Development of Temperature-controlled and Humidity-controlled three-body Abrasive Wear Testing Machine based on MLD-10 Dynamic Abrasive Wear Testing Machine

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Abstract. In order to simulate engineering machinery (such as mining machinery, feed pellet machine, building machinery and so on), which existence of different degrees of high temperature and humid corrosion three-body abrasive wear behavior in the laboratory environment. In view of the current three-body abrasive wear testing machine cannot simultaneously take into account the composite conditions characteristics of the three-body abrasive wear behaviour, high temperature and humidity, and make the optimization design, based on the MLD-10 dynamic abrasive wear tester. It includes corrosion and wear groove, fluid medium, temperature measuring and controlling device, stirring device, etc. A three-body abrasive wear testing Machine that can control temperature and humidity. Subsequently, the simulated working condition test of the ring die of feed pellet machine were carried out. The test results show that the wear appearance of the test sample is basically consistent with that of the real ring die of feed pellet machine. It indicates that the developed testing machine can simulate the high temperature and humid three-body abrasive wear behavior, and has good reliability and applicability.

Keywords: Testing machine; Three-body abrasive wear behaviour; Temperature control; Humidity control; Development; Corrosion; Wear.

Three-body abrasive wear is a common working condition of construction machinery, and it is also the main cause of surface loss of metal materials [1]. Due to the increasingly complex environment facing today's construction machinery, the wear of surface is often in a composite medium of high temperature and humidity. Literature [2-3] shows that some high temperature and humid abrasive media often form a corrosive environment on the metal surface. Corrosive environment can accelerate dislocation migration, destroy the hardened layer with relatively high energy, and reduce the resistance of surface materials to plastic deformation, so as to reduce the hardness of materials. On the one hand, corrosion causes a lot of pits and material loss, at the same time, it seriously deteriorates the mechanical properties of metal surface, weakens the metal surface and reduces the energy required for wear [4]. That is to say, corrosion can promote the wear of surface materials of construction machinery [5]. Therefore, in order to study the three-body abrasive wear failure mechanism of high temperature and humidity on the surface of construction machinery materials, it is necessary to simulate the working conditions in the
Laboratory environment to provide a test platform for material selection. However, the three-body abrasive wear tester sold on the market cannot simulate the complex working conditions of three-body abrasive wear, humidity, and high temperature at the same time. For example, ring-block three-body abrasive wear tester cannot provide temperature control and humidity control conditions [6]; high temperature friction tester can only control temperature and must require that the abrasive is dry [7]; wet grinding rubber wheel friction and wear tester can only control abrasive humidity but not temperature control [8]. Therefore, the development of a three-body abrasive wear tester which can control temperature and humidity is an urgent problem to study the surface failure mechanism of engineering machinery materials working under three-body abrasive wear conditions in high temperature and humid media.

Therefore, based on the working principle of MLD-10 dynamic abrasive wear tester, we have developed a three-body abrasive wear tester which can control temperature and humidity by designing corrosion wear tank, fluid medium, temperature measuring and controlling device and mixing device. This paper takes this as the test platform to test the simulated feed granulator's ring model working condition, and verifies the effectiveness and reliability of the equipment.

1. **Structure and working principle of MLD-10 dynamic abrasive wear tester**

MLD-10 dynamic abrasive wear tester, as shown in Figure 1, is mainly divided into abrasive flow control zone and impact wear zone. In the abrasive flow control zone, the abrasives of different densities are loaded into large buckets and evenly flow to small buckets. In the small buckets, the control plugs with scale lines are installed. The adjusting screw of the control plugs is used to control the abrasive flow into the impact wear zone. At the same time, the abrasives can be mixed in this area, and a certain proportion of water or liquid can be added to make the abrasives have a certain humidity, so MLD-Model 10 dynamic abrasive wear tester can carry out three-body abrasive wear under certain humidity. The impact wear zone consists of motor, several gears, belt, hammer, upper sample fixture and lower sample. Its working principle, as shown in Fig. 2, is that the sample is clamped on the upper sample clamp. The hammer has a certain weight. It is connected with the spindle through gear and belt. When the spindle rotates, it drives the hoisting hammer to move freely in a reciprocating manner, thus providing impact load for the upper sample, the lower sample and the three bodies of fluid flowing through it. The impact load can be passed through the hammer. At the same time, by replacing the pulleys with different diameters installed on the lower spindle, the upper spindle can get different rotational speeds, so that the hammer can get different impact times (50, 100, 150, 200 rpm). The lower sample is a metal ring. In impact wear, the lower sample rotates with the spindle. The lower sample mainly plays the role of entraining abrasive particles into the impact wear zone and bringing out the impact wear zone after impact wear, which provides abrasive wear conditions for the impact wear zone. The material of the lower sample can be replaced according to the specific simulated working conditions [9]. Specific parameters are shown in Table 1.

![Fig. 1 MLD-10 dynamic abrasive wear testing machine](image)
2. Optimum Design of Tri-body Abrasive Wear Testing Machine with Temperature and Humidity Control

In order to achieve the optimum design of temperature and humidity control, based on MLD-10 dynamic abrasive wear tester, the device of abrasive flow control is removed. At the same time, in order to immerse the upper sample in the abrasive, the belt between the gear and the spindle of the hammer is removed, so that the hammer can no longer carry on the reciprocating free-falling motion, that is, the impact load is removed, and the weight of the hammer itself is loaded on the upper sample. The cyclic stress output of wear between the specimen and the lower specimen [10]. At the same time, the cyclic stress between the upper and lower specimens can be adjusted by replacing the hammers of different qualities.

### 2.1. Optimum Design of Thermal Insulation and Moisture Preservation for Testing Machine

In order to minimize the fluctuation of temperature and humidity of abrasives and provide a place for the temperature control of abrasives and other factors. Design a stainless-steel corrosion groove and a foam cover on it, as shown in Figure 3. Corrosion wear groove is composed of inner groove and outer groove. The inner groove is welded in the outer groove. The top of the inner groove is equal to the top of the outer groove. At the same time, the inner groove and the outer groove are aligned. The connecting hole of the spindle is located on the same side of the inner groove and the outer groove. The spindle is connected with the motor outside the groove. The lower sample is installed in the groove, after installing the spindle, the crack can be sealed with tetrafluoroethylene. The inner groove is used to hold abrasives and provide a place for three-body abrasive wear. Abrasives can meet the requirement of working condition humidity by mixing a certain proportion of water. The outer tank holds fluid medium with high specific heat capacity, such as water or oil. By heating, the abrasive in the inner tank can be continuously heated and kept warm. During the test, the foam cover is buckled on the entire corrosive wear groove to reduce the contact between abrasive and fluid medium and air, so as to reduce the change of abrasive temperature and humidity.

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**Fig. 2 Wear zone of MLD-10 dynamic abrasive wear testing machine**

**Table 1. Technical specifications and parameters of MLD-10 dynamic abrasive wear testing machine**

| Impact work/(J) | Quality of hammer/(kg) | Impact times/(t/h) | Free fall height of hammer/(m) | Axis speed of lower sample/(r/min) | Abrasive particle size/(mm) | Abrasive flow rate/(kg/h) |
|-----------------|------------------------|-------------------|-------------------------------|----------------------------------|---------------------------|--------------------------|
| 0.5             | 10                     | 50, 100, 150, 200 | 0.5                           | 200                              | 0.1-4                     | 0-50                     |

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2.2. Optimum Design of Sample Enhanced Coiling Capacity under

