.

1 INTRODUCTION

In the process of long-distance travelling, the locomotive will pass through the power supply areas of different traction substations, and there is an automatic split-phase zone at the intersection of two traction substations. In order to prevent phase-to-phase short-circuiting, the automatic split-phase zone is prohibited from energizing, and the locomotive needs to independently complete the disconnecting and closing action of the main circuit breaker in this zone. In the automatic over-phase area of the entrance and exit are set up in the buried magnet, locomotive head is equipped with a sensor, when the locomotive passes through the magnet, the inductor will receive the magnetic signal and send out a pulse signal, transmitted to the microcomputer system to control the main circuit breaker opening and closing. In the process of locomotive travelling, if the abnormal magnetic signal from the rail surface is larger than the sensing threshold of the car inductor 36Gs (Li Teng, 2022; Li Lifeng, 2022; Ma Chunlian, 2022), the car inductor can also sense the signal, which leads to an abnormal tripping of the main circuit breaker of the locomotive, and has an impact on the normal operation of the locomotive. The maximum remanent magnetism of the rail has reached 100Gs by the railway field measurement, therefore, eliminating the abnormal magnetic signal is of great significance for the normal operation of the locomotive.

The traditional demagnetization methods for magnetic pipes in industry are DC demagnetization method, AC demagnetization method and DC-AC composite method (Tan Xiao, 2020; Liu Shaozhu, 2020; Xu Congcong, 2020), but these methods are not applicable to the demagnetization of rails. Because the rails are fixed on the railway, it is not possible to wrap the cable around them, and the high-voltage power supply required for degaussing by DC and AC degaussing method is not suitable for field operation. Permanent magnet demagnetization method is used to demagnetize workpieces by arranging the magnets without the need for power supply and winding cables, which overcomes the drawbacks of the traditional demagnetization methods and is suitable for demagnetization of steel rails. A permanent magnet demagnetization device has been developed for oil and gas pipelines by the team of Shelikhov G S, which consists of two to three rings of magnets, with the polarities of the neighbouring rings arranged in opposite directions. magnetic field with reduced amplitude and direction change, so as to achieve the purpose of demagnetization. In order to eliminate the residual magnetism of oil and gas pipelines after leakage detection, Yang Xiaoli designed a demagnetizing device that can walk inside oil and gas pipelines, which is installed with two magnet rings with opposite poles and different mounting heights,

Li, Y. and Zhang, Y.
Design and Experimental Study of Rail Degaussing System Based on Permanent Magnet.
DOI: 10.5220/0012875900004536

In *Proceedings of the 1st International Conference on Data Mining, E-Learning, and Information Systems (DMEIS 2024)*, pages 17-21
ISBN: 978-989-758-715-3

and generates a decreasing commutative magnetic field in the process of walking to demagnetize the pipelines. The robot designed by Zhang Jiawei can adapt to the variable diameter pipe and detect efficiently, according to the magnetization simulation of typical deformation types and deformation of different lengths and widths, the basic law of magnetic field intensity change is obtained: the types and characteristics of deformation in pipelines can be predicted according to the simulation parameters, which is of significance for the development of deformation detection technology in oil and gas pipelines. The rotating permanent magnet demagnetization machine designed by Li Xibi uses rare earth permanent magnet material NdPeB as a magnetic source to make a magnetic roll or abstract disk, and uses a small power motor to drive it to turn, and generates an alternating magnetic field in space to demagnetize the workpiece. The demagnetization field has adjustable frequency and magnetic field gradient, high work efficiency and long service life. At present, the permanent magnet degaussing method has limited application scenarios, and has not been studied in depth in the railway field, and the magnetic field amplitude that can be eliminated by the existing permanent magnet degaussing device for oil and gas pipelines is relatively small, and the research on the degaussing mechanism of permanent magnet is not in-depth and detailed enough, and the relevant degaussing method has not formed a system. Therefore, the development of permanent magnet degaussing device for rails is necessary.

Based on the principle of permanent magnet degaussing, a permanent magnet degaussing array is designed in the paper. According to the degaussing array, rail structure and railway environment, the permanent magnet degaussing device is developed, and the degaussing effect of the permanent magnet degaussing device is examined through the function verification test.

