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FAILURE ANALYSIS ON EQUIPMENT MAINTENANCE OF A CRUSHING UNIT

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Abstract. *The productivity of a mining company depends on many factors, thereby the availability of the industrial equipment of the sectors that constitute it is a predominant factor. It is in this context that the present work was developed, addressing the aspects of operation and maintenance of the sector of a mining unit of a mining company, being this sector one of the main chain of activities of a mining company. A technical analysis of the main problems of maintenance and operation of the sector was made, based on the impacts on the equipment availability and the productivity of the sector. Critical analyzes of failures were carried out, culminating in the emergency corrective maintenance of two fundamental equipment of the process. In the first equipment, the fatigue process of the drum shaft of a belt conveyor was identified and the cause of intervention in the second one was due to a crack in the support frame of an electric motor of operation of a crusher. As a result, the methodological application of flaw analysis was highlighted in the aforementioned two events. The investigative approach of each of the events has allowed to identify the root causes of the failure, thereby providing the starting point for solving the problem for its causes and preventing failure from occurring again, provided that preventative measures are adopted. It was conclusive that the adoption of the suggested measures during critical failure analyses can reduce the frequency of interventions by operation and maintenance crew, providing predictability of the desired availability for the equipment and consequent Company's satisfactory productivity.*

Keywords: *crushing, maintenance, equipment, failure analysis.*

1. INTRODUCTION

The productivity of a mining company depends on many factors, where the availability of the industrial equipment of the sectors that constitute it is predominant. The mining sector, has an extensive field of production since the exploration of the ore to the final production of metals, among other products.

Unexpected downtime due to equipment failures and operations interventions lead to reduced process reliability and also loss of productivity in the crushing unit. Interventions by operations personnel occur when the ore enters on the crushing process outside the specification of moisture and granulometry or even when it brings with it non-brittle material (Chaves and Peres, 2003).

Based on the typical maintenance encountered in a crushing unit, such as emergency corrective maintenance, preventive maintenance and corrective maintenance based on predictive analysis are the most common. Regarding the topic of failure analysis, it is a fundamental tool to find the root cause of a failure and from that point, plan solutions so

that the failure does not happen again. The applicability of this tool ranges from the study of the interventions made by the operating personnel to the study of the failures that caused the emergency corrective maintenance (Pinto and Xavier, 2013).

Therefore, this work aims to analyze the interventions made by the operation personnel, the types of maintenance performed at the equipment and failure analysis of cases that occurred in a crushing unit for a mining company. These analyzes aim to propose effective solutions avoiding the recurrence of problems and also seeks to show the reader the difficulties of operation and maintenance inherent to the mining sector of a mining company. At the outset is described the process and equipment of the crushing unit. Next comes a study on the types of maintenance on which this work will be based. There is then a context in which the problems of operation, maintenance runs and failure analysis are dealt with later.

2. METHODOLOGY

This section covers the stages of the crushing process, the main equipment used in the area and the types of maintenance present in the unit. In addition, an overview of equipment availability is presented, as it is directly related to maintenance and operation interventions.

Common maintenance and operating problems are critically analyzed. The maintenance that is used in this crushing unit is discussed and with them, examples and case studies are developed in this work. This allows a technical analysis of major maintenance and operating problems in the industry, based on impacts on equipment availability and crushing productivity.

Critical analyzes of failures were carried out, culminating in the emergency corrective maintenance of two fundamental equipment of the process. On the first one has occurred the fatigue of the drum shaft of a belt conveyor and at the second one was identified the cracking of the support frame of an electric motor that drives the crusher.

2.1 Crushing process

The crushing process consists basically of ore fragmentation and sieving. The steps are presented in a simplified and contextualized way to the reality of a mining unit of a certain mining company analyzed in this work.

According to Chaves and Peres (2003), mineral fragmentation is the set of operations, which consists of reducing the physical dimensions of a given set of blocks or ore particles, by means of a controlled external mechanical action. The reduction of ore size has different objectives, which can be classified into two large groups. In the first, the goal is to achieve the granulometric specifications required by subsequent operations present in a mineral treatment process. In the second, the objective is to achieve the granulometric specification required for the commercialization of products. In the case of this mining company, after the ore is crushed, it is sent to a mineral processing plant, that is, the objective here steps in at the first group.

