ISSN 2286-4822
www.euacademic.org

EUROPEAN ACADEMIC RESEARCH
Vol. X, Issue 7/ October 2022

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Proposal for maintenance actions in a dispensing and encapsulating machine in an industry of the Manaus Pole

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Abstract

In industrial productive processes, where the machines work in series, the maintenance management has an important place; the same is responsible for keeping these machines in operation and detecting with anticipation the critical items of the process and developing a system of maintenance actions to minimize the interruptions during the work process of these, since, for the series production, if one of them fails the rest will have affectations in the productivity due to the fact that in this type of production each machine processes the product once received from the one that precedes it. In the company that is the object of the study, there is a production line with these characteristics of serial production, which is dedicated to the development of electronic

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products. In this work, the result of the application of some quality tools and the use of some world-class indicators is presented in the analysis of the work of the pick-and-place and encapsulating dispenser machine, as well as, aiming to determine the main points of attention in this machine and to elaborate preventive actions that make it possible to maintain it in operation with the highest reliability in order to achieve the best results.

Keywords: maintenance, equipment, indicators

INTRODUCTION

Maintenance is a very broad term, and is applied in all industries worldwide, from the smallest to the largest.

There are several concepts widely used in maintenance:

Maintenance is all the actions necessary for a component, equipment or system, to be maintained or restored so that it can remain in accordance with a specified condition.

Maintenance has the function of ensuring that all assets of a company meet and continue to meet the functions for which they were specified.

Maintenance management is the management of all the company's own assets, aiming to maximize the return on investment in these assets.

According to the European Standard [5], "maintenance is the combination of all technical, administrative, and managerial actions during the life cycle of an asset, intended to maintain it or restore it to a state in which it can perform the required function."

There are several tools that contribute to Quality Management and help improve the processes and services of an organization, enabling greater efficiency. However, when it comes to Quality Tools, there are 7 consecrated methodologies that refer to this expression, they were gathered by Kaoru Ishikawa. [2]

The correct application of these tools can help in maintenance management, by allowing to describe the technical organizational factors that aggravate the productive progress. Their frequent use in maintenance management is a common practice in companies that are increasingly trying to use all possible actions to increase the operational availability of their equipment and, consequently, the increase of productivity.

In this work, the result of the application of some quality tools in the analysis of the work of the dispensing and encapsulating machine is presented, aiming to determine the main points of attention in this machine and to elaborate preventive actions that make it possible to maintain it in operation as reliably as possible, in order to achieve the best results.

Development

The unplanned machine stoppages are always a problem, because besides delaying production and generating unplanned expenses, most of them have many raw material losses that are discarded. For this type of challenge, it is necessary to do a survey of the amount of problems x amount of people to solve the problem, after that define the tools that will be used to implement the solution of the problems found, which will attack the root cause. Several authors plant that, finding a way to zero losses will always be better than firing employees [8].

Maintenance teams sometimes focus too much on repairing a malfunction when a line stoppage occurs instead of preventing outages. However, the goal of maintenance is to prevent all losses caused by equipment problems. [11].

The mission of a maintenance department is to achieve and maintain [11]:

1. **Optimal availability** - The productive capacity of a plant is in part determined by the availability of the production systems. The maintenance team must ensure that all equipment is in good operating condition.
2. **Optimal operating conditions** - It must be ensured that all equipment and systems, both direct and indirect, are in their optimal operating conditions**.**
3. **Maximum utilization of maintenance resources** - The maintenance staff controls a substantial portion of the total operations budget in most plants. In addition, it typically manages parts inventory, contracting with outside companies, and requisitions millions in components for repair or replacement equipment. Therefore, one of maintenance's goals should be to manage these resources efficiently**.**
4. **Maximum equipment life** - One way to reduce maintenance costs is to extend the life of equipment.
5. **Minimal parts inventory** - Inventory reductions should be one of the major goals of the maintenance department. However, the reduction should not jeopardize the first four goals. With preventive maintenance technologies available today, maintenance can anticipate the need for specific equipment or components early enough to purchase them based on need.
6. **Ability to react quickly** - Not all breakdowns can be prevented. Therefore, the maintenance team must be able to react quickly to an unexpected breakdown.

According to the European Standard [5], "maintenance is the combination of all technical, administrative, and managerial actions during the life cycle of an asset, intended to maintain or restore it to a state in which it can perform the required function."