2 PRINCIPLE OF PERMANENT MAGNET DEMAGNETISATION

The demagnetization of magnetic materials generally takes advantage of their hysteresis properties. For workpieces with a certain amount of remanent magnetization, the core of the demagnetization method is to apply a decreasing and alternating magnetic field to the remanent magnetized parts. The traditional method of demagnetization in industry is to wind a cable around the workpiece, energize the cable, and change the size and direction of the current to produce a variable magnetic field on the surface of the workpiece, as shown in Fig. 1 for the magnetic field amplitude curve of the AC demagnetization method. Permanent magnet demagnetization is achieved by increasing the distance between the magnet and the surface of the workpiece and changing the N and S poles to achieve changes in the magnetic field.

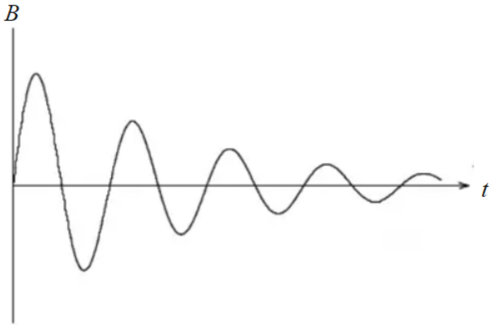


Figure 1: Magnetic field amplitude curve of AC degaussing method.

3 DESIGN OF DEGAUSSING ARRAYS

3.1 Arrangement of Degaussing Units

From the principle of demagnetization, it can be seen that the magnet array needs to generate a commutative magnetic field with decreasing amplitude during the movement, so the magnet units are arranged in a stepped row, and the magnetic poles of two adjacent magnet units facing the surface of the rail are opposite. As shown in Fig. 2, the black unit is the permanent magnet, and the rail is below. The degaussing array generates an AC-like magnetic field on the rail surface.

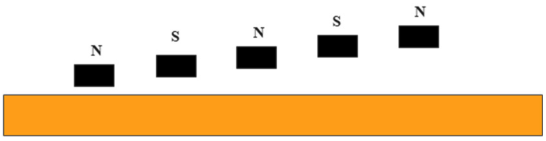


Figure 2: Arrangement of degaussing units.

3.2 Parametric Design of Degaussing Arrays

As shown in Fig. 3 for the relevant parameters of the rail degaussing array, the number of degaussing units is set to three in order to make the degaussing array not to affect the unmagnetized area and not to cause waste. When the magnetic field of the rail surface for the N pole, it is composed of three magnets array N-S-N to eliminate it; when the magnetic field of the rail surface for the S pole, it is composed of the last two magnets S-N to eliminate it; when the surface of the rail is not magnetized, the first magnet magnetized rail, the last two magnets composed of an array S-N can eliminate the effect. The parameters to be determined for the demagnetizing array are the horizontal spacing between the magnet units as *d* and the vertical distance between the lower surface of the magnet units and the rail surface l_1,l_2,l_3.

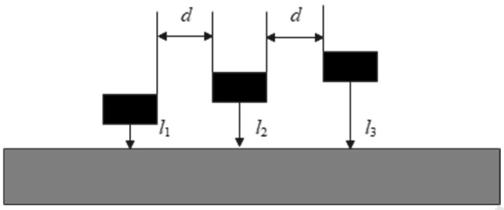


Figure 3: Arrangement of degaussing units.

In order to make the magnet units unaffected by each other, it is necessary to determine the maximum range of action of the magnet's magnetic field. The three sizes of rectangular NdFeB magnets used in the degaussing array have a maximum field range of 90 mm, so the horizontal spacing d of the magnet units in the design of the magnet array should be greater than 90 mm, and the horizontal spacing d is taken to be 100 mm.

From the principle of permanent magnet demagnetization, it can be seen that the demagnetization process of the permanent magnet on the rail is the process of using the attenuating magnetic field to make the hysteresis line constantly converge to the origin of the coordinates. Therefore, before designing the demagnetizing height of the demagnetizing array, it is necessary to obtain the hysteresis lines corresponding to different remanent magnetism of the rails. The rail is made into a circular sample as shown in Fig. 4, Fig. 5 is the experimental schematic diagram, the hysteresis line of the sample is measured by the oscilloscope method, the test loop is divided into the excitation loop and the induction loop, the excitation loop is energized with an AC power at an industrial frequency, and then the voltage at the ends of the sampling resistor and the capacitance at the ends of the RC integrator are measured, and the voltage data are then calculated to obtain the hysteresis line of the rail, and the hysteresis line of the rail can be obtained by changing the amplitude of the excitation voltage. By changing the amplitude of the excitation voltage, different hysteresis loops can be obtained. The three hysteresis lines corresponding to the rails with remanent magnetism of 125Gs, 62Gs and 32Gs are obtained through experiments, and the perpendicular distances l_1, l_2 and l_3 from the magnet unit to the plane of the rails are determined to be 6mm, 12mm and 18mm, respectively.

