



Productivity Study in an Iron Ore Crushing Process

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Abstract: In the present work shows the method used to carry out a productivity study in an iron ore crushing process, with the objective of identifying the main causes of delays, determining possible improvement alternatives to break them down and complying with the monthly crushing program established. The results obtained show that the crushing system currently operates with delays that represent 22.8% of the net operating time and that the most significant delays are "large stones in grid R-1", "lack of ore" and "non-operational delays" "; with 31.8%, 22.5% and 19.2% of composition respectively, for a total of 73.5% of the total delay time. Basically, due to these delays, it is not possible to comply with the monthly crushing program.

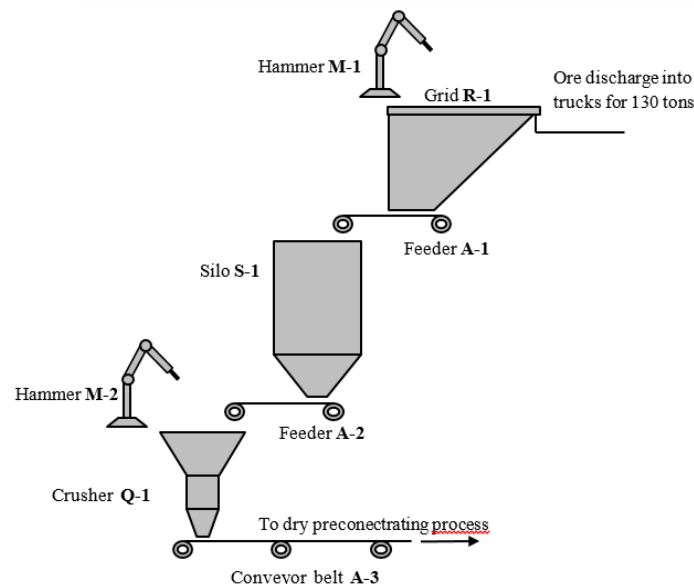
Keywords: Delays, hammer, grate, silo, feeder, breaker, large stones.

I. Introduction

Mexico is a country with abundant mineral resources (Romero & Gutiérrez, 2010), which is why mining is one of the most traditional economic activities in Mexico, which contributes to the economic development of the country by supplying inputs to a series of industries (Salinas & Hernández, 2016). According to the study conducted by Correa et al., (2014), the demand for minerals has increased greatly after the year 2000, under the combined effect of Asian growth and the crisis of Western economies. The problems related to mining projects have been widely studied from the environmental point of view as reflected in the work of (Correa et al., 2014), in its edition of best environmental practices in mining, focusing on the fact that it is not possible to eliminate the cost environmental, if it is possible to reduce it through the improvement of the mining operation.

Diverse have been the investigations realized to harness the increase of the productivity in the mining sector, some authors like (Pretty et al., 2003), show expositions for the design and the planning of optimized mining processes. In (Lemieux, 2000) a feasible solution is presented in the reduction of time for the development of the mining process. In the work Glehn & Bluhm (2001), reference is made to the installation of aeration faucets to favor the performance of workers. These elements are auxiliary installations of ventilation, compressed air, electrical and water installations for the water intake and water conduction for drilling holes.

Figure 1: Proceso de trituración de mineral y nomenclatura de los equipos.



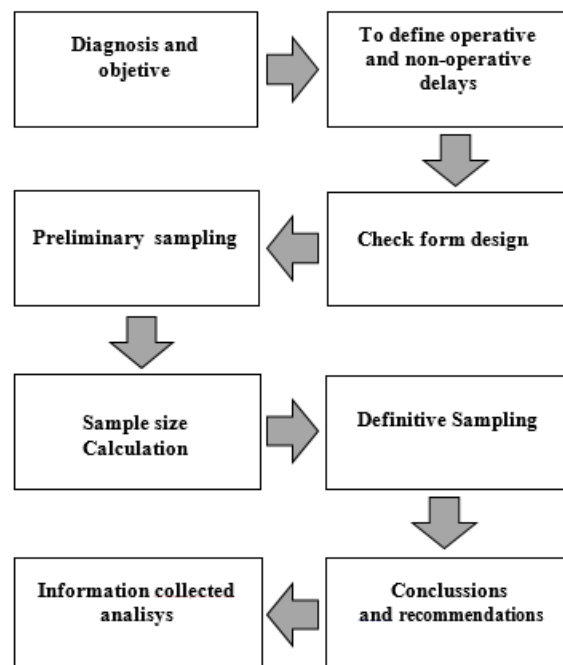
The crushing process of iron ore begins in a large hopper, where the fragmented iron ore is discharged from the mine in trucks with a capacity of 130 tons; in the upper part of this hopper is the grid R-1, in which all the stones with a size greater than 50 cm remain, which must be broken with the hydraulic hammer M-1, so that they can pass through this grid and do not cause problems in the process. The ore falls into the plate feeder A-1, to be deposited in the S-1 silo; in the lower part of this silo is the feeder A-2, which takes the ore to the Q-1 breaker, where it is crushed to a maximum size of 10 cm.

