# Determination of factors that affect the availability in critical equipment of the grinding area in a sugar mill

# Determinación de factores que afectan la disponibilidad en equipos críticos del área de molienda en un ingenio azucarero

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**Abstract**

A production system in which there are no stoppages is the ideal of any company, so in this work we make a study comparing the factors that reduce the time that an equipment can be available to perform the primary function of the equipment. The objective is to compare the factors that affect the availability of critical equipment in a sugar mill. The work focuses on the beginning of the process at the batey area and mills, the decision is made because they show the highest number of stoppages. To be able to generate the results, it starts with the collection of faults and stops presented in the analysis area, with the pertinent information a fault book is generated to facilitate its analysis, a 49.10% availability is obtained for the mill area and 94.73%. for batey. It is concluded that the Mean Time Between Failures, Mean Time To Repair and availability indicators from these indicators establish strategies to reduce equipment unavailability.

**Availability, Critical equipment, Maintenance**

**Resumen**

Un sistema de producción en el que no se presenten paros es el ideal de toda empresa, por lo que en el presente trabajo se realiza un estudio en donde se comparan los facotres que reducen el tiempo que un equipment pueda estar disponible para poder cumplir la función primaria del equipment. El objetivo es determinar los factores que afetan la disponibilidad de los equipments criticos en un ingenio azucarero. El trabajo se enfoca en el inicio del proceso área de batey y molinos, se toma la decision debido a que en ellas se presentan el mayor numero de paros. Para poder generar los resultados se inicia con la recolección de fallos y paros presentados en el área de análisis, con la información pertinente se genera un libro de fallos para poder ser facilitar su análisis, se obtiene una disponibilidad del 49.10% para el área de molinos y 94.73 para batey. Se concluye que los indicadores *Mean time Between Failures, Mean Time To Repair* y disponibilidad a partir de estos se establecen estrategias para reducir la indisponibilidad de los equipments

**Disponibilidad, Equipment Crítico, Mantenimiento**

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## Introduction

Since the 1950s, a new stage in industrial maintenance has begun, as it begins by adopting a reactive culture to a proactive culture, based on actions that seek to prolong the useful life of the equipment; these actions are known as maintenance management through the implementation of methodologies such as maintenance focused on reliability and total productive maintenance (Díaz, Del Castillo, & Villar, 2017).

Industrial maintenance is responsible for ensuring the ability of a equipment to perform its function at the time or in the time that is required. These functions can be classified as primary or secondary; The primary ones are those reasons why the equipment was acquired to satisfy a need, a secondary function is those that complement the primary function and add value to the equipment (Mesa, Sánchez, & Pinzón, 2006). On the other hand, the tendency to "preserve the equipment" that is considered as part of the literary review carried out for the present investigation, this approach generates that only maintenance is carried out when it is required or thought that the failures are all the same. Certainly that way of thinking hides the consumption of resources in an irrational way, moving to a reactive and not preventive approach, since due to the diversity of the equipments, methods focused on a specific process, lack of interest; resulting in a problem in maintenance control (Deshpande & Mahant, 2013; Petrovic, Milosavljevic, & Lozanovic Sajic, 2018)

Currently, industrial processes are governed according to strict reliability and availability indicators, because if these parameters are not taken into consideration, the equipment may present failures that result in economic losses, damage to personnel or the environment. Permanent failures are the ones that most often affect systems because they disturb the following system components (Silva, Guedes, Portugal and Vasquez, 2012). It can also be considered that if, after a fault occurs, it is repaired immediately, the system's availability is not affected (Ruggeri & Pievatolo, 2004). For these reasons, maintenance focuses on technical, organizational and management achievements through relevant strategies based on statistical analysis, cost reduction, resource management, reliability and availability. (Petrovic et al. 2018)

According to Mokhtari, Modzgir and Nakhai Kamal Abadi (2012) theoretically a equipment must be available for its operation, however, equipments must have a time for preventive maintenance, when preventive services are not performed on a machine its availability tends to be reduced because it will increase the possibility of failure of it.