Figure 4: Samples of rail rings with coils wrapped around them.

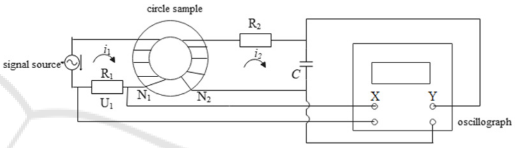


Figure 5: Hysteresis loop test schematic.

The equivalent magnetic circuit equation of the excitation circuit can be expressed as:

$$N_1 I = Hl \tag{1}$$

$$I = \frac{U_1}{R_1} \tag{2}$$

$$H = \frac{N_1 U_1}{l R_1} \tag{3}$$

Where H is the intensity of the excitation magnetic field, I is the current of the excitation loop, U_1 is the voltage of the excitation loop, R_1 is the resistance of the excitation loop, N_1 is the number of turns of the excitation coil, and l is the average length of the measured magnetic circuit. A channel of the oscilloscope is connected to both ends of the sampling resistor R1 to measure its voltage, and then the measured voltage data can be converted into magnetic field strength data.

The equivalent magnetic loop equation of the detection loop can be expressed as:

$$RC\frac{dU_c}{dt} + U_c = N_2 S \frac{dB}{dt} \tag{4}$$

$$B = -\frac{R_2 C}{N_2 S} U_c \tag{5}$$

Where B is the magnetic induction intensity of the rail sample after magnetization, resistance R_2 and capacitor C constitute an integral circuit, and the value should meet , U_c is the voltage at both ends of the capacitor, N_2 is the number of turns of the detection coil, and S is the sample cross-section area. The other channel of the oscilloscope is connected to both ends of the capacitor C to measure its voltage, and then the measured voltage data can be converted into magnetic induction intensity data. Alternating current changes one cycle, the oscilloscope can display a complete hysteresis loop of the magnetic material sample, if you want to measure the hysteresis loop corresponding to different coercivity and remanence, just change the voltage amplitude of the AC power supply.

The final design of the permanent magnet degaussing array is shown in Fig. 6. Five groups of degaussing arrays are set up for the whole rail, one group of degaussing arrays is set up on the top surface, and two groups of degaussing arrays are set up on the left and right sides of the top side and the middle surface, and they are symmetrically distributed. The parameters of each array are consistent except for the size of the magnet unit.

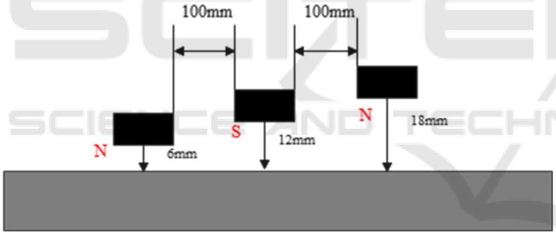
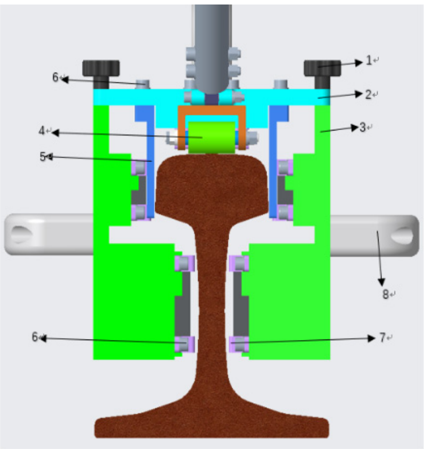


Figure 6: Permanent magnet degaussing array.

4 DEVELOPMENT OF PERMANENT MAGNET DEGAUSSING DEVICE

4.1 Model of Permanent Magnet Degaussing Device

Based on the permanent magnet degaussing array, rail structure and railway environment, a model of the permanent magnet degaussing device was designed and a sample of the permanent magnet degaussing device was developed, and the model and sample of the permanent magnet degaussing device are shown in Fig. 7.