For the Association of Technical Standards - ABNT maintenance is "The combination of all technical and administrative actions, including supervisory ones, intended to maintain or return an item to a state in which it can perform a required function."[3]

In our understanding, maintenance can be understood as the set of technical activities developed in equipment to ensure the regular and permanent functioning of machines, equipment, tools and facilities. These activities are related to conservation, adjustment, restoration, replacement, and prevention.

The ideal maintenance of a machine is that which allows high availability for production during the whole time it is in service and at an adequate cost.

The work in the maintenance areas needs a lot of attention from the management, they decide in many cases the production rhythm in the companies.

A complexidade da área de manutenção pode ser ilustrada pela citação de Mobley; Higgins; Wikoff [10]:

> Maintenance is not just preventive maintenance, although this aspect is an important ingredient. Maintenance is not lubrication, although lubrication is a major function. Nor is maintenance simply a frantic race to repair a broken part of a broken machine or a segment of construction, although this is often the dominant maintenance activity. In a more positive perspective, maintenance is a science, since its execution depends, sooner or later, on almost all or if not all sciences. It is an art, because apparently identical problems require and receive different approaches and actions, and also because some maintenance managers, supervisors, and technicians have a greater aptitude for it than others show or can achieve. It is above all a philosophy, because it is a discipline that can be applied intensively, modestly or not, depending on a wide range of variables that often transcend more immediate and obvious solutions. Furthermore, maintenance is a philosophy because it must be carefully tailored to the operation or organization, serving as a fine suit that is fitted to its wearer, and also because how it is viewed by its executors will shape its effectiveness.

The use of maintenance indicators is an everyday tool in the analysis of the maintenance of equipment, facilities, and systems. Among these, world-class indicators occupy a predominant place.

According to NBR 5462-1994, reliability can be defined as:

> Reliability is the ability of an item to perform a required function under specified conditions over a period of time. The term reliability is used as a measure of reliability performance.

Another form of definition would be, "Reliability is the probability that an item will perform a required function under defined conditions of use over a set time interval." [1].

According to the standard NBR 5462-1994, the definition of availability, is given by:

> The ability of an item to be in a condition to perform a certain function at a given instant or during a given time interval, taking into account the combined aspects of its reliability, maintainability and maintainability support, assuming that the required external resources are secured. The term "availability" is used as a measure of availability performance.Maintenance indicators are a series of relevant data that allow you to observe the performance of equipment. They are important tools used in maintenance management.

The use of indicators [7] for maintenance allows: Avaliar a qualidade dos serviços prestados;

- Identify existing or potential problems;

- Control the activities of the maintenance sector;
- Define the distribution of resources;
- Verify the results obtained and comfort with the objectives set.

Due to the existence of countless indicators, nowadays indicators called "World Class Indices" are used, named this way because they are the indicators most used by companies, which are: Tempo Médio Entre Falhas (TMEF) ou Mean Time Between Failures (MTBF);

- Mean Time Between Failures (MTBF or TMEF)
- Mean Time To Repair (MTTR);
- Mean Time To Failure (MTTF);
- Physical Availability (or operational);
- Maintenance Cost per Billing;
- Maintenance Cost per Replacement Value.

MTBF allows you to determine the averages of the running times for each repairable item or piece of equipment between one failure and another.

The severity of this indicator is to observe the behavior of the machines, in the face of maintenance actions. The TMEF is determined by dividing the sum of hours available for operation (HD), by the number of corrective interventions in this equipment during the period (NC).

$$TMEF = HD/NC \qquad 1$$

If the TMEF value increases over time, it will be a positive sign, because it indicates that the number of corrective interventions has been decreasing, and consequently, the total hours available for operation is increasing [13].

The TMR indicator represents the average time that the maintenance team takes to restore the machine to operating condition, from the failure until the repair is completed and the machine is in operating condition [5].

The lower the TMR, the better the maintenance progress, because the corrective repairs have less and less impact on production [14].

The TMR is given as the division between the sum of the hours of unavailability for operation due to maintenance (HIM) by the number of corrective interventions in the period (NC).

$$TMR = HIM/NC \qquad 2$$

The TMPF indicator, on the other hand, has the purpose of defining the average of the operation times of each non-repairable item (items that after a failure are discarded and replaced by new ones) between a failure and the next failure of this item, requiring the replacement by a new item [10].

The TMPF consists of the ratio between the total number of hours of equipment available for operation (HD) divided by the number of failures detected in nonrepairable components [9].

TMPF = HD / number of failures detected in non-repairable components.