The feeder A-2 unloads in the breaker Q-1, here is the hydraulic hammer M-2, which does not work as such; since its function is limited only to move the stones that are "encampanadas" or stuck in the cone of the Q-1 breaker, obstructing the flow of ore. The ore already crushed falls on the conveyor belt A-3 to take it to the dry pre-concentration process; Figure 1 shows schematically this crushing process and the nomenclature of the equipment. During the first eight months of operation in 2016, the monthly ore crushing program has not been reached, with 86.2% compliance on average and with a clear downward trend; this is due to continuous operation delays of the crushing process due to different causes not justified, which cause it to stop or operate in a vacuum; that is, without mineral flow, which increases the cost per tonne crushed. When the feeder A-2 operates under vacuum, it means that the ore in the S-1 silo has run out and that the Q-1 breaker also operates under vacuum; this is an increasingly frequent operation delay, due to which it has been necessary to carry out a productivity study of the crushing process, in order to determine the main causes that cause the problem, as well as propose alternative solutions to eradicate them.

II. Materials and Methods

The method used to carry out the present investigation is summarized in the stages shown in figure 2 and described below.

Figure 2: Method used.



Diagnosis and objective: This stage basically consisted in knowing the crushing process and its operation, becoming familiar with the nomenclature of the equipment, as well as establishing a specific, clear and achievable objective.

Define operational and non-operational delays: For this phase, it was first necessary to clearly establish the concept of "crushing delay" for this study.

Crushing delay: "When the feeder A-2 works under vacuum; that is, without load or stops, without just cause". Under this definition, all possible operative and non-operative causes that could generate a crushing delay were identified and classified; within the first ones were:

- Plugging of chutes.
- Lack of mineral.
- Pulleys of dirty bands.
- Large stones in grid R-1.
- Equipment failure.

- Stones stuck in Q-1.
- Plugging of chutes.
- Silo-bedded ore S-1.

Among the non-operative causes were:

- Lubrication of equipment.
- Visual inspection of equipment.
- Food intake.
- Change of shift.

Record sheet design: To facilitate field sampling, a record sheet was designed to allow as little time as possible to record the time of each crushing delay.

Preliminary sampling: Since the crushing process is a continuous process, field sampling must be continuous as well; the unit to sample was the work shift, where p (success) is the time the process works with load and q (failure), is the time that the process works without load or stops. From a preliminary sample of 6 work shifts (2 first, 2 seconds and 2 third), it was determined that $p = 81.9\%$ and $q = 18.1\%$; This stage was also useful to improve the designed log sheet, make some adjustments to the sampling plan and modify some of the causes of the crushing delays identified.

Calculation of the sample size: With the information obtained in the previous stage, the sample size was calculated using equation (1), considering a confidence level of 95% and a margin of error of $\pm 10\%$, which resulted in a total of 32.8 turns that in practical terms are 33 work shifts.

Definitive field sampling: It was carried out during the 33 shifts according to the sample size obtained (11 first shifts, 11 second shifts and 11 third shifts); the time allotted for the food intake, as well as for the shift change is 40 minutes [8], after that time it was considered as a delay. On the other hand, the lubrication and inspection of the equipment are carried out during the food intake or during the change of shift according to the circumstances [8], similarly if they were used more than 40 minutes, it was considered as a delay. The sampling time is broken down below:

Total time sampled: (33 shifts) $\times$ (8 hrs.) $\times$ (60 min.) = 15,840 min.

Non-operative time due to change of shift: (33 events) $\times$ (40 min.) = 1,320 min.

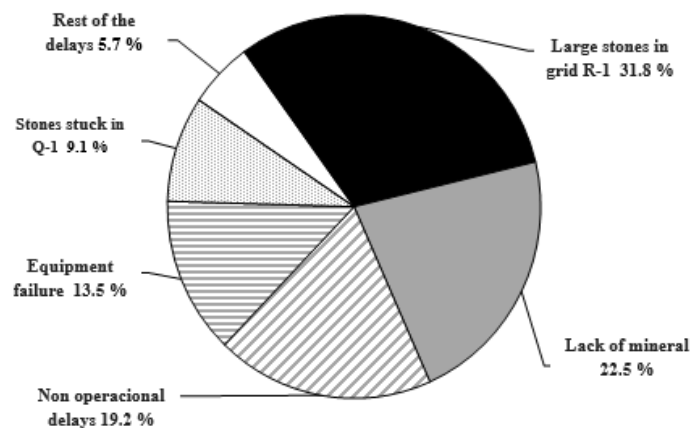
Non-operative time for food intake: (33 events) $\times$ (40 min.) = 1,320 min.

Net time sampled: (15,840 min.) - (2 $\times$ 1, 320 min.) = 13,200 min.

III. Results

The figure 3 shows the results of the field sampling, where it can be observed that the delay "large stones in grid R-1" is the most significant in terms of duration and composition, with 1,150 minutes of duration and 31.8% of composition; the "non-operational delays" turn out to be the longest average duration with 21.0 minutes and the delay "stones stuck in Q-1" the most frequent with 138 events. There were 513 delays, for a total of 3,613 minutes, representing a net unproductive time of 22.8%, and an average duration of 7.0 minutes per delay.

