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Mine acoustic wave signal generator

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Abstract. Based on the requirement of mine acoustic wave technology for the signal generator, this paper aims to explore the key factors affecting the amplitude of the output acoustic signal of rare earth giant magnetostrictive materials (RE-GMM), including bar size, magnetic field strength and pre-stress in order to set an optimal plan based on the influence of various factors on output signal amplitude. This paper establishes a test platform for measuring the output performance of the acoustic signal generator and to test the prototype. Result verifies the correctness of the scheme.

1. Overview

The mining acoustic wave transmission technology is a kind of new technology that transmits the measurement data of the bottom of the hole from the bottom to the orifice by using the characteristics of the sound wave transmission with the drill pipe as the transmission medium. As shown in Figure 1, the equipment encodes measurement data and sends the acoustic signal according to the coding format. Then, the acoustic signal is sent coupling to the orifice along the wall of drill pipe. The vibration sensor sticking on the end of the drill pipe converts the acoustic signal into electrical signal and decodes and displays the electrical signal from the vibration sensor. This method of data transmission takes the drill pipe wall as the transmission medium, making it more universal in application and suitable for directional drilling of conventional holes and shallow holes.

One of the keys to realize mine acoustic wave transmission is to find a reliable acoustic wave signal transmitting device that can be installed in the drill pipe for coal mines underground. According to latest research on magnetostrictive materials, using rare earth giant magnetostrictive alloy as the core material to design a signal source suitable for coal mines underground.

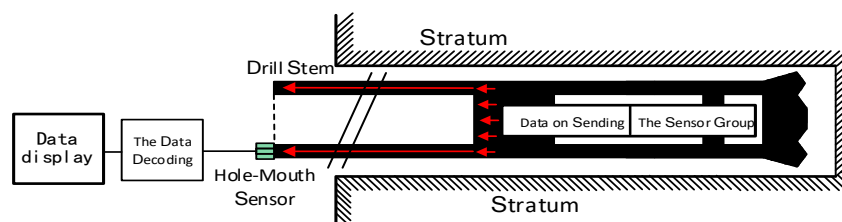


Figure 1. The Ideal Model of Drill Pipe Column.



2. Rare earth giant magnetostrictive material

RE-GMM, as the latest magnetostrictive functional material in the world, is a kind of efficient Tb-Dy-Fe alloy. The strain value of piezoelectric ceramics in the low magnetic field reaches 1500-2000 ppm, which is 5 to 8 times that of traditional magnetostrictive materials such as piezoelectric ceramics, 40 to 50 times that of nickel-based materials. That is why it is called the giant magnetostrictive material. RE-GMM can produce high stress and high energy density, and it responds instantly with high reliability and high Curie temperature. It also boasts outstanding electromagnetic energy and mechanical energy or sound energy performance, making it a far better choice than traditional giant magnetostrictive materials.

2.1. Magnetostrictive Characteristics

RE-GMM has a relatively large magnetostriction coefficient λ in the weak magnetic field.

$\lambda = \Delta l / l : \Delta l$ refers to the length variable while l refers to the original length.

The magnetostriction coefficient λ is the function of magnetic field strength H , temperature and pressure. $|\lambda|$ increases as magnetic field strength increases at a certain temperature and pressure. When H reaches a certain value, $|\lambda|$ basically stops increasing, which is called magnetostrictive saturation.

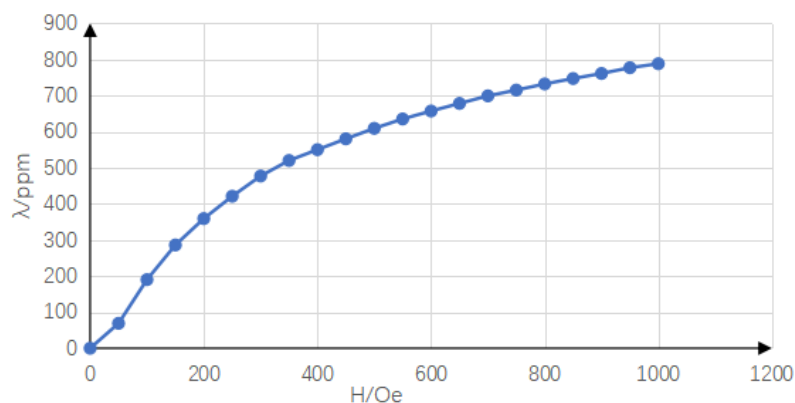


Figure 2. Magnetostrictive Performance.