Branco Filho [10] points out that some equipment can be technically repaired, but are not economically interesting to be recovered, because a new component is cheaper. In this case, the item is discarded.

Maintaining and increasing a company's profit is a premise for it to remain sustainable and competitive. There are basically three ways to achieve this goal: increase revenue, reduce costs, or increase revenue and reduce costs [9].

To increase production there is usually modernization of processes or acquisition of new equipment. However, in this case there is a concomitant goal of reducing costs. Based on this the focus is directed on process losses. These losses are measured in the form of an indicator called OEE (Overall Effectiveness Equipment).

The OEE is the result of the multiplication of three other indicators that are: $\mu 1$ (availability), $\mu 2$ (performance) and $\mu 3$ (quality). [7].

Quality tools are techniques and methods used to measure, define, analyze process improvement and problem solving in quality. The use of these tools aims to develop greater process control, clarity in the work, and most importantly, improved decision making, developed based on facts and data, rather than opinions. These tools are used in various sectors to solve the causes of problems, obtain higher productivity and reduce losses [6].

METHODOLOGY

For the development of this work, a methodology sequence of actions was followed that made it possible to obtain the results shown. It was part of an exercise to conclude the maintenance course of the Additive Manufacturing Specialty and Intelligent Production Processes under the Context of Industry 4.0 offered by the Embedded Systems Laboratory of the School of Technology of the Amazonas State University in partnership with the company Salcomp of the Manaus Industrial Pole. Here is the flowchart of the actions followed.

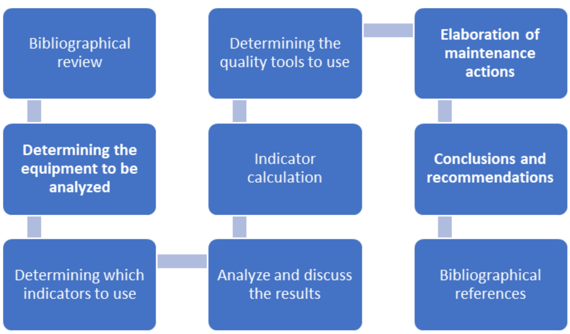

Figure1. Sequence of the research. Source: Authors, 2022

RESULTS AND DISCUSSION

Due to the weight, it has in the production line of some equipment, was chosen the Machine - dispenser pick and encapsulation for the analysis of its performance during the period days.

This equipment, with an automated system of dispenser jets for gripping and encapsulation, performs the application of gripping and encapsulation using for the operation of the machine the compressed air, solenoid valve (electric) and the Heter that makes the heating of the tip of the Nozzle to reduce the density of encapsulation / gripping and its operation is produced by the action of the program installed in the machine makes the application to which the necessary amount is applied, as required by the customer for the product.

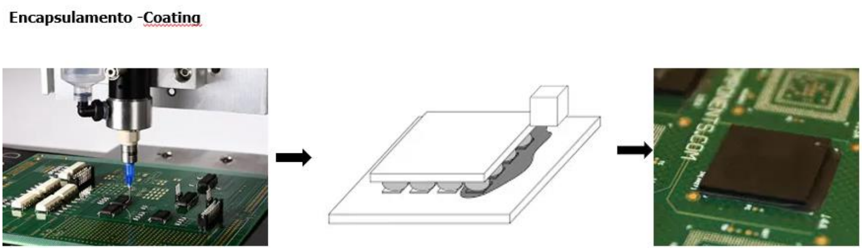

Figure 3: Filling and encapsulation process in the product. Source: Nordson. 2022[12].

The tack is an epoxy material that fills the gaps between a chip and its carrier or a finished package and the PCB substrate. It protects electronic products from shocks, drops and vibrations, and reduces stress on fragile solder connections caused by the difference in thermal expansion between chip and carrier (two different materials).

The tack is dispensed by the machine along the side of a chip to flow underneath through capillary action, filling air gaps around solder balls that connect chip packages to PCM's, after curing in the oven at 150°C reduces mechanical impact that can crack the solder and other causative damage.

The encapsulation is applied on top of the component to protect it from moisture and liquid penetration.

Both serve to prolong the life of the components after they are mounted on the electronic circuit board.

The indicators to be used would be some of those used in the Engeman software, MTBF, MTTR and thus be able to calculate the % of failures and availability in order to develop actions to minimize failures and thus increase production.

The results are shown in the table below:

Tabela de EQ									
Data	Equipamento	Hrs disponíveis	Hrs paradas	Hrs utilizadas de trabalho	Nº de Defeitos /Paradas	MTBF	MTTR	% Falhas	Disponibilidade
17-Aug	Encapsulation	6.67	0.42	6.25	1	6.2533	0.4167	6%	0.938
24-Aug	Encapsulation	6.67	4.52	2.15	1	2.1533	4.5167	68%	0.323
25-Aug	Encapsulation	6.67	6.29	0.38	1	0.3783	6.2917	94%	0.057
26-Aug	Encapsulation	13.34	7.89	5.45	3	1.8167	2.63	59%	0.409
27-Aug	Encapsulation	13.34	6.03	7.31	1	7.3067	6.0333	45%	0.548
29-Aug	Encapsulation	13.34	8.34	5.00	4	1.25	2.085	63%	0.375
31-Aug	Encapsulation	13.34	0.25	13.09	2	6.545	0.125	2%	0.981

In the first 3 days of the analyzed week, it was obtained values of 6.67 available hours with high incidence of the half time between failures that occupied a maximum value of 6.5 hours and a minimum of 0.37 hours.

On the remaining days observed the available hours were higher, occupying a value of 13.34h, however, on these days there was also an increase of stopped hours, with the highest values between 8.34 and 7.89 and the lowest between 6.03 and 0.25h respectively.

Os defeitos foram constantes neste período, observando-se oscilação e incremento deste número como apreciado na tabela acima.

These results showed a great oscillation in the machine's production and the diagram below shows the behavior of the machine's failures, noting that in the period analyzed only one day the production values were above 90% and the other days this value occupied significant values, 2% being the lowest and the rest oscillating between 6% and 68%, respectively.

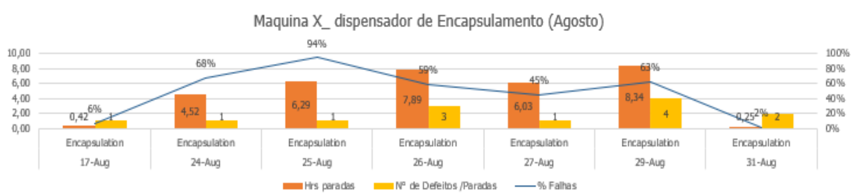

Figure 3: Machine behavior vs. downtime, defects and failures

In possession of the results, it was evident that there were nonconformities related to quality in the application of glue in the working process of the aforementioned machine (nonconforming application, excess, bubbles), it was necessary to apply some quality tools, the Ichikawa 6 M diagram, which makes it possible to have a definition of the causes by categories, ensuring that different sources were evaluated to determine the possible causes and the root cause of an effect.

The categories used were:

1. Method - way of working: manuals, work instructions, procedures;
2. Raw Material - material used: supply, specification, storage;
3. Labor - employees involved: experience, training, motivation;
4. Machines - equipment in general: conservation, compatibility, operationalization;
5. Measures or Measurement - appropriate metrics: instruments, calibration, indicators;

6. Environment - internal and external: climate, location, relationships.

The figure below shows the results obtained:

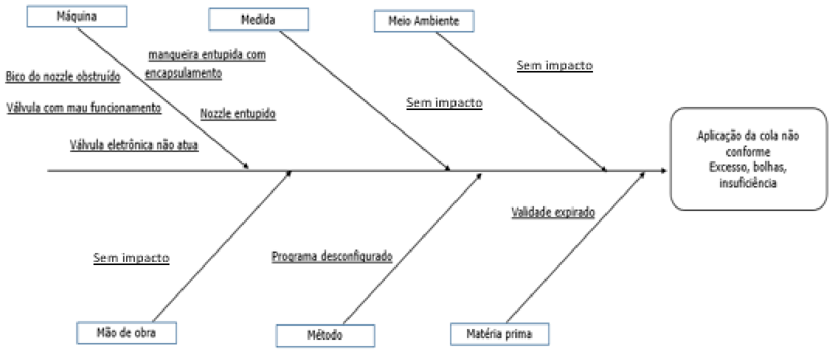

Figure 4. Ishikawa Diagram. Source: Authors, 2022

Once the data was processed, the following considerations were made:

The measurements did not impact since the instruments used were according to the manufacturers' recommendations and the previous results with high productivity index were achieved with the same metrics observed in the research.

The environment also had no impact because the workplace is within the technical recommendations for this type of production and also did not change.

The labor force was also disregarded because the staff has adