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Original Research Article

Study on the corona characteristics of a 10kv anti-explosion motor with multi-rubber mold insulation system

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Abstract: Safety incidents in mines, such as gas explosions and chemical accidents, have underscored the growing emphasis on safety management within corporations. This has led to an increased demand for explosion-proof equipment in the market. The presence of extremely weak coronas can trigger explosions in gas mixtures containing hydrogen gas at concentrations around 21% ± 5% in the air. Consequently, preventing corona formation is pivotal for the effectiveness of explosion-proof motors. This paper consolidates a theoretical and practical examination to outline a 10kV electromechanical anti-corona structure for anti-explosion motors.

Keywords: Anti-explosion; Motor; Corona; Test

1. Introduction

With the frequent occurrence of industrial safety accidents, the importance of enhanced safety explosion-proof equipment is becoming increasingly prominent. This paper focuses on the multi-adhesive press-molded insulation system of 10Kv enhanced safety explosion-proof motors, discussing the causes, influencing factors, and hazards of corona discharge, and proposes a series of effective anti-corona measures. Through theoretical analysis and experimental verification, this paper aims to provide a scientific basis for the safe operation of high-voltage motors, ensuring the reliability of equipment in flammable and explosive environments, which is of great significance for improving the level of industrial safety management.

2. Causes of corona and corona

Corona (discharge) refers to the discharge of the purple and blue glow on the surface of the conductor and its vicinity when the voltage gradient exceeds a certain critical value due to the high voltage that ionizes the surrounding air.Conductor corona produce because of not smooth produce non-uniform electric field, small curvature radius around the uneven electric field near the electrode when voltage rises to a certain value, because the air free discharge occurs, the formation of corona. Because the electric field in the corona is very weak, there is no collision, and the charged particles on the periphery of the corona are basically electric ions, which form the corona discharge current. In short, a conductor electrode with a small radius of curvature produces a corona.

3. The generation part of the anti-explosion motor corona

1. The winding outlet is a typical casing structure, and the electric field of the groove is very concentrated, which is the most likely place to generate corona.

2. Iron core section ventilated trench. The steel section of the ventilation channel is sharp edge, which is easy to cause the local unevenness of electric field.

3. The wire rod surface and the iron core groove contact with the bad place or the air gap.

4. End hoop dressing place.

5. The cable is close to the core distance.

6. Between the end of the coil. Winding end electric field distribution is complex, especially the coil and the hoop, bands, and the contact area and edge block, because of technology it is often difficult to completely eliminate the air gap, in the air gap is easy to generate the corona.

4. Corona is harmful to motor

The electric field distribution on the insulating surface of the stator coils of the high voltage motor is extremely uneven. When the local field intensity reaches a certain value, the gas will be partially free, and blue halo will appear, resulting in corona. The occurrence of corona is accompanied by the generation of heat, ozone and nitrogen oxides, which are extremely harmful to motor insulation. In addition, due to the bad or unstable contact between the thermosetting insulation surface and the groove wall, the spark discharge in the slot will be caused by the electromagnetic vibration. The local temperature rise caused by this spark discharge will cause serious erosion of the insulation surface, which will cause great damage to the insulation of the motor.

In order to effectively eliminate the corona phenomenon, it is very important to correctly determine the parameters of the corona structure and to select good anti-halo materials.

5. The factors that affect the corona generation

Based on the study of the model of multi-rubber mold insulation of 10Kv anti-explosion motor, it is found that the generation of corona has many influencing factors besides theoretical calculation, and the uncertainty is very strong. Even if you do the experiment in the same place, there will be no corona today, and you will be dizzy tomorrow at some point. The following table is the data of the corona test of the same stator model in different locations. The test process is that the model is made in Beijing and transported to Shanghai without corona. In the absence of any treatment, the corona test is made, and the corona is found to be treated without corona. From Shanghai to nanyang, in the absence of any treatment to do the corona test, the test found the dizzy point, processing to no corona. From nanyang to jiuquan, without any treatment to make corona test.

Table 1. Test data table of each factor.