In order to improve the tape rolling ability of the lower sample, it is suitable to use no abrasive, especially to deal with the slippage of tape abrasive particles in abrasive materials with certain temperature and humidity. A cross groove with a depth of about 1 mm is designed on the smooth surface of the specimen. As shown in Figure 4, it is used to increase the amount of abrasive involved in the wear zone between the upper and lower specimens so as to achieve better wear test results. In order to adjust the cyclic stress between upper and lower specimens, the material of the lower specimens can be adjusted accordingly according to the working conditions. At the same time, the quality of the impact hammer can be adjusted. The diameter of the lower specimens can be adjusted according to the relative moving speed of the two pairs of wear surfaces under the actual working conditions, so as to change the linear velocity of the wear surface of the lower specimens, and then the relative moving speed of the upper and lower specimens can be adjusted to meet the Requirements of the situation.

2.3. Optimum design of abrasive homogeneity

In order to improve the uniformity of abrasive composition, temperature and humidity in the corrosive wear trough, the temperature of the outer trough can be uniformly transferred to each area of the abrasive in the inner trough. At the same time, in order to prevent abrasive adherence in the wear process, and better push the abrasive to the wear zone composed of upper and lower samples. A propeller device is designed and installed at the outer end of the lower sample, as shown in Fig. 5. The propeller consists of three blades, which are fixed at the outer end of the specimen under the spindle and rotates with the spindle. The blade length is designed to be slightly longer than the diameter of the lower sample, and it is guaranteed not to collide with the clamp of the upper sample. During the spindle rotation, the propeller device agitates the abrasives by rotating, so that the abrasives in the heated part of the corroded wear tank can quickly transfer heat to other areas. The abrasive composition and humidity caused by gravity
and other factors will also become uniform due to agitation. Because there will be idling during the relative movement of the lower sample during the wear period, the friction between the upper sample and the lower sample for a long time has not been fully friction with the abrasive, resulting in the result that the three-body abrasive wear cannot be well simulated. Therefore, the blade design of the propeller device has a certain slope, which can mix the abrasive and move the abrasive into the wear zone at the same time, and then the abrasive in the tank can be propelled to move towards the wear zone. The three-body wear of the upper sample, the lower sample and the abrasive can be fully carried out. At the same time, in order to improve the efficiency of the propeller device, it is required that the abrasive in the groove of the corrosion wear groove should not pass the wear area composed of upper and lower samples.

**Fig. 5** Helix structure of nut

### 2.4. Abrasive Temperature Control Design

In order to adjust and control the abrasive temperature to meet the test requirements, a digital temperature controller is set up, as shown in Figure 6. The heating tube is placed in the fluid medium of the outer groove of the corrosive wear trough, and the temperature sensor is placed in the inner groove of the corrosive wear trough. Before the test, the temperature required for the test can be set for the digital display temperature controller. When the temperature of abrasive detected by the temperature sensor is lower than the setting temperature about 5 °C, it will be heated at one end of the heating tube to increase the temperature of the fluid medium in the outer groove of the corroded wear tank. The temperature is then transferred to the abrasive in the inner groove of the corroded wear tank through the heat exchange between the inner groove and the outer groove, and the abrasive in the corroded wear tank.

**Fig. 6** Heating Tube of Digital Temperature Controller

The improved design of MLD-10 dynamic abrasive wear tester can basically meet the working conditions of three-body abrasive wear test at a certain temperature and humidity through the above four aspects. The schematic diagram of the test platform is shown in Fig. 7.
3. Test Verification and Result Analysis

3.1. Test Verification
Because the working condition of feed granulator's ring die inlet meets the three-body abrasive wear condition under certain humidity and temperature, this paper takes the working condition of feed granulator's ring die inlet as an example to test and verify. Firstly, the working conditions of the inlet and outlet of the ring die are analyzed, and the technical parameters of the test platform are set according to the working conditions, and the tests are carried out.