Under constant temperature, λ and the output quantity change with H . As shown in Figure 2, when H is smaller than 1000 Oe, the output of giant magnetostrictive material increases significantly; when H is larger than 1000 Oe, the output tends to be stable. Therefore, 1000 Oe is generally used as a standard for measuring the output performance of materials.

2.2. Pre-stress

RE-GMM can withstand compressive stress of 700 MPa, but it is brittle and can only withstand tensile stress of 20 MPa. Therefore, it is necessary to apply a certain compressive stress to the giant magnetostrictive rod to ensure that it will not receive extensive stress or shear stress in order to make it safer to operate. Most giant magnetostrictive materials need an appropriate amount of pre-stress in practice, which can improve its working performance. As shown in Figure 3, different pre-stress, especially pre-stress within 7~14 MPa, can affect the output characteristics of the material.

Nowadays, the spring or the disc spring is often used to apply pre-stress. This method is simple in design, compact in internal structure, and easy in adjustment. This paper uses a disc spring to provide pre-stress, and forms the pre-stress applying structure using a disc spring, an output rod, and an end cap in the outer casing.

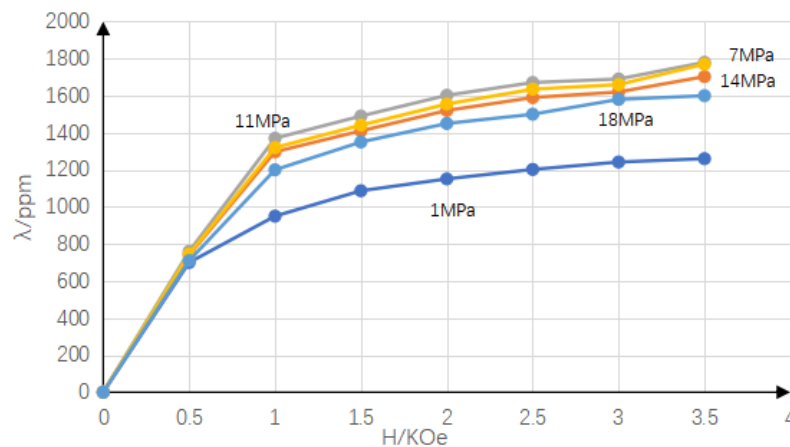


Figure 3. Magnetostrictive Performance under Different Preloading Stresses.

3. Structural parameter design

Mine acoustic wave signal generator requires the frequency to be within 5 and 25 Hz, which belongs to the low frequency range, thus the influence of eddy current and resonance can be neglected. The working temperature is stably maintained between 10 and 30 °C. Due to space limitation, it is difficult to install the temperature control system, thus temperature can also be neglected. The device uses the positive voltage pulse generated by the battery to excite the rare earth magnetostrictive material to vibrate and tap. The direction of magnetic field remains unidirectional, so the frequency doubling elimination in loading bias magnetic field can be neglected. Therefore, the key factors affecting the tapping intensity of the acoustic signal generator are the bar size, pre-stress, and magnetic field strength. Structural parameters are designed based on the performance of the bar material, as shown in Table 1.

Table 1. Design Value.

	Bar size	Prestress	Coil length	Current peak	Coil turns
Value	Φ10×120mm	11 MPa	130 mm	11 A	1000

Figure 4 shows the structure of the mining acoustic wave signal generator. The locking bolt and the belleville spring apply pre-stress to the giant magnetostrictive alloy because stress can cause large deformation. The excitation coil applies excitation current signal to generate the transient magnetic field. RE-GMM, which can generate the stretching vibration in changing magnetic field, serves as the driving component of the voice device. The knocking block, as the output component, is pushed by RE-GMM to vibrate and radiates sound waves to the device casing.

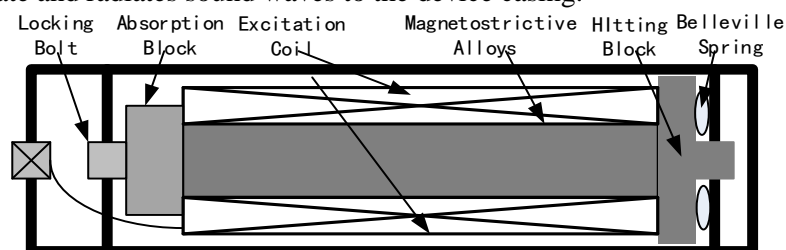


Figure 4. Mine Acoustic Wave Signal Generator.