Test site	Test voltage	The altitude	Relative humidity	Presence of corona	The halo voltage	Observation method
Beijing	15kV	44m	50%	no	no	Eye observation and uv imager observation
Shanghai	15kV	4m	60%	yes	10000V	Eyeobservation and uv imager observation.
Nanyang	15kV	75m	60%	yes	13000V	Eye observation and uv imager observation. no explosion in the hydrogen test.
Jiuquan	15kV	1500m	40%	yes	12000V	Eyes to observe

It is found that the occurrence of corona is related to the following factors:

1. It has to do with altitude. The higher the altitude, the thinner the air, the lower the corona discharge voltage.

The corona voltage of the motor coil should not be lower than the formula (1) :

$$U_{BS} = 1.5U_N(1 - KH_S)/(1 - KH_A). \quad (1)$$

In the formula:

UBS -- the corona voltage of the coil, unit kV.

U_N -- the rated voltage of the motor, unit kV.

K -- the decline rate of the initial voltage of the corona with the elevation of the elevation, taking K=0.1, and the unit is km-1.

HS - the altitude of the motor test site is km.

HA -- the elevation of the motor installation site is km.

The corona voltage of the motor winding should not be lower than equation (2).

$$U_{IS} = 1.3U_{\Phi}(1 - KH_S)/(1 - KH_A) \quad (2)$$

In the formula:

UIS -- the starting voltage of the motor winding, unit kV.

The rated phase voltage of the motor, unit kV.

K -- the decline rate of the initial voltage of the corona with the elevation of the elevation, taking K=0.1, and the unit is km-1.

HS - the altitude of the motor test site is km.

HA -- the elevation of the motor installation site is km.

2. Related to humidity, the humidity increases, the surface resistivity decreases, and the corona voltage drops.

3. High end resistance anticorona layer related to temperature, such as high resistance, high temperature resistance anticorona layer temperature increase its dizzy and a higher voltage. Under normal temperature such as high resistance to low resistance anticorona layer, the halo voltage with temperature rise and fall.

4. The slot corona is related to the clearance of the slot wall. The gap between the coil and the wall of the core wire can cause the spark discharge between the corona and the core. The danger gap between epoxy powder mica insulation and local discharge is 0.2 ~ 0.3mm.

5. It is related to the potential and electric field distribution in the position of the coil, the higher the higher the fainter, the more uneven the distribution of electric field is.

6. Increase safety of antidetonation electric machine

Some feasible measures are put forward in the analysis and a large number of experiments.

The forming process of the stator coil anti-halo structure is related to the main insulation system, and the main insulation system is divided into the multi-rubber mould pressing system and the low-glue vacuum impregnation system. In this paper, we mainly study the multi - plastic molding system.

According to the position of the stator coil, the anticorrosion can be divided into the groove and the end.

6.1. Anti-halo measures in the groove

Slot department anticorona refers to the stator coils in the inside of the stator core slot anticorona, purpose is in the process of the motor running, make internal coil groove surface does not produce corona, wrong stator core discharge, and do not overheat. The anti-halo layer should have the appropriate and stable linear resistance value, not too large or too small, too general assembly will make the anti-halo layer and the potential gradient

rise, resulting in corona or iron core discharge; Too small will cause the corona current to increase or short-circuit iron core, resulting in overheating, harm coil and iron core. Experience shows that resistance in 102 ~ 105 Ω is appropriate. The resistance of the corona resistance should be relatively stable to the temperature, the parameters should not be affected by the main insulation, and the main insulation performance should not be affected.

The measures are as follows:

1) Before the main insulation is solidified, a low resistance corona belt is placed on the main insulation, and then molded with the main insulation.

2) After curing, it is a reinforcing measure to brush low resistance and anti-halo paint in the linear part of the coil.

3) Spray low resistance anti-halo paint in the stator groove.

4) The coil and groove are fully exposed to the coil and the tank with a semiconductor laminate or semi-conductor impregnated polyester felt between the coils and the bottom of the slot.

5) Stator groove wedge should be pressed tightly.

6.2. Anti-halo measures at the end

The purpose of the end of the anti-halo is to distribute the electric field evenly, so that no corona can be produced under 1.5UN, and no discharge during the pressure test. The requirement of the end corona structure and material is similar to that of the groove, and the difference is that it has good non-linearity.

Numerical analysis of end corona[2]

The nonlinearity of the end corona material and structure can be expressed as follows:

$$\rho = \rho_0 e^{-\beta E}$$

In the formula:

ρ-- resistivity, nonlinear Ω.cm or Ω

ρ_0 -- resistivity, the certificate of linear Ω.cm or Ω

β-- nonlinear coefficient, cm/kV.