Availability is the relationship that exists between the effective operating time of a device, known as the Mean Time Between Failures and the time it is out of service, whether programmed or not, which is called Mean Time To Repair . However, being an indicator, it only takes into account the distribution of faults and the time that is applied to repair it (Melo, Lara & Jacobo, 2009). Formula [1] is applied to determine the availability of a device:

$$A = \frac{MTBF}{MTBF+MTTR} \quad (1)$$

The result of A is considered as the risk that a equipment is not fit to perform its function when required in a period of time, therefore the indicator facilitates the generation of actions that prolong the useful life of the equipment, despite to this the evaluation of maintenance from indicators is unclear because not all impact the goals of the organization, that is why it is recommended to have few to not measure activities that do not generate value. (Penabad, Iznaga, Rodríguez & Cazañas, 2016).

A device can be labeled as critical due to the frequency of failure due to the consequence, its impact, safety, environment, operating costs, repair time. Failures in a equipment can hardly be predicted with accuracy, but according to the literary review carried out for the present work it has been identified that the fault history is used, statistical methods, what is sought is to predict the closest fault to implement preventive actions (Gasca, Camargo & Medina, 2017; Melo et al., 2009;) has also been recognized the application of the analysis of the mode and effect of the failure to determine the criticality of the equipments from an easy and clear methodology where you can understand the operation of a equipment and the different ways in which a failure occurs, that is, it allows to establish preventive maintenance programs according to the needs of the equipments (Purarjomandlangrudi, Nourbakhsh, Tan Esmalifalak, 2013; Aguilar, Torres & Magaña , 2010).

The present work is applied a statistical analysis to be able to determine the time in which the next failures would appear, by means of the determination of the availability, the average time between failures and the average time to repair.

Another important aspect to take into consideration is having systems that optimize administrative maintenance processes, in order to monitor preventive and predictive maintenance, since the effectiveness of these should be measured. (Schmidt & Schmidt, 2018).

## Methodology to develop

The present research work was developed by choosing a qualitative approach with a non-experimental design, because the data collection was done in a single moment and the variables were not manipulated. It has a descriptive scope because it collects the information and is subjected to a statistical analysis to detail the behavior of critical equipment in the grinding area.

It began with the collection of faults and times that were generated in the study area, to facilitate the handling of data, a database was developed to determine the department where the failure occurs, the duration and the cause of the unemployment.

From the previous point a codebook was generated for the faults to be able to translate the faults into quantitative values, this with the purpose of being able to submit the collected information to a software which processes the data to be able to obtain the behavior of the faults of greater frequency.

We proceed to obtain indicators of the performance of critical equipment; Mean Time Between Failures (2), Mean Time To Repair (3) and availability. According to the work of Mesa et al. (2006). In order to increase the availability of a device, the average time between failures must be increased and the average time to repair must be reduced.

$$MTFB = \frac{TTO}{N°F} \quad (2)$$

$$MTTR = \frac{TTR}{N°F} \quad (3)$$

## Results

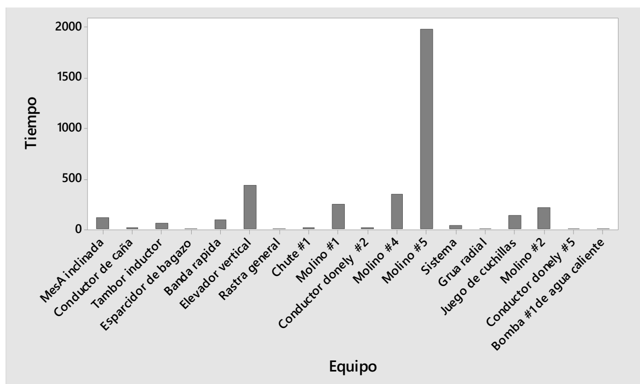
With the information gathered, a statistical analysis was carried out, in order to identify which are the faults that directly affect the availability of critical equipment in a sugar mill.