4. Test verification

This paper establishes the force measuring platform of the signal generating device based on the structural characteristics of the mining acoustic wave signal generator. As is shown in Figure 5, the device is pressed on impact force sensor by the spring, whose pressure is adjustable. The stabilizer

keeps the device in the condition of radial output. The impact force sensor detects the output force in real time. It is connected to the data acquisition card, whose sampling frequency is up to 30 KHz. The acquired data is uploaded to the computer, which displays data fluctuation curve in real time.

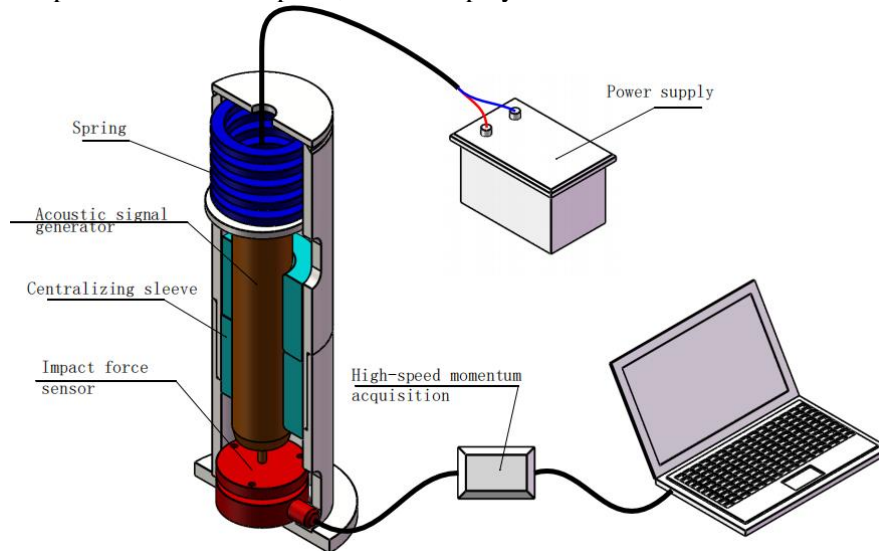


Figure 5. Device Performance Test Platform.

RE-GMM can bear pressure greater than 20 MPa, and the output force of the device under the excitation of the external magnetic field depends on the excitation field strength of the magnetostrictive rod. In the experiment, 200 N pre-stress was applied to the device, while the excitation current was gradually increased from 19 A to 86 A. Test result shows that when the input current is gradually increasing, the output force increases in a linear manner, as shown in Figure 6.

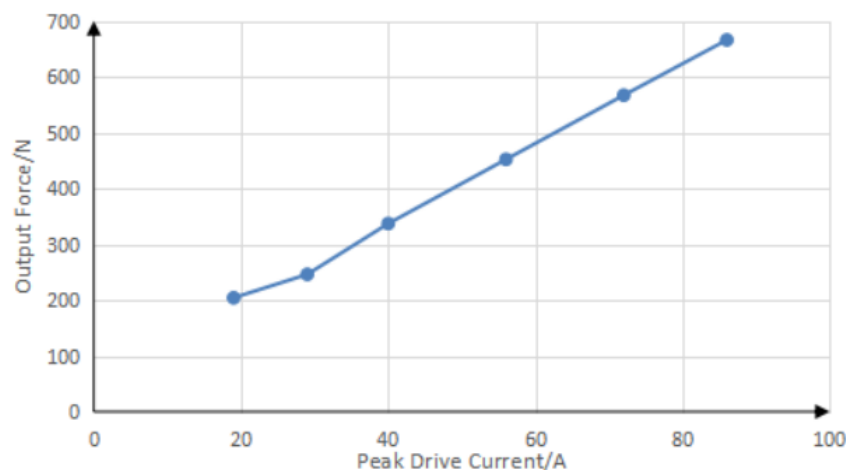


Figure 6. 200 N Current-Output Force Variation Curve.

5. Conclusion

RE-GMM is suitable for the development of the mining acoustic wave signal generator. It has low requirement for the excitation voltage, and can handle large power with efficient conversion and wide adjustment range. In addition, many factors affecting the output performance of the material interfere with each other. When we only consider the bar size, pre-stress and magnetic field strength, we can design a mine acoustic wave signal generator that satisfies the requirement for the output impact force.

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