E -- effective value of point gradient, kV/cm.

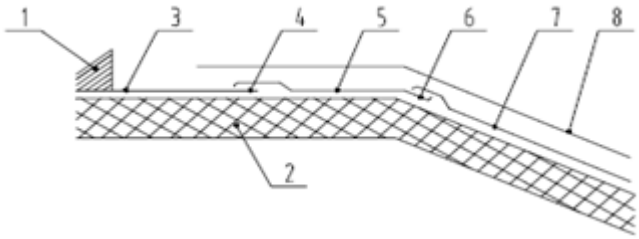
The physical model of the end corona structure (figure1) is a resistance capacitance chain circuit of a partial parameter. The mathematical model derived from it is a nonlinear second order ordinary differential equation. After the solution, the anti-halo structure can be optimized, thus:

1) The initial potential gradient of the anti-halo layer at all levels (including the bonding layer at all levels) is not more than 8.1 kV/cm in the pressure test.

2) The initial unit surface loss of the anti-halo layer at all levels (including the bonding layer at all levels) is within the same order of magnitude, and no more than 0.6w /cm2.

3) At the end of the final stage, the voltage of the conductor is within the specified index.

4) Under 1.5UN, the maximum potential gradient is no more than 2.1kv/cm to avoid the corona.



1. Stator iron core 2. Stator coil 3. Low resistance layer 4. Middle resistive layer bonding layer
5. Middle resistance layer 6. High resistance layer 7. High resistance layer

Figure 1. Schematic diagram of corona structure of stator coil end.

7. Additional insulation and coating paint

The measures taken are as follows:

1）For the effective uniform electric field and the process, the coil end insulation adopts the three-stage anti-halo structure, as shown in Figur1.

According to the structural parameters of some old products,the 10kV coil is adopted by experiment.

Low resistance and anti-halo: 1/2 packets of low resistance band on the surface of the ground insulation layer 1/2 hl-1 (the number of a manufacturer in Harbin), the length of the binding length is 70mm longer than that of the core.

Resistance to halos: 1/2 of the bag with hl-p3, 20mm with low resistance strap and 60mm bandage (not including 20mm with low resistance).

High resistance and anti-halo: 1/2 hl-p9 with high resistance band, 20mm with medium resistance strap and 110mm bandage (not including 20mm with middle resistance).

2）Additional layer anti-halo: 1/2 packets F class 594 epoxy mica with 1 layer, starting from 15 ~ 20mm at the beginning and 15 ~ 20mm at the end.

3） External high resistance anticorrosion: 1/2 package 1 layer of anti-daze resistance band hl-p6 on the surface of the additional anti-halo layer, the initial end exceeds the additional anti-halo layer 20mm, and the end to the tangent part of the circular arc at the end of the coil.

Additional layer outside the anticorona and high resistance anticorona role is: as a result of chosen additional insulation and high resistance with dielectric constant, dielectric constant is smaller than the main insulation of air near the anticorona layer method to the electric field intensity is reduced, thus improve the voltage.

4）Coil from the slot to the end of the film with a high temperature thermal shrink film with a layer of 2/3, which can make the coil clutch insulation to tighten during the hot pressing drying process.

5）The high resistance corona is used between the end hoop and the coil.

6） In the corona test, the corona shall be taken as auxiliary measures: in order to reduce the potential gradient, the coil will be painted with low resistance paint, medium resistance paint and high resistance paint.

7） In the design, we should try to increase the gap between the end of the coil and the experience data above 10mm.

8. The concluding

Corona, generated by a high voltage motor stator winding is corrosion motor of main insulation, serious

will cause flashover discharge, a direct impact on the life and reliability of the motor, especially for increased safety explosion-proof motor, there is no production of corona, otherwise it will cause gas explosion in certain conditions, endangering people's life. It is generally believed that when more than 6kV, the stator coil should take anti-halo measures. With the improvement of motor voltage and the strict control of national security, to prevent dizzy technology put forward higher request, this paper sums up a set of theory with practice practical anticorona measures, provide the reference for the readers. Due to my limited knowledge and ability, there are some wrong places.

About the author

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