2.1.1 Crushers, screens and grids

According to Chaves and Peres (2003), the crushers are characterized by presenting compression process as the predominant mechanism of fragmentation, which occurs through the periodic movement of approach and removal of a moving surface against a fixed surface. In the analyzed crushing unit, there are two types of crushers, one of the jaw type and two of the cone type.

In consultation with Chaves and Peres (2003), sieving can be defined as an operation consisting of thinning the material that will feed a fragmentation equipment. In the sieving operation, the separation of two fractions of the material in different sizes takes place through its presentation to a fixed and predetermined opening template. In the case of such a crushing unit, the templates may be parallel bar with vibrating grids or square meshed screens of a vibrating screen. In the analyzed crushing unit, there are two inclined vibrating screens and one vibrating grate.

2.1.2 Other equipment used in the process

The other equipment of relative importance for the understanding of the production process of the crushing unit are: belt conveyor, scrap extractor and metal detector. The equipment responsible for transporting the ore in the crushing line is the belt conveyor (Metso, 2005). The scrap extractor assists the operation team by automatically removing non-brittle ferrous material from belt conveyors when in operation, preventing this material from moving forward and causing the circuit to stop (this may cause damage to the belt). There is equipment called a metal detector, and is similar to the above. This equipment will attract and accumulate the material up to its magnetized area and then the operator must remove this ferrous material.

2.1.3 Process Flowchart

Defining the main concepts involved in a crushing unit and describing the equipment of the unit, the simplified flow diagram of the process is shown in Figure 1. It is noted that there are three crushing lines: the primary, secondary and tertiary.

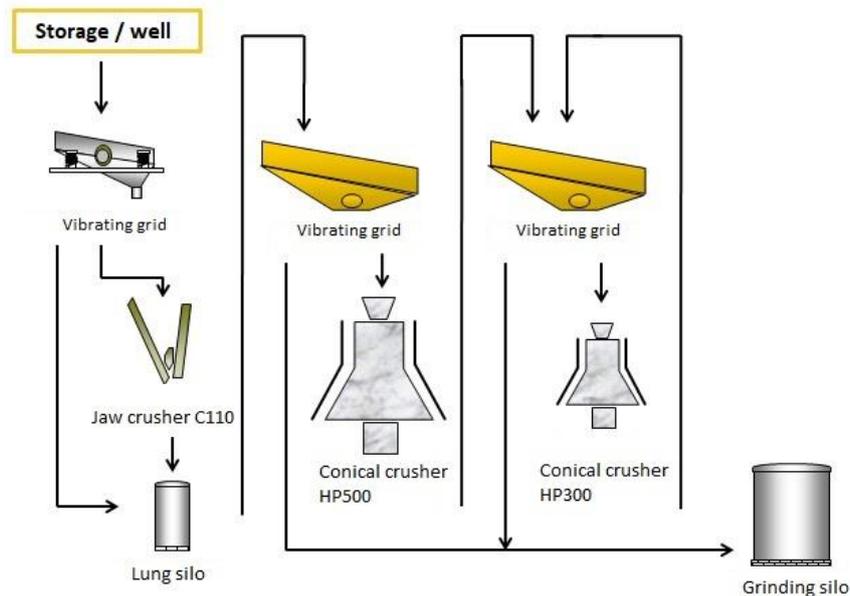


Figure 1. Simplified Process Flowchart.

In primary crushing, the ore comes from the well (underground mine) or from the stockpile (whose ore comes from another mine of the company). It is directed to the vibratory grid, where the passing material goes to the lung silo (ore slurry reduced but still with an rough granulometry) and what does not pass in the template goes to the jaw crusher, undergoing fragmentation process. This non-passing material, after being crushed, is sent to the same silo. The lung silo has the function of reserving material from the secondary and tertiary crushing system when there is a shortage of ore in the well and in the square. In the secondary crushing, the material stored in the lung silo is conveyed to the first vibrating screen, the material that it is able to pass goes to the milling silo (ore slurry with reduced particle size, which is already the final product) and the non-passer goes to the first conical crusher. After this material is crushed it is sent to tertiary crushing. In tertiary crushing, the ore is directed to the second vibrating screen, the passing material goes to the grinding silo and what does not pass goes to the second crusher. After this material is crushed, it returns to tertiary crushing. It is noticed that in primary and secondary crushing the circuit is opened, that is, the ore passes through it only once, as soon as the tertiary crushing circuit is closed and the material recirculates in this step until it meets the specified granulometry and goes to the silo grinding. The grinding silo is where the final product of the crushing is intended. The ore that arrives at the crushing plant with an average granulometry of 150 mm. The final crushed product has a particle size of 9.5 mm. From the milling silo on, it is the ore beneficiation process, whose theme is not addressed in this work.