3.1.1. Working condition analysis. The working principle of the ring die of the feed granulator: during the operation of the ring die, the feed powder can be formed. The feed powder is mixed with water vapor, rolled into the die hole, and saturated with the whole die hole, and finally extruded in the form of feed particles. Because of the feed extrusion wear at the feed inlet of the ring die hole at a certain humidity and temperature, it is the first place where the ring die fails [11]. It is also the first problem to be solved in order to improve the service life of the ring die of the feed granulator. Therefore, it is of great practical significance to analyze the surface failure of the ring die.

3.1.2. Determination of Test Parameters. According to the working parameters of the feed pellet machine ring die provided by a feed pellet manufacturer and the working conditions of the feed pellet machine ring die inlet, such as: there is a certain inclination at the feed pellet machine ring die inlet, so the upper sample is also designed with a 15 degree inclination angle; in the production of feed pellet, in order to be able to form smoothly, water vapor should be injected into the feed powder during the granulation process, and the feed pellet is manufactured. The water content is about 15%. Considering that the water in the abrasive will be lost a little with the experiment, the abrasive set water content is 17%. The main ingredients of feed powder include corn stalk, soybean stalk, rice straw, wheat stalk and so on. Because of its source, the feed granules will be mixed with a certain amount of quartz sand more or less to simulate the actual feed ingredients as far as possible. When the content of quartz sand is too high, the wear morphology is changed greatly, so the proportion of quartz sand mixed into feed powder is 5%, and the size of quartz sand particles is controlled to 105 meshes. Through repeated tests, when the abrasive in the corroded wear tank reaches the required 80 C, the fluid medium in the outer tank only needs to be less than 100 C, so it corrodes outside the wear tank. The tank fluid medium is set to water. Other specific parameters are set according to the operation parameters of feed granulator [13-14]. The main technical parameters of the test platform are shown in Table 2.
| Samples                        | Value                  |
|-------------------------------|------------------------|
| Quality of hammer/(kg)        | 10                     |
| Inclination of the upper sample/(°) | 15                  |
| Material of upper sample      | 4Cr13 stainless steel  |
| Material of lower sample      | 100Cr6 steel           |
| Axis speed of lower sample/(r/min) | 200                  |
| Diameter of lower sample/(mm) | 70                     |
| Feed with moisture content/(%) | 17                    |
| Quartz sand content in the feed/(%) | 5                    |
| Quartz sand mesh/(mesh)       | 105                    |
| Fluid medium of the outer of corrosion wear tank | Water |

3.1.3. **Test Method.** According to the technical parameters of the test platform, the test platform is assembled. We intercepted the failure ring die of 4Cr13 martensitic stainless-steel feed granulator and made it into a sample. Subsequently, we simulated the abrasion test of feed granulator's ring die inlet, as shown in Fig. 8. Firstly, we pre-grind for 5 minutes, then wear and tear for 30 minutes. Through scanning electron microscope photography observation, we compared the wear morphology of the sample after the test platform with that at the entrance situation of the failure ring [15] and judged the feasibility of the test platform.

![Fig. 8 SEM images of wear morphology: (a) the wear morphology of failure ring, (2) The wear morphology of sample of test platform](image)

4. **Conclusion**

1) According to the structure and working principle of MLD-10 dynamic abrasive wear tester, this paper optimizes the functions of heat preservation and moisture preservation, strengthening the ability of sample winding, homogenization of abrasive and temperature control. In order to satisfy the working condition of three-body abrasive wear test under certain temperature and humidity, we also developed a test platform.

2) In this paper, the main technical parameters of the test platform are set up, and the simulation test is carried out and the results are obtained.

3) By comparing the SEM photos of wear morphology, this paper confirms that the test platform can successfully simulate the three-body abrasive wear at a certain temperature and humidity, and has good reliability and applicability.

**Acknowledgments**

Supported by the "Teaching Quality and Teaching Reform Project of Guangdong Undergraduate Colleges and Universities: Construction Project of Experiment Demonstration Center (2017002) and Innovation Cultivation Project of Zhuhai College of Jilin University(2018XJCQSQ057)

5. **References**

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