Figure 3: Composition of delays.

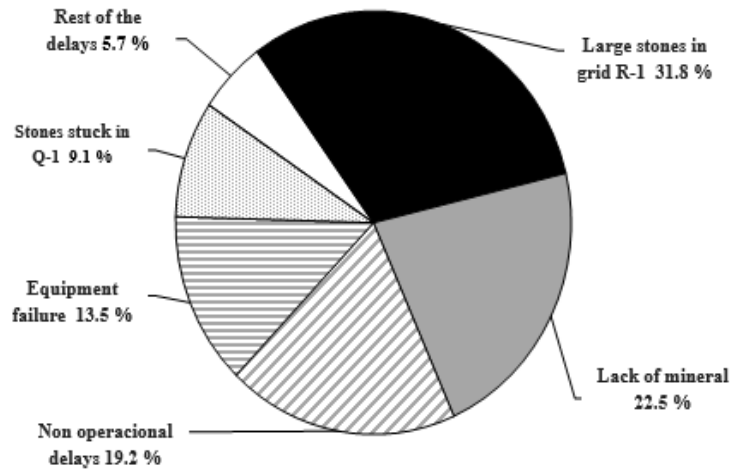


The "non-operational delays" were grouped into a single item since they are originated by the same cause, in this case it was detected that on average the change of shift lasts 52 minutes and the food intake 49; that is, 12 minutes more in the first case and 9 minutes more in the second case, representing a total of 21 minutes of delay per shift

for both events, with a total of 693 minutes, for a composition of 19.2% compared to total delays; It can be seen that these delays are greater during the third shift with 29.1 minutes of average duration.

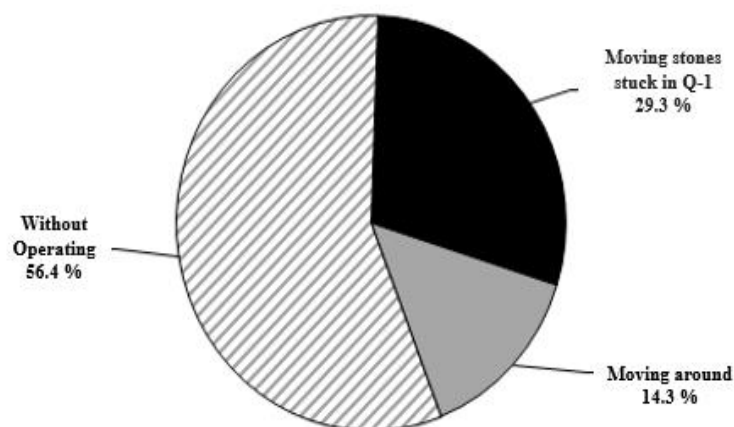
On the other hand, there is a clear and direct relationship between the delays "large stones in grid R-1" and "lack of ore", because when the first occurs, the ore is left unloading because this cannot be done while the M-1 hammer is breaking the stones left in grid R-1; when the M-1 hammer completes its task, it usually passes a period of time during which mineral can already be discharged to a breaker, but it is not done due to lack of communication between the plant personnel (operator - supervisor - shift manager), generating the second one, until the discharge of mineral to quebradora is reestablished; that is, often the first delay is followed by the second delay or in other words, often the second delay is a consequence of the first delay.

Figura 4: Operation of the M-1hammer.



The analysis of the work shift delays indicates that the problem is more serious in the third shift, with a total of 1,455 total minutes of delay, against 1,163 minutes and 995 minutes of the second and first shifts respectively, with this it can be said that During these shifts the problem is similar; On the other hand, the delay "lack of ore" is the one with the greatest impact in the second shift, with a 31.8% composition. In figures 4 and 5 the operation of the hammers M-1 and M-2 is observed; where it is appreciated that the first is not enough to reduce the magnitude of the delay "large stones in grid R-1", since only 15.4% of the total net time is stopped, while the second one does 45.6%, which assumes that it is adequate for the magnitude of the delay "stones stuck in Q-1".

Figura 5: Operation of the M-2 hammer.



IV. Conclusion

After the analysis and considering everything related to the operation of the crushing process equipment observed during the field sampling, it is possible to establish some conclusions:

The delays "large stones in grid R-1", "lack of ore" and "non-operational delays", turn out to be the most significant, with 31.8%, 22.5% and 19.2% of composition respectively, which represents 73.5% of the Total time of delays of the crushing process.

During the third shift the delays increase significantly with respect to the first and second turns; however, although there is a slight increase of the second with respect to the first, this difference could well be due to random causes; that is, the delays have a similar behavior during these two work shifts.

The delays "large stones in grid R-1" and "lack of ore" have a direct relationship; since usually the first one causes the second one.

The delay "lack of ore" is often caused by the lack of communication and supervision of plant personnel.

The "non-operational delays" are generated by the lack of supervision of the supervisor in turn.

The hammer R-1 is insufficient for the magnitude of the delay "large stones in grid R-1".

Based on the above, the improvement actions should be oriented towards the delays "large stones in grid R-1", "lack of ore" and "non-operational delays", as well as towards the operation of the third shift.

V. References

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