Electroacoustic Conversion Technology Research Based on the Giant Magnetostrictive Material

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ABSTRACT

The realization of Acoustic Telemetry System (ATS) in the oil field development and production is mainly dependent on the high-power and low-frequency electroacoustic transducer. However, the traditional piezoelectric transducer cannot meet the requirements. In this paper, how to realize high-power and low-frequency electroacoustic transducer with the giant magnetostrictive materials was studied through theoretical analysis and experimental method. It is at least 14 times larger; especially it has wide frequency band and can work under high temperature[3]. These are important bases for generating high-power and low-frequency sound waves in the downhole. The research results show that the electroacoustic transducer based on giant magnetostrictive material has the advantages of large output power, wide frequency range, high conversion efficiency and high temperature resistance, which can well meet the ATS for underground information transmission.

Key words: Giant magnetostrictive; Electroacoustic conversion; Acoustic telemetry system

INTRODUCTION

In the process of petroleum exploration and development, it is urgent need to obtain the underground information quickly and in time through the Acoustic Telemetry System (ATS). ATS is mainly composed of underground acoustic emitter, drill pipe or tubing string as transmission medium and ground reciever three parts. Digital transmission of underground information is achieved by coding with burst sound wave[1,2]. So the high-power and low-frequency electroacoustic transducer is very important to realize the downhole ATS. However, the traditional piezoelectric transducer is far from being able to meet the requirements, so the research on the high-power and low-frequency electroacoustic transducer is very necessary.

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THE PRINCIPLE OF THE ELECTROACOUSTIC TRANSDUCER DESIGN
Characteristics Analysis Of The Giant Magnetostrictive Material

For a long time, all the electroacoustic transducers have been realized by piezoelectric ceramics. But it is very difficulty in generating high-power and low-frequency sound wave. In recent years, a new type of giant magnetostrictive material has been developed, this material has an incomparable advantage than piezoelectric ceramic materials. Through the comparison with the piezoelectric ceramics, we found that the magnetostrictive material has obvious advantages in many aspects. Especially, its magnetostriction coefficient is very large, strain value is 5 - 20 times larger than the piezoelectric ceramic material; magnetostrictive strain energy density

Electroacoustic Transducer Structure Design

Figure 1 shows the structure diagram of the giant magnetostrictive electroacoustic transducer[4,5]. Its core components are the giant magnetostrictive rod (6), the prepressing spring (7), the permanent magnet(5), the excitation coil (4) and the counterweight block (9). When the excitation coil is connected to an alternating current, magnetostrictive rod with counterweight block can produce the vibrations, and then it can coupled to acoustic media generating high-power and low-frequency sound waves. But in order to achieve the best working condition, there must be a suitable prestress, permanent magnetic field and counterweight block.

![Figure 1. Transducer structure diagram.](image1)

![Figure 2. Magnetostrictive characteristics.](image2)

Characteristics Analysis of Giant Magnetostrictive Material

Figure 2 shows the changes of giant magnetostrictive rod strain value with increasing magnetic field in a certain pressure bias when the temperature is 20℃. We can clearly see that the strain coefficient is an even function of magnetic field, so a giant magnetostrictive material has a "multiplier" feature, its deformation output frequency is two times the frequency of the excitation current, therefore it should be eliminated as much as possible. In addition to the alternating excitation field, exerting a constant magnetic field called bias magnetic field to the giant magnetostrictive material will make giant magnetostrictive rod in the polarization state, thus eliminating the phenomenon of the "multiplier" feature. Obviously, when a permanent bias magnetic field is larger than the alternating magnetic field, the alternating strain part of the giant magnetostrictive rod is in proportion to alternating magnetic field. Therefore, after determining the material and prepressing, the optimum bias field should be selected at the point corresponding the middle part of straight line in the magnetostrictive strain curve. the axial prepressing is applied to the giant magnetostrictive rod by the spring assembly. the pressure should not be too large or too small, generally 6 ~ 12MPa.
EXPERIMENTS RESULTS AND DISCUSSION

The performance test was carried out after the development of the electroacoustic transducer was completed. The diagram of the test is shown in figure 3.

Figure 3. Electroacoustic transducer dynamic measuring principle block diagram.

The main apparatus: GFG-8016G signal generator, GF-10 power amplifier, GZ-6C vibrometer which can measure the acceleration, velocity and displacement. The signal generator generates AC signal with different frequency. Through the power amplifier, it supplied to the transducer coil to generate a driving magnetic field, then the dynamic strain appeared. This dynamic strain can be collected by the vibrometer and displayed by the oscilloscope. By detecting the voltage across the coil and the current though the coil can monitor the power of electroacoustic transducer.

The experimental results show that in the case of non-resonance. The output wave is almost no distortion, which indicates that the magnetostrictive transducer has good linearity and repeatability by correctly configuring the partial magnetic field. The output power is obviously increased more than the piezoelectric transducer by correctly configuring the bias pressure and weight block. When the frequency is changed and the mechanical resonance is reached, the amplitude increases obviously. If the capacitance is then changed to the driving circuit to reach the electric resonance, the amplitude is maximum.

The equivalent structure of the transducer is shown in figure 4.

Figure 4. Equivalent structure of the transducer.

To select the counterweight is very important for the transducer design, if the quality of balance weight is too large, so that the maximum amplitude is reduced, thereby reducing the acoustic energy; on the contrary, the smaller counterweight block, there is no guarantee that the transducer work has sufficient power output. According to the principle of resonance, the selection principle of the weight block for the best transducer is found. The giant magnetostrictive rod is equivalent to a spring $K$. The weighted sum of the giant magnetostrictive rod and the counterweight block are $M$, so that the mechanical resonant frequency of the system can be expressed as equation 1.

$$ m_0 = \sqrt{\frac{K}{M}} $$

Because the excitation coil contains the inherent inductance $L0$, it will impede the passage of current and reduce the electroacoustic conversion efficiency. In order to overcome the impediment of the inductor to the current, A suitable capacitor is required to be connected in series to meet the equation 2, so that it can achieve electric resonance at the mechanical resonance frequency.

$$ C_0 = \frac{1}{\omega_0^2 L0} $$
Among them, $L_0$ is the coil inherent inductance; $\omega_0$ is the operating frequency; $C_x$ is the capacitance of the external series capacitor. It can greatly improve the power factor and further increase the output power, which indicates that the electric resonant drive can significantly improve the performance of the electroacoustic transducer.

CONCLUSIONS

The results show that the giant magnetostrictive rod is an ideal material for making sound generator for low frequency and high power used in ATS, but to ensure that the linear output of the driving signal, it need to apply a bias magnetic field with suitable intensity and uniform distribution to the magnetostrictive material rod; to ensure that the larger magnetostrictive coefficient, the pre-pressure with particular strength must be applied to the magnetostrictive material rod; to ensure high conversion efficiency and high output power, the mechanical and electrical dual resonance driving mode should be used as far as possible.

REFERENCES