For the period of analysis according to Table 1, where a total of 110 failures are presented, equivalent to 3760 minutes, during which time 11,392.8 tons of sugarcane were processed.

| Area | Frequency | Time (min) |
|---|---|---|
| Batey | 35 | 881 |
| Mills | 75 | 2879 |

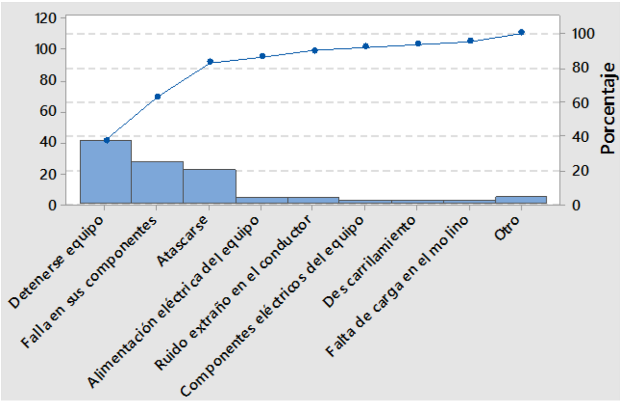
**Table 1** Distribution of time lost by area

For the period one of measurement the following failures were presented in the equipments that integrate the areas to analyze, according to the graph 1 it is possible to observe the elements of the system that presents the greater number of stoppages; the three that generate most lost time are the mill # 5 with 1976 minutes, vertical elevator of bagasse 436 minutes and the mill # 4 with 348 minutes.




**Graph 1** Equipments that generated stoppages

On the other hand, with the collected information an analysis is elaborated, which serves as a support to identify the reasons why the stoppages occur in the areas of mills and batey. According to graph 2, where the results of the analysis are shown by a Pareto diagram, where the biggest source of stoppages is because the equipment stops with 41 events that represent 37.3% of the failures. 82.7% of failures are generated when the equipment stops, component wear or clogging.




**Graph 2** Equipments that generated stoppages

In order to obtain indicators of the areas of batey and mills, the stoppages programmed in the equipment must also be taken into account, in this way, in table 2, the generated times are shown in the same way that an unscheduled stoppage affects the availability of a machine, for the purposes of the present investigation there is a total of 87777 minutes per programmed stoppages.

| Equipment | Frequency | Time |
|---|---|---|
| Dump | 5 | 416 |
| Inclined table | 3 | 3730 |
| Mill # 3 | 1 | 70855 |
| Mill # 4 | 1 | 2315 |
| Water pump # 1 | 3 | 1275 |
| Radial crane | 3 | 1075 |
| Mill # 2 | 2 | 8111 |

**Table 2** Time lost due to scheduled stoppages

Once the failures have been collected and analyzed the times they generate, the indicators of the area to be analyzed are determined by applying the Mean Time Between Failures equations (2), Mean Time To Repair (3) with the previous equations. the availability (1) of the equios. From the information generated in table 3 it can be seen that the equipment with the longest time to repair it after a fault is the mill # 3 with 70855 minutes, on the other hand, there are equipment such as the mill # 5 that presented a fault every 2900.2 minutes. With this information you can generate maintenance programs focused on preventing failures that are detected, applying preventive actions before the event occurs. As mentioned in the previous section, a failure can not be predicted when it will be presented, but it is possible to present actions that seek to prolong the appearance of the fault.

| Equipment | Failure | MTBF | MTTR | A |
|---|---|---|---|---|
| Inclined table | 9 | 9023.11 | 23.88 | 99.7 |
| Conductor of cane | 2 | 40604 | 6 | 99.98 |
| Blade set | 2 | 40604 | 67.5 | 99.83 |
| Inductor drum | 1 | 81208 | 60 | 99.92 |
| Bagasse spreader | 2 | 40604 | 3 | 99.99 |
| Fast band | 14 | 5800.57 | 6.5 | 99.88 |
| Vertical elevator | 3 | 27069.3 | 145.66 | 99.46 |
| General harrow | 1 | 81208 | 10 | 99.98 |
| Chute # 1 | 6 | 13534.6 | 2.83 | 99.97 |
| Mill # 1 | 17 | 4776.9 | 2.83 | 99.69 |
| Donely Driver # 2 | 2 | 40604 | 2.83 | 99.97 |
| Mill # 4 | 12 | 6767.33 | 2.83 | 96.82 |
| Donely Driver # 5 | 1 | 81208 | 2.83 | 99.98 |
| Mill # 5 | 28 | 2900.28 | 2.83 | 97.62 |
| Mill # 2 | 2 | 40604 | 4055.5 | 90.91 |
| Mill # 3 | 1 | 81208 | 70855 | 53.40 |

**Table 3** Maintenance indicators in equipments

One of the specific objectives of this work is to determine the reasons for failures that occur in the equipments during the production process, for this it is supported in a database where the reason for failure is recorded, the frequency with which it is repeated and the time lost during the stop. These data can be seen in Table 4, which showed the reasons that generated the most time lost when there was a component failure, equipment stoppage and derailment, respectively.

| Reason for failure | Frequency | Time |
|---|---|---|
| Scheduled stoppage | 2 | 67 |
| Derailment | 41 | 457 |
| Get stuck | 22 | 143 |
| Component failure | 28 | 2131 |
| Noise in conductor | 4 | 38 |
| Electric components | 2 | 12 |
| Electrical power supply | 4 | 30 |
| Lack of load MP | 2 | 10 |
| Derailment sensor | 1 | 2 |
| Others | 1 | 36 |
| Total | | 3,302 |

**Table 4** Main failures in equipments

In order to make future decisions about the maintenance programs that will be applied from table 5 it is observed that for the area in which there is a longer time to be able to re-establish the equipment.

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| Area | Mtbf | Mttr | A |
|---|---|---|---|
| Batey | 2194.81 | 122.05 | 94.73 |
| Mills | 1027.94 | 1065.31 | 49.10 |

**Table 5** Maintenance indicators by area

## Conclusions

The main objective of this work was to compare the factors that affect the availability of critical equipments in a sugar mill, as a result it can be seen that mill # 3 has a dissonibility of 53.4%, which shows that only half operates of time, which impacts the availability of the area as it is 49.1%.

From the data obtained it is important to take into consideration that every 1027.9 minutes there is a fault in the area of mills and 2194.8 minutes in the area of batey; where the raw material is received, weighed and the sugarcane enters the process, it is observed that there is practically a relationship where, for every 2 work stoppages in mills, 1 is presented in batey. The availability of assets is of vital importance within the production process and is not only an indicator of the maintenance department, it is the assurance that equipment is profitable for its use and unnecessary expenses are reduced, therefore, the optimum capacity is maintained of the asset (Ynzuza, Izar, Larios, Aguilar, Bocarando, & Acosta , 2017)

Failure analysis cannot predict the exact moment in which a failure occurs, however, with the data obtained, a means can be generated to establish the necessary strategies to apply maintenance that helps prolong the useful life of an asset. The strategies should focus on the effectiveness of the entire system, consequently, it should have an integral asset management with a strategic focus improving the capacity of the organization. (Simões, Gomes , & Yasin, 2016)

At the beginning of the present work with the fault analysis it was thought that the origin of the stoppages was due to failures due to overloads of raw material in the equipments, in the areas of batey and mills. However, with the information generated from the statistical analysis it is determined that the stoppages in the equipments are generated by failures in the components, for this reason it is rejected that the stoppages are generated by the overload of raw material in the line.

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