2.2 Types of maintenance analyzed

The maintenance activity needs to be no longer just efficient but instead of that must be effective, that is, it is not enough just to repair the equipment or installation as quickly as possible, but to keep it available for operation, to avoid further failure and to reduce risks of an unplanned downtime. Maintenance has started to be seen as a driving force behind a real revolution that can lead a company to stand out with competitive differentials, by increasing the operational reliability of assets, reducing intrinsic costs, reducing waste, rational use of available resources and increase of production rates, among others (Viana, 2002).

The types of maintenance used in this crushing unit were analyzed and some examples and case studies are developed in this text. These are unplanned corrective maintenance, preventive maintenance, and planned corrective maintenance based on predictive analytics.

2.2.1 Unplanned corrective maintenance

According to Pinto and Xavier (2013), the unplanned corrective maintenance is characterized by the performance of the maintenance team in an event that has already occurred, whether due to a failure or a performance below

expectations. There is no time for service planning and scheduling, so it is termed as corrective or unplanned maintenance. Usually this type of maintenance entails high costs, as unexpected breakage can lead to loss of production, loss of product quality and high indirect maintenance costs, and can affect safety and the environment.

2.2.2 Preventive maintenance

According to Pinto and Xavier (2013), preventive maintenance which is performed at predetermined intervals is intended to avoid and prevent the occurrence of failures and the degradation of the functioning of an asset. It is usually applied when there are aspects related to personal, environmental or installation safety that make it mandatory to substitute components for opportunity in critical equipment that is difficult to operate, among other examples.

2.2.3 Planned corrective maintenance based on predictive maintenance

According to Pinto and Xavier (2013), the planned corrective maintenance structured through the prediction fundamentals is characterized by the corrective intervention process when the equipment performs less than expected based on the monitoring of the parameters and indicators that give the actual condition and diagnosis of the equipment at that moment, detecting any anomalies. A planned job is always cheaper, faster, and safer than unplanned work, and will always be of better quality.

2.3 Crushing availability and productivity

Availability can be defined as the ratio between the time an equipment or industrial plant is in the right conditions (mechanical, electrical, electronic and civil) to perform the operation and the total number of scheduled hours.

The crushing unit is scheduled to operate 24 hours per day. However, the interruptions due to the operation and the stoppage of the maintenance, the availability of the operation is considerably reduced. The data collected from the interruption time count for the maintenance and operation of the period corresponding to the first half of 2016 were analyzed and are presented in Table 1, in which it brings the stratification of these interruptions and presents the unavailability resulting from the interruptions by the operation and by the stops maintenance.

Table 1. Production Interruption.

Interruption of production correlated to time (%)				
Maintenance		Operation		
Preventive and planned corrective	Corrective unplanned	Clogging	Adjustments	Lack of ore
9.5	8.5	4.1	8.6	4.3

It is noticed that the stops performed by the maintenance of the unplanned corrective type represent the lowest percentage, when is compared with the preventive and the corrective planned. It is important to note that planned corrective maintenance pass by an predictive analysis in its development and that interruptions due to unplanned corrective maintenance are the ones that most impact on productivity. As for the interruptions made by the operation, there is the problem of clogging, lack of ore on the well and the storage area (a problem that is part of the unit's work routine, since it depends on the shipment of the ore through the well and transportation by truck from the ore from another company mine to the square) and last and most representative, the adjustments. These adjustments include empty lung silo stops (reserve of secondary and tertiary crushing), operation of scrap extractors requiring support to prevent non-brittle material from tearing the belts, cleaning conical crusher arms to remove non-brittle and non-ferromagnetic material, equipment adjustments and release of the control room, among others.

Table 2 presents in general the availability of the time for the maintenance, for the interventions made by the operation and for the production of ore crushing. Table 2 shows that the availability for production in the period evaluated was 65%. During this period, an average production of 267 tons / hour was also recorded, taking into account the production unavailability data. The monthly production is 125,000 tons / month.