1-Hand screwed bolt 2- Top magnet fixing platform
3- Both sides magnet fixing platform 4- Roller
5- Anti-vibration slot 6- Fixing bolt 7- Pressure plate
8- Handle

Figure 7: Model of permanent magnet degaussing device.

4.2 Model of Permanent Magnet Degaussing Device

After magnetizing the rail surface, the permanent magnet demagnetization device is used to demagnetize the rail, and the demagnetization process is shown in Fig. 8. From the demagnetization results in Fig. 9, it can be seen that the magnetic field on the rail surface can be demagnetized to within 5Gs, which is lower than the induction threshold of 36Gs for the locomotive inductor, indicating that the demagnetization effect meets the requirements. After the demagnetizing device passes through the unmagnetized area of the rail, the magnetic field on the rail surface does not change by more than 5Gs, so the influence of the demagnetizing device on the unmagnetized area can be ignored when walking on the rail surface.

Figure 8: Degaussing experiment diagram.

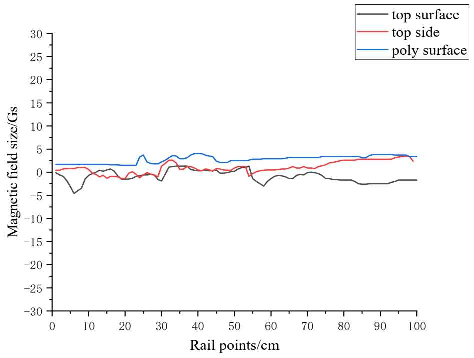


Figure 9: Degaussing experiment diagram.

5 CONCLUSIONS

Based on the degaussing mechanism of permanent magnets, a linear stepped degaussing array was constructed in the paper, and the parameter design of the degaussing array was completed according to the principle of degaussing of permanent magnets and magnetic characteristics of rails, forming a permanent magnet degaussing system for rails. Based on the degaussing array, rail structure and railway environment, a permanent magnet degaussing device for rails was developed in the paper, which overcomes the shortcomings of the traditional degaussing device that requires power supply and winding cables, and was more portable and safe. The permanent magnet degaussing device was tested for functional verification, and the test results showed that the degaussing effect of the device on rails meets the requirements, and it had strong applicability for degaussing of rails in electrified railways. The degaussing device has a strong inspiration for the development of rail mature degaussing equipment in the future.

REFERENCES

Li Teng, Li Lifeng, Ma Chunlian, et al. A study of the effect of heavy railway traction reflux on split-phase induction devices. Electric Railway, 2022, 33(4): 84-91.

Tan Xiao, Liu Shaozhu, Xu Congcong, et al. Comparative analysis of degaussing technologies for oil and gas pipelines at home and abroad. Technology Supervision in Petroleum Industry, 2020, 36(10): 46-53.

Shelikhov G S, Lozovsky V N, Krasilnikov V A, et al. Device for demagnetization of main pipelines: RU2285254. 2006-01.

Shelikhov G S. Demagnetizing technique for main pipelines. Materials Evaluation, 2014, 72(6).

Yang Xiaoli, Zhao Hong, Wang Weibin, et al. Magnetization characteristics of oil and gas pipeline and demagnetization. China Petroleum Machinery, 2019,47(3):111-116.

Zhang Jiawei, Zhao Hong. Research on design and deformation detection of in-pipe snake robots. Journal of Chongqing University of Technology(Natural Science) , 2022, 36(11): 312-319.

Li Xibi, Ding Xueqiang, Guo Jinru. Application of rotating permanent magnetic demagnetizer. Journal of Harbin Bearing, 1994(02): 27-33.

Liu Siran, Chen Jianyun, Yue Guo. Calculation of impedance parameter matrix of traction network impedance considering steel rail ferromagnetic properties. Journal of East China Jiaotong University, 2018, 35(4): 97-105.

Chen Y, Li A, Xie J, et al. Three-dimensional positioning of rotating permanent magnet in pipeline based on multi-point magnetic field optimization method.The 32nd International Ocean and Polar Engineering Conference. OnePetro, 2022.

Wikkerink D, Mor A R, Polinder H, et al. Magnetic signature reduction by converter switching frequency modulation in degaussing systems. IEEE Access, 2022, 10: 74103-74110.

Ng A K, Martua L, Sun G. Dynamic modelling and acceleration signal analysis of rail surface defects for enhanced rail condition monitoring and diagnosis.2019 4th International Conf. on Intelligent Transportation Engineering (ICITE). IEEE, 2019: 69-73.