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The Ball Mill Driving Device Fault and the Main Bearing Lubrication Analysis

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Abstract

This article from the analysis of the power consumption of the ball mill and the work characteristic of the motor, analyzes the fault reason of ball mill transmission equipment. The paper mainly deals with a side-transmission ball mill. The main fault is about the breakdown in the elastic rubber coupling of the transmission system. It is found from the analysis of the real cases and data that the actual power consumption is increased and it is caused by the overload. The main parameters which influence the ball mill power consumption are load of the mill, feed material mass, ball mill rotational speed and friction. The main part of power consumption for ball mill is used to elevating grinding body and material, a portion is used to overcome the friction force between the main bearing. Under the conditions in which the load of the mill and feed material mass are kept the same, the parameters which influence the ball mill power consumption are rotational speed and friction status. When the ball mill voltage decreased, according to the motor characteristics, its rotation speed will decrease, which will disrupt the hydrodynamic lubrication state of the hollow shaft and spherical surface, so that the power consumption of the ball mill increase. The larger power leads to the transmission fault. This paper also put forward to make sure kept the ball mill main bearing lubrication status.

Keywords: *ball mill driving system, power of ball mill, the motor characteristics, hydrodynamic lubrication*

1. Introduction

Ball mill is mainly composed by a cylindrical body with thin surface. Most ball mills bodies are supported by roller bearings. With rubbing and feed staff inside, when the ball mill is rotating, rubbing and feed staff are brought to a certain height. When there is no contact force between the rubbing staff and ball mill body, feed material is dropped down. By using this drop-down process, the material could be milled to powder. Ball mill machine's structure is quite simple with high repeatability and it is widely used in cement, elecric power, metallurgy industries. The research on its power consumption in order to have a high effiency is quite meaningful.

One ball mill used in a cement factory,the drive arrangement is as shown in Figure 1. It is side transmitted and in its center the material is dropped down. On both sides of the ball mill there are hollow shafts working as rigid joints. The ball mill body is supported by a ball bearing system. The driving system includes main motor ring gear, small gear, elastic rubber coupling, reduce box and rigid coupling.

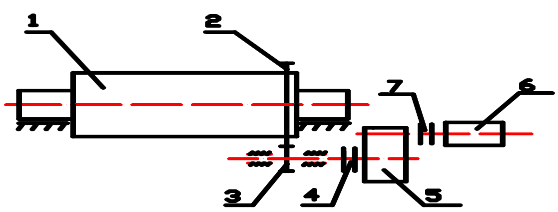

Figure 1. Ball Mill Driving Arrangement

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The ball mill specifications are：$\phi 2.2x6.5$ meter, Divided into 2 cabins used as the room for feed material mill. The useful length is 6.5 meters. The thick cabin is 3 meters. The thin cabin is 3.25 meters. The route for dropping down the material is 0.25 meters. Th useful volume is 22.3 cubic meter. The load for rubbing staff is 22 tons. The main moter is a JR1420-8 type with power of 280KW.

When the mill is in working in normal the motor current is 40A,voltage is 6000V. the rated power is 280KW。The ball mill working power is about 240KW. One fault often occurs in operation, which is in driving system. Between small gear and reduce box, there is elastic rubber coupling, Elastic shaft connection system is composed by elastic covered pin-shafts. It is compose by 2 half-connected shafts, pins and panels. the elastic rubber is wringed. At first the operators thought the wringed rubber may be due to rubber block quality problems, so they replaced the rubber. But after starting the ball mill the new rubber wringed again. This caused author attention. The rubber quality may not be the mail reason of the fault. Then they checked the ammeter and the voltmeter. The ammeter was 44A, and the voltmeter is 5800v.the working power of ball mill can be calculated as bellow:

$$N = IV = 44X5800 = 255200(W) = 255.2(KW)$$

When the ball mill is in normal, the motor current is 40A, the voltage is 6000 volt。So the ball mill normal power is 240KW. The power is increased by 6.3 %, when the raw material was fed and the grinding media charging kept fixed. The actual power increased might be the main reason accusing the Elastic rubber of elastic rubber coupling cracked.

2. What is the reason Leading to the Power Increase of Ball Mill

2.1 The Power of the Ball Mill

From the working principle of the ball mill machine, it is known that ball mill body is rotating with a certain speed with transmission system. By centrifugal force, the rubbing and feed staff inside is brought to a certain height. When there is no contact force between the rubbing staff and ball mill body, rubbing staff starts to drop down. With a certain downwards speed, rubbing staff gives thrusts to the feed material and mills it.

When the ball mill is working, the power of the ball mill has two contributions: the great part power of the ball mill is used elevating the grinding media and raw material. The rest power are used to overcome friction. The power used to elevating the grinding media and raw material is proportional to the charging of the grinding media and the raw material. Increasing rubbing staff and feed material power consumption is the main power consumption of the ball mill machine. Increasing feed material poer consumption is related to the increase of the rubbing material load and speed increase.The power of ball mill used to elevating the grinding media and raw material can be calculated as bellow:

$$N_0 = 0.4GRn \tag{1}$$

where: N_0: the power used to elevate the grinding media and raw material, KW:

G: the charge of the grinding media, ton:

R: the radius of the ball mill shell, m:

n: rotation speed of the ball mill shell , r/m。

As mentioned above, it can be known that the power of ball mill is proportional to the rotation speed of the mill and the charging of the grinding media. That is to say, if the feed material quantity is increaed, its power consumption will be increase. If ball mill machine's rotational speed increases, its power consumption also increases.

The other part of the ball mill machine power consumption comes from the friction work. Talking about the side-transmission ball mill machines, there is the friction in the electric motor, speed reduction gears , between its small gear and large gear and in the place between the ball mill machine body and its supporting bearings. The friction in the electric moter, speed reduction gears and betwwen its small gear and large gear has lower power consumption because of their lower reaction forces. So for these parts, it could be taken into consideration by using a efficency coefficient. The supporting force in the main bearing is the sum of the rubbing staff mass, feed material mass and ball mill machine mass, interior panels and panels for separation.

The friction consumption between the ball mill machine body and support bearing is equal to the total mass multiplied by friction coefficient. Since the total mass is quite large, the friction is also large. If the lubrication changes, its friction coefficient would change and influence the power consumption. Usually the lubrication in the main support bearing is of static pressure start and dynamic pressure working. That is to say during its start, high pressure pump gives oil for the friction, forming a lubricant membrane. When the ball mill machine is rotating in the normal working condition, since the diameter in the support zone is large, thus speed is high. It is possible to form dynamic pressure lubrication with geometrical design. So it is possible to consider the lubrication is in dynamic pressure state when the ball mill machine is working. Considering all above talking about, ball mill machine's friction power consumption could be calculated with a efficiency coefficient.

The power used to overcome the friction includes all assumed to overcome the friction. When the ball mill is in working condition, the power used to overcome the friction is the smallest among total power. The power which the ball mill needed use the transmission efficiency, the formula as below:

$$N = \frac{0.4GRn}{\eta} \tag{2}$$

Where: N: power of the ball mill, KW:
η: mechanical efficiency。

The ball mill with center transmission ,the efficiency, $\eta = 0.92 \sim 0.94$

The ball mill with wring gear transmission ,the efficiency, $\eta = 0.86 \sim 0.90$

The power used to overcome the friction includes two parts. One part used to overcome the friction between the driving parts. The other used to overcome the friction between the hollow shaft and spherical surface bearing. According the formula (2), the mechanical efficiency only considers the friction.

But the ball mill bearing system lubricate is hydrodynamic lubrication. It is known from the formula (2),the mechanical efficiency only considers the friction between the transmission elements. But the weight of ball mill is very large, the friction force between the hollow shaft and the sliding bearing are direct proportional to force acting on the bearing . Because the force is great, so the friction force are varying to the lubrication. when the lubrication condition is changing, the force will be change too。

Let's analyze the friction power consuming between the hollow shaft and spherical bearing. The power consumption overcoming friction between the mill shaft and spherical surface is represented as following:

$$N_2 = (G + G_1) gf \bullet r\pi n / 30 \tag{3}$$

Where : N_2: the power consumed between the hollow shaft and bearing, KW;
G: the weight of the grinding media and the raw material in the ball mill, ton;
G_1: the weight of the rotating department of the ball mill, ton;
f: the friction coefficient of the hollow shaft and the bearing;
r: the diameter of the shaft, m;
g: gravity acceleration, m/s^2。

In general the ratio of the radius of the hollow shaft to that of the mill shell is about :0.3~0.55, that is to say: $r/R = 0.3 \sim 0.55$. In general, the weight of the rotating department of the ball mill is smaller than the weight of media and the raw material. the weight of the rotating department of the ball mill can be ignored when the power is calculated. That is to say : $G \approx G_1$. So the formula (2-2) can be written as below:

$$N_2 = (0.0627 \sim 0.115)GRnf \quad (4)$$

Comparing the type (1) and type (4), when the friction coefficient is with different values, friction power consumption to the total power consumption of the ball mill are listed in Table 1.

Table 1. The ratio of the friction power consumption to the total power consumption of the ball mill changes with the friction coefficient between the hollow shaft and spherical surface bearing

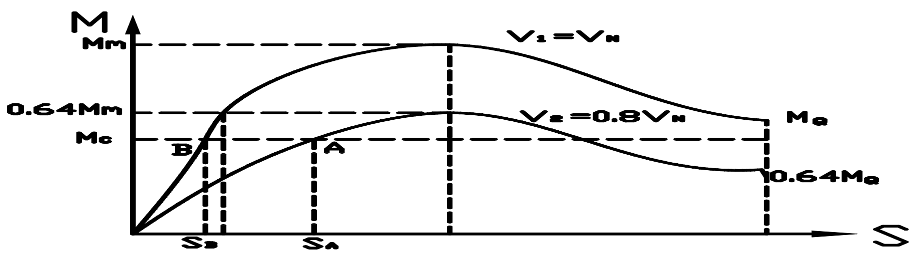
f	0.001	0.005	0.01	0.02	0.03	0.04	0.05
N_2 / N_0 (%)	0.0157~ 0.0288	0.097~ 0.0144	0.157~ 0.288	0.314~ 0.576	0.471~ 0.864	0.628~ 1.152	0.785~ 1.440
$N_2 / (N_2 + N_0)$ (%)	0.015~ 0.029	0.079~ 0..0144	0.156~ 0.287	0.313~ 0.572	0.468~ 0.857	0.624~ 1.139	0.778~ 1.420

From Table 1 it can be derived that when the friction efficiency less than 0.01, $N_2/(N_2+N_0)$ less than0.156%~0.2875, in project, N_2 can be neglected consideration. When the friction efficiency is larger than 0.03, $N_2/(N_2+N_0)$ is more than 0.926%, in project, N_2 must be taken in to account. When the friction efficiency is larger than 0.04, the power used between the shaft and bearing must be considered.

2.2. What is Affected the State of Bearing Lubrication

According to the working principle of the motor, its electromagnetic torque is proportion to the square of the source voltage. When the source voltage decreases, the curve of motor's mechanical properties (Figure 2) will change (see Figure 2), when the source voltage decrease, the motor starting torque and the breakdown torque decrease sharply. If the source voltage decreased while other ball mill conditions are kept unchanged, then the motor working point will change from point B to A, this can be seen as Figure 2. the motor rotation speed decrease.

It can be said that the rotation speed of the ball mill shell becomes lower as the motor source power decreases. According the Figure 2, it is known that the power of the ball mill should be decreased .The height of the media in the ball shell is lower when the shell rotation speed is decrease. This accordance to the Figure 2.



S: the ratio of revolution M_m: the motor maximum torque M_c: the ball mill working torque

Figure 2. The Motor Mechanical Properties

But the ball mill fault stated force told that when the revolution of the mill decrease the power of the ball mill increased. From the power consuming analysis, it can be known that when the elevating power decrease, the total power increase, the increasing power must be caused by the friction. The lubricate state has not any changes when the shell rotation speed decrease. But only the lubricate state between the mill shaft and bearing may change, so this may be the main reason causing the power to increase when the ball revolution decrease.

What affect the lubrication state between the hollow shaft and bearing are the geometry condition, lubricating oil viscosity and the liner velocity of the contact point. The geometry condition and lubricating oil viscosity are kept fixed, but when the ball mill rotation speed decrease the liner velocity will decrease sharply. So the lubrication state may be changed from boundary film lubrication to hydrodynamic pressure lubrication.

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According to hydrodynamic lubrication theory, the carrying capacity of the sliding bearing deals with the bearing characteristic number. Bearing characteristic number is the function of eccentricity ratio, the width diameter ratio and wrap angle. When the characteristic number is greater than the critical value, the sliding will be in the state of hydrodynamic pressure lubrication.

$$S_0 = 10^{-6}\frac{\mu n}{p\varphi^2} \quad (5)$$

Where： S_0： bearing characteristic number，Dimensionless quantity；

n：the revolution of the ball mill r/m ;

φ：Relative gap between the shaft and the bearing，Dimensionless quantity；

p ： $p = 10^4 \frac{F}{BD}$ Average pressure（MPa）， F Bearing load，kN；B Bearing width，cm；D: Bearing diameter，cm；

μ：Lubricating oil viscosity，$Pa.S$。

From the type (5) it can be seen that the running speed of the bearing, the average pressure and viscosity and relative clearance affect sliding bearing characteristic number. When the ball mill speed decreases, the bearing characteristic number becomes smaller, if the bearing characteristic number is less than the critical value, the hydrodynamic pressure lubrication balance will be destroyed.

Ball mill hollow shaft diameter and ball mill cylinder clearance diameter is about 0.3~0.55. With the normal operating voltage, because the hollow shaft is larger in size, so the liner velocity of hollow shaft is relatively higher, so the lubricating state belongs to liquid dynamic pressure lubrication, so the friction coefficient is relatively smaller. It is about 0.0005, friction power consumption is lower, it can be seen from the Table 1, friction power consumed in sliding is less, and it can be negligible. When the supply voltage is reduced, due to the output shaft of the motor speed decreasing, the hydrodynamic pressure lubrication conditions between the hollow shaft and the spherical surface have been destroyed, so the lubricating state between the hollow shaft and the spherical surface changes from dynamic pressure lubrication into boundary film lubrication, friction coefficient will increase greatly. Thus the power surges, more than the entire transmission system design safety factor. Thus, causing the elastic rubber coupling rubber block is broken, the breakdown is due primarily to the increase of power, while the power increase is mainly due to the low power supply voltage.

2.3. Fault Treatment

From the above analysis it can be known that the lower supply voltage is the reason leading to destroy the hydrodynamic lubrication condition of the hollow shaft and spherical bearing of ball mill, which caused increased power consumption. The actual power increases of ball mill, causing the following consequences:

a) Causing components such as transmission parts, parts destruction, bearing burning and other faults, it will seriously affect the production.

b) From the motor mechanical characteristic curve it can be seen, when the power of the ball is increased, the output of the motor rotational speed is reduced, based on the previous analysis known, this will also lead to the power consumed by the friction between the hollow shaft and spherical surface

c) Leading to the load increase of every part of the transmission, reducing the equipment life, leading to lower the equipment operation rate

d) Power increase will lead to the operating costs raising.

Therefore, in production the voltage surge should be avoided, the voltage fluctuation will cause the power of a ball mill increase. According to the above analysis, suggestions for manufacturers to adopt are shown as follow:

1. in the production to ensure stable voltage supply, which is said to ensure the stable speed of ball mill.
2. Make a reasonable choice of the lubricating oil, choose a greater level for the viscosity. In this way, this can be avoided that when the source voltage is not stable, it does not cause a power surge problem. This will make the mill transmission load relatively smooth, improving transmission service life and operation rate.
3. Lubrication management system, fuel cycle, the period of oil replacement must align with to the actual situation. Correctly ensure the good lubrication between the hollow shaft and spherical tile.

References

[1] Chu rui-qing, general building materials machinery equipment, Wuhan Wuhan industry university press.

[2] Xu Linfa. *Building materials, machinery and equipment*. China: Building Industry Press. 1980; 12.

[3] Pan Xiaoliang. *Cement production machinery and equipment*. China: Building Industry Press. 1981;9.

[4] Xu Xuequan. *Fundamentals of electrical engineering*. Fudan University press. 2007.

[5] Zhang Liufei. *Cement, tube mill main bearing lubricating oil selection and alarm temperature*. 2003; 4.

[6] Shen Lei, Cement Works, Measures for control slide-shoe temperature of Φ4.2 m × 13 m double slide-shoe tube mill. 2008; 4.

[7] Chuangzhong Xian, Liyang Cao, Pei Wu, Yanhua Ma, Ding Han. Development on a Hammer Mill with Separate Sieving Device. *TELKOMNIKA Indonesia Journal of Electrical Engineering*. 2012; 10(6): 1181-1186.

[8] Wei Bing Zhou, Gang Zhou, He Shun Wang. Research on the Reciprocating Sealing of Fracturing Pump. *TELKOMNIKA Indonesia Journal of Electrical Engineering*. 2012; 10(3): 1181-1186.