Table 2. Global Availability.

Time-related global availability (%)		
Maintenance	Operation	Production
18.0	17.0	65.0

Emphasizing further the data, the forecast of operation of the crushing that was of 24 hours, reduces to 65% of that time, that is to say, 15.6 hours of effective production. The rest of the time is spent, almost equally, between maintenance and operation interventions.

2.4 Analysis of interventions

2.4.1 Analysis of interventions made by the operating team

Some problems were presented in which the operation team intervened, corresponding to 17% of the productive unavailability of the crushing during the period evaluated, according to Table 2.

Figure 2 (A) shows the log of the problem caused by the clogging due to excess moisture in the ore coming from the well and the problem of clogging of the jaw crusher by boulders. Boulder can also lock the conveyor belt at some point when encountering an obstacle (jamb) at the top, or even at the sides if it is larger than the width of the conveyor belt.



Figure 2. (A) Clogging due to excess moisture (B) Blocked with boulders.

The established humidity of the ore is 3%, but in this situation the humidity percentage is well above. This causes the interruption of belt conveyor by weight overloading, mechanically affecting the drive assembly of the conveyor. The overflow of this mud (highly moist ore) contributes to the local dirt, creating difficulty for the area access. Contamination of other components of the belt conveyor, such as the rollers, accelerating their wear. If this ore continues, it causes clogging in the grate or in the primary crusher, and if it does that, it causes further damage by being stored in the lung silo in this wet form. From the lung silo for secondary and tertiary crushing, the ore with excess moisture clogs the screens of the vibrating screens, reducing their sieving capacity and making the material circular for a longer time.

Figure 2 (B) also presents the problem of clogging of the jaw crusher, but caused by boulders. The average size of the ore that reaches the crushing is 150 mm, but the ore from the storage place may have a higher grain size, as in this case. This problem causes the primary crushing line to stop for several hours (around 6 hours).

An inherent fact in the crushing routine is the presence of non-brittle material along with the ore to be crushed. There is equipment such as the scrap extractor and metal detector responsible for removing this non-brittle ferromagnetic material from belt conveyors. Failure to operate this equipment can be by the fact that the scrap extractor is deactivated by the operation, or even because the metal detector is saturated with ferromagnetic materials and has not been cleaned by operation personnel, and this can cause rips on the belts and the crushing unit will stand still for several hours until an amendment is made in them. This problem also occurs when lamellas of the ore, that is, in format of stone blades enter the circuit. Both the non-metallic material and the ore in lamella when attached to the walls of the conveyor and in contact with the belt act as a blade, tearing it. Figure 3 (A) shows a ferromagnetic material and Figure 3 (B) ore lamella, both cases caused tear in the conveyor belt in which carried them.



Figure 3. (A) Tear belt done by metallic material (B) Tear belt done by ore lamella.

2.4.2 Analysis of interventions made by the maintenance team

From Table 2, it can be seen that 18% of the production unavailability of the crushing unit in the evaluated period is due to maintenance. Of this percentage, almost half is due to emergency corrective maintenance. The impacts caused by equipment failures were considered.

As contextualized in the part of interventions by the operation, the belt tear paralyzes the belt conveyor and that sector of the crushing circuit becomes inoperative. Depending on the size of the damage of the belt (greater than 50 cm), the repair can only be done by a third-party company. It is a case of an emergency repair, which until the service be contracted and carried out, several hours of production have been lost (around 6 hours) depending on the criticality of the sector in which that belt is part.

It was also contextualized the problem generated by boulders (fragments of ore with dimensions above the limit of granulometry defined by the unit) that enter the crushing circuit. In addition to the production loss caused by the time spent by the operating team to remove these boulders from the crushing circuit, damage to the physical structure of the belt conveyors may occur due to the weight and impact of them entering the circuit. There may occur fracture of trestles and stringers that make up the physical structure of the conveyor, as well as irreparable damage to the rollers that support and allow the belt to move, requiring replacement. Depending on the proportions of damage, that sector of the conveyor will need to be repaired for the belt re-operate. Figure 4 shows the support structure of the belt conveyor and a support roller damaged by the impacts of the boulders on the belt.

