Experimental Research on Temperature Rise of Mining Explosion-proof Turbine Generator

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Abstract: In order to prevent the temperature of a mining explosion-proof turbine generator from exceeding the safety threshold due to faults during operation, this paper monitors the temperature in real time during the operation of the turbine generator under extreme conditions by installing a temperature sensor inside the generator. This paper aims to reveal the mechanism and verify the reliability of temperature rise of the turbine generator.

1. Background
To ensure safe and efficient coal mining, the mining electrical equipment must meet the explosion-proof requirements in the explosive environment GB3836. The highest surface temperature of any components is required to be less than 150 °C under the most adverse operating conditions (but within the specified tolerance range), so as not to cause dust combustion.

The turbine generator, as a sustainable working power source for underground borehole instruments, is a kind of new product. Therefore, it is necessary to study and demonstrate its explosion-proof performance, including the temperature rise of the generator in operation under various working conditions (the temperature rise shall not exceed 150 °C).

2. Classification of working conditions of the generator
It is necessary to install a temperature sensor inside the generator before the temperature rise test. The circuit is shown in Figure 1. The measured temperature is regarded as the internal temperature of the generator, which is because that the generator casing in contact with water cools down significantly, and the circuit board should be the place with the highest temperature of the entire generator. It is feasible to conduct temperature rise tests under different operating conditions according to the changes of the working state of generator. The specific operating states are classified as follows:

(1) Due to the existence of the stabilivolt, the temperature rise tests are conducted under two working conditions, namely, operating stabilivolt and non-operating stabilivolt. According to the design parameters of the turbine generator, the stabilivolt starts operation at a flow rate of about 270L/min. Based on this, the temperature rise tests are divided into two groups: one with a flow rate less than 270L/min and the other with a flow rate greater than 270L/min.

(2) The power generating device has two working states, namely, battery charging and nonbattery charging. Therefore, the tests can be divided into two types: ① Temperature rise test when the generator is charging the battery normally; ② Temperature rise test when the generator is not connected to the battery.
It is important to point out that the downhole turbine power generation device designed in this paper is only suitable for water-driven drilling. For wind-driven drilling, however, due to the high speed rotation of the turbine and slow heat dissipation, the temperature rise is obvious; therefore, it is not suitable for working downhole. Therefore, the power generation device must not be driven by wind; at the same time, the temperature rise state of wind-driven drilling is not considered in the test.

3. Temperature rise test under different working conditions

Based on the different working conditions of the generator, this paper tests the internal temperature of the generator to check whether its temperature rise meets the requirement. The test result is shown in Figures 2-5.

It can be seen from Figure 2 that the temperature of the device decreases slightly without load. At this time, the voltage after rectification is too low (the voltage regulator is not working), the motor is in a light-load state, the electromagnetic torque is very small, and the input energy of the entire motor system is correspondingly reduced; therefore, there is only a small amount of generated power and thermal energy. Based on the theoretical analysis and test results, this test has basically achieved its purpose, so no further test is conducted. It can be seen from Figure 3 that the temperature rise gradually increases under load. However, the temperature rise is generally slow, and becomes even slower after reaching 30 °C.
This paper measures the internal temperature of the generator under the condition of no battery and no load continuous operation, with the mud pump flow fixed at about 400L/min. The test results are shown in Figure 4. The temperature of the recycled water in the tank gradually rises and fails to deliver a good cooling effect. Therefore, fill the tank with water in the 177th minute, leading to a significant drop of the internal temperature; stop adding water in the 205th minutes, leading to a slow temperature rise. The tank water temperature is measured to be 35 °C in the 234th minute and is 45 °C in the 328th minute. Turn off the mud pump in the 330th minute and the generator stops working. Continue to measure the internal temperature of the generator until the 354th minutes, and the working temperature is always below 60 °C.

When the mud pump flow rate is greater than 270L/min, the voltage-regulator diode 1N3311B starts working. At this time, when the generator charges the battery, some energy will be consumed on the voltage-regulator diode, thereby accelerating the internal temperature rise of the generator. As shown in Figure 5, the internal temperature continues to rise and gradually becomes stable, with the maximum temperature below 65 °C.

In actual drilling construction, circulating water system will not be adopted (test result shows relatively obvious heat dissipation effect of water); the continuous pumping time will not last so long (test data shows that the temperature drops relatively fast after the pump stops working).

4. Test under the most severe working conditions

The power generating device on the open laboratory test platform, so part of the heat will be lost in the air. Compared with the closed downhole environment, the above test conditions are not strict enough; therefore, this paper conducts test under the most severe working conditions. Cover the outer tube of the generator with heat insulation materials, so that the heat dissipation into the air in the laboratory
environment is smaller than that of the drilled hole. The temperature rise of the power generator is shown in Figure 6.

![Simulation of the most Severe Conditions Test Photos](image1)

Based on the calculation using thermal conduction theory, covering the outer tube of the power generator with a 6.4 cm thick rubber-plastic sponge material for temperature insulation can ensure that laboratory testing conditions to be more severe than actual drilling conditions. The test result is shown in Figure 7.

![Simulate the Actual Temperature Curve](image2)

It can be seen from the result that the temperature rises rapidly in the initial stage, slows down as the test progresses, and finally stabilizes at about 41 °C. Since the water exchange volume in the tank is small, the water temperature increases slowly. Throughout the three-hour test, the water temperature slowly increases from 15 °C to 23 °C. It can be inferred that if the water passing through the power generator is completely drained in time during the test, the internal temperature shall be less than 41 °C.

5. Conclusion

The maximum working temperatures of the generator under both the normal and the most severe working conditions are lower than 65 °C, which is far less than the safety threshold of 150 °C. The
water used in actual conditions is the groundwater with the temperature generally lower than the ambient temperature. In addition, the water is not recycled, so the maximum operating temperature should be slightly lower than the measured value in the experiment.

Funded Projects
[1] Major National Science and Technology Special Tasks in the 13th Five-Year Plan (2016ZX05045-003-001).
[2] Development of Explosion-proof Turbine Generator for Underground Wireless While Drilling Measurement (2018XAYMS01).
[3] Special Fund for Scientific and Technological Innovation and Entrepreneurship of CCTEG(2018MS007).

References
[1] Tan Chao, Li Zongliao, Wang Jiacheng. Design and Test Analysis of Underground Turbine Generator in Coal Mine[J]. Micromotor, 2019, 47(05):32-35.
[2] Jia Huiqin, Wan Mi, Jiao Wei. Design and Experimental Study of Small Diameter Turbogenerator[J]. Electronic Measurement Technology Abroad, 2019, 38(01):63-66.
[3] Liu Shuang. Parametric Design of Downhole Generator Turbine while Drilling[D]. China University of Petroleum (East China), 2017.