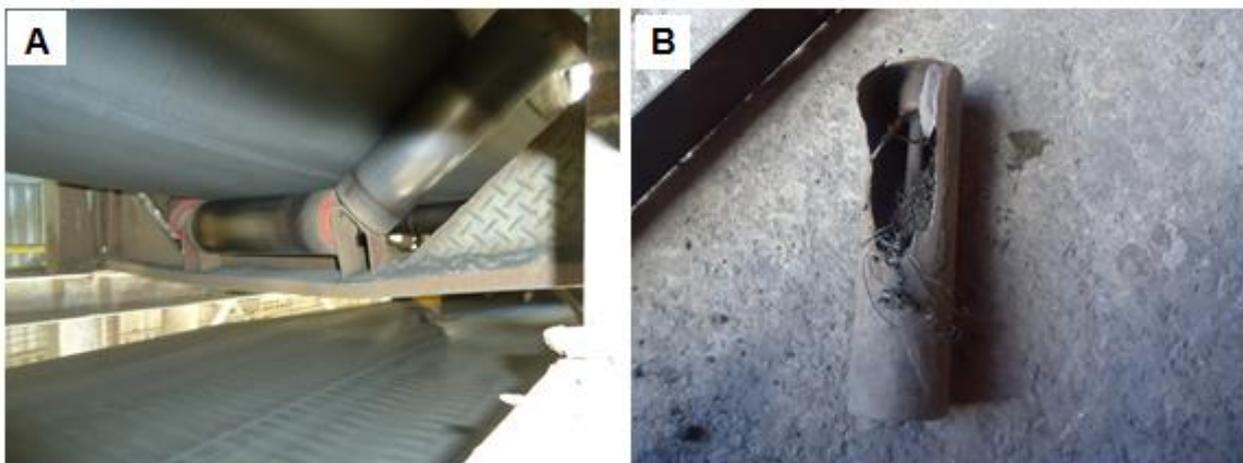


Figure 4: (A) Conveyor physical structure and belt support (B) Belt Conveyor Roller Damaged.

Considering the operating and maintenance problems at the analyzed crushing unit, it is proposed to identify measures with the objective of reducing downtime due to operations and maintenance interventions and reducing losses due to repair costs of the damaged equipment.

2.5 Failure analysis

Failure analysis has as main objective: the increase in the operational reliability of the plant, which is done by increasing the equipment availability; reduction of maintenance costs; reduction of accident risks involving the technical team, the environmental part and the equipment. These goals can be achieved if new failures can be avoided. The investigation should determine the root causes of the failure and this information should be used to allow the introduction of corrective actions that prevent a recurrence of the problem (Affonso, 2014).

Next, two analyzes of failures were carried out in equipment of high criticality of the crushing process, due to the representative loss of productivity due to the interruption of the operation.

At the first one, failure analysis was made on the drive system of a belt conveyor that failed at a point of high criticality of the crushing line. The transporter is responsible for resuming the ore stockpiled in the storage square for the crushing line. When the failure occurred, this ore remained for 48 hours without being crushed and the primary crushing started to work when ore from the well came, working in an intermittent process, since there are periods when it does not supply the crushing line. That is, the productivity of primary crushing was greatly affected.

Each crushing belt has two drums, a motor drum that transmits the torque needed to move the belt overcoming the resistors and the driven drum, being that the drums are located at the opposite ends of the belt conveyor. This failure in the belt conveyor occurred by breaking the driven barrel axis which keeps the belt tensioned and moving (Figure 5-A), close to the bearing support, and by breaking the bearing of the other end of the shaft of the drum. When the shaft broke at one of the side of the drum, it provocate a radially movement and the other end of the shaft applied a momentum greater than the bearing could hold and consequently has broken either (Figure 5-B).



Figure 5. (A) Moved barrel shaft break (B) Bearing failure on the opposite side of the fractured shaft.

The second failure analysis was performed on the electric engine that drives the secondary crusher. This crusher is responsible for processing the fragmentation of the secondary crushing and is a highly critical in the process. The interruption of the operation caused the stop of production of the secondary and tertiary crushing, compromising the supply of the milling silo. Inspection of the operation crew interrupted the process for 12 hours as there was an imminent risk of an accident. This emergency corrective stop required a lot of effort from the mechanics and electrical teams to search for a new engine in the warehouse, prepare it and install it, and then resume the process, which has compromised the execution of the other scheduled activities of the aforementioned teams.

The failure occurred in the starting drive of the crusher which is performed by a high-power (500 hp) electric engine (Figure 6-A). There was a crack in one of its bases, responsible for maintaining it connected to the support structure at the floor. In figure 6 (B) stands out the cracked foot of the engine.



Figure 6. (A) Electric motor (B) Cracks at engine stand and detail of the fixing bracket.

3. RESULTS AND DISCUSSION

Proposals for solutions to the analyzed problems are presented in this section, taking into account both the interventions made by the operation and the maintenance, as well as the two failures analyzes of the process equipment.

3.1 Solutions for the interventions made by the operation and maintenance teams

Typical failures of operation and maintenance described were proposed. Note the importance of adopting measures to eradicate routine problems that represent around 17% of the unit productive time unavailability for the operation and 18% for maintenance.

The problem of excess moisture from the ore was solved when it was sent to the storage square to dry, or to passing through a controlling process of humidity by the responsible team of the well not allowing the ore to go forward on the line with a high state of humidity.

The immediate solution to the problem of clogging caused by boulders is based on their removal by hydraulic clamping if they have entered the circuit. But this is not a definitive solution, as it depends on the surveillance of the operation team. The problem is solved by providing a hydraulic breaker in the square area to undo the bumps before they enter the crushing line. The abovementioned recommendations for eliminating boulders are relevant in order to avoid damage to the conveyor belt, support rollers and belt guide structures, since the maintenance required to recover the operation of the conveyor are based on emergency maintenance type, soon undesirable.

Regarding the problem of tearing of belts by non-brittle material, it is necessary the replacement of the metal detector, which requires the presence of the operation personnel to remove the captured material, by a scrap extractor, as it has a dynamic system of operation and removes automatically the captured metal. It is important that the operation maintains these equipment actives during the conveyor work, or in case of maintenance of them, the movement of the conveyor belt must be interrupted until they come into operation again. Regarding the belt strains consequent on the ore lamellas, the operation should be attentive to this mineral format, removing the smaller stones or breaking the larger stones with the help of a hydraulic breaker after being diverted to the ore storage square.

The aforementioned recommendations regarding auxiliary equipment such as scrap extractors and the attention of the operation team are of high relevance to avoid the intervention of the maintenance team, since these types of repairs are classified as emergency maintenance type.

3.2 Discussion on the failure analysis

Due to the amount of boulders present in this ore, the overload of bending and torque applied on the shaft of the drum, the impact of falling rocks and also the process to transport this material, provided an accelerated process of fatigue on the axis. Due to the amount of boulders present in this ore, the overload of bending and torque applied on the shaft of the drum, also the impact of falling rocks and the process to transport this material, caused an accelerated process of fatigue on the axis.

In this case, the fatigue failure is identified by analyzing the fractured surface (Figure 7 - A). A small corroded area is perceived representing the level of the final effort in which the fracture occurred, that is, the effort was low. It is observed that the crack propagates from the outer surface of the shaft, where the torsional and flexural stresses are greater, to the center. The cracking process evidences that the shaft has ruptured with a high stress concentration. The beach marks are not clear, but the rest of the shaft surface is smooth.

The aggravating factor in this emergency maintenance was that there were no spare parts in the warehouse, that is, the driven drum, rolling bearing type used and bearing case. An emergency purchase of the components was necessary, which contributed to the total time spent to re-operate the equipment being relatively high, although the maintenance team used 5 hours to perform the repairs. Figure 7 (B) records the time after corrective maintenance has been performed, where the belt conveyor re-operates. It would be necessary to keep in stock the spare parts of the aforementioned components, as a suggestion, to reduce the impact caused in the production due to the excess time in which the equipment was out of operation (total time of 48 hours), since it is complex to estimate the total numbers of life cycle for this drum axis because it is subjected to a very variable and intermittent applied load inherent in the process. Human and environmental risks are zero, however, the loss due to unproductivity is high, and is often caused by the long process of buying spare parts.

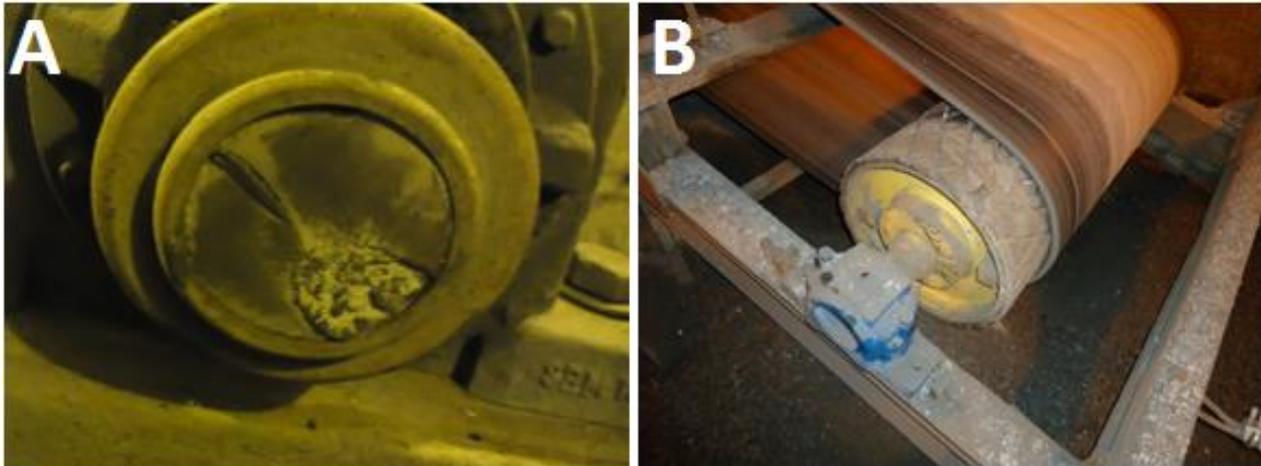


Figure 7. (A) Fracture of the shaft attached to the bearing (B) Drum and bearing after maintenance.

The operation interrupted the operation of the crusher after noticing unusual vibration of the electric motor. An inspection made by electrical crew found a crack in one of the engine support feet as highlighted in figure 8A. For safety reasons, the engine was replaced as a preventive measure to avoid the rupture of this cracked foot. In case of breakage the vibration would increase and the engine would become unstable and could be pulled out of the support and thrown, causing damage to other equipment and as a more serious risk to the employees of the area.

Critically analyzing the failure of the electric motor due to the appearance of a crack in its fixing foot, it is perceived that the causes of the problem are several. From the analysis of Figure 6 (B), it can be seen the non-conformity of fixing the foot of the motor to the support. The motor foot has two screw fixing holes and the foundation bracket has only one, allowing part of the foot to be out of the holder and thus secured by only one screw. This installation reduces the stiffness of the engine, making it vibrate more when starting up. There is also a hypothesis that this screw was poorly fixed, which provided a higher level of vibration of the motor and consequently the appearance of the crack in this foot. Detail of the crack can be seen in Figure 8 (A). It was necessary to change the electric motor and arrange for the motor with the crack to be sent to a company specializing in this type of repair. In addition to the engine change, the pulley driven by this engine and the power transmission belts were also changed. Figure 8 (B) reveals several cracks of the belts removed, evidencing their accelerated wear caused by the misalignment of the motor pulley with the driven pulley of the crusher. This misalignment caused significant vibration in the engine and the crusher, in addition to premature wear of the belts and possible damage to the pulleys. Another problem diagnosed was the mode of operation of the crusher powered by this electric motor. The crusher had its operation started many times with the ore loaded circuit, being necessary in the departure of the crusher extra application of power in relation to it start without load. This overload was passed to the electric motor and greater effort was required to start the crusher until it entered nominal operation, a fact that could be observed and heard by the sliding of the belts at the pulleys during the operation of the crusher (transient operating regime).

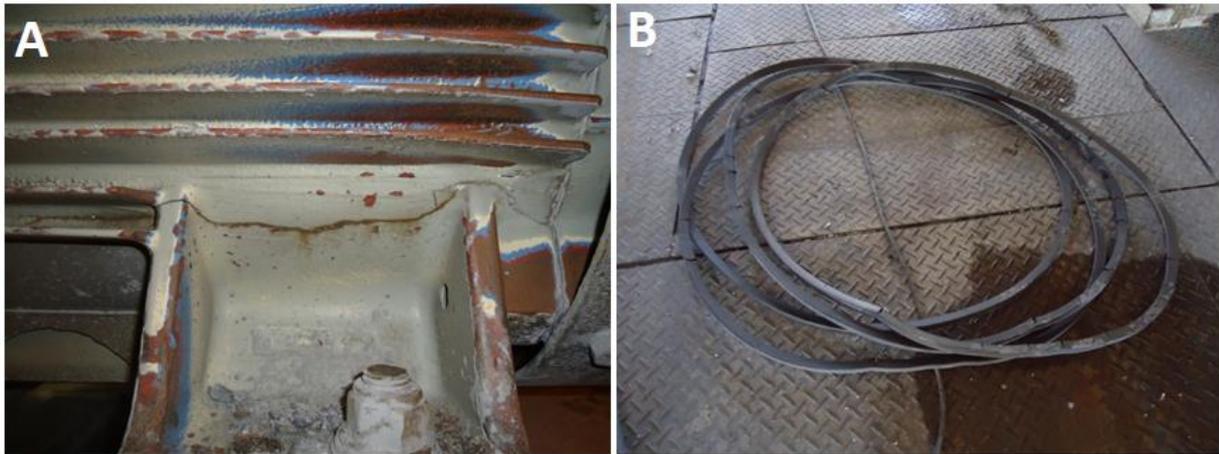


Figure 8. (A) Detail of the crack at the foot of the engine (B) Damaged crusher drive belts.

The new engine installation was made on the same support, however provisionally, because the production had to be resumed. Nevertheless, a specialized company was contracted to design a new support structure, adjusting the drilling of the support to the feet of the electric motor.

The cost for the recovery of the electric motor structure was high, since it was made necessary to replace the housing together with the stator winding, since it could not undergo a welding process. The high temperatures reached in a welding process to recover the housing could compromise the winding of the stator coils. The repair budget was R\$ 50,000.00, but a quotation of this same engine in the new state, was in the amount of R\$ 80,000.00. The crushing management chose not to recover the engine but instead of that to buy a new one for the warehouse.

Suggestions were made to avoid repeating this unexpected crash. Firstly, the engine mounting bracket must be changed and a new one installed with a larger base width and fastened by two screws, as well as the design of the electric motor. The fastening state of these screws must undergo a continuous inspection process to ensure their tightening since the vibration of the motor and the crusher can induce a loosening of the fastening of the screws. When installing the belts on the pulleys, it is necessary to apply an efficient alignment process to eliminate the possibility of vibration caused by the misalignment of these flexible elements when in operation. In addition, the operation team must be advised to unload the crusher if it is full of ore before putting it back into operation, thus avoiding engine overload and excessive vibration at its base.

4. CONCLUSIONS

This article had as objectives to show the process of crushing in a mining company, problems of operation, of maintenance and approach of analysis of equipment failures. The crushing process together with process flow chart was presented. The main typical equipment and their respective functions have been described. The types of maintenance performed in the sector and their advantages and disadvantages have been discussed, and an improvement become necessary in order to reduce the efforts with unplanned corrective maintenance and to intensify the actions in preventive maintenance and mainly in predictive maintenance.

The correlation between availability and unavailability by operation and maintenance in the crushing process was presented. The problems faced by the operation and maintenance team were analyzed, and in addition, measures were suggested to avoid their recurrences. The solutions presented do not involve major investments when compared to losses due to lost profits caused by disruption of the process. These investments are intended for the acquisition of new equipment, replacement of others, training and greater awareness of the operation team

Finally, two analysis of failures were made in a high criticality equipment of the process, showing the applicability of this tool in the search for the causes of the failure and suggestions to avoid the repetition of the problem. The first failure analysis refers to the breaking of a drum shaft of a belt conveyor due to fatigue failure. The second analysis refers to a crack in the fixing base of an electric engine. Both failures caused the interruption of the productive process and there was a need for emergency intervention of a corrective maintenance. In the first case, the repair time was high due to lack of spare part, in the second case, the repair was performed relatively quickly.

Failure analysis has proved to be a valuable tool to solve the problems reported in this work and, as in other industrial maintenance sectors, if correctly applied, provides an increase in the availability of the industrial park equipment and, consequently, increase the productivity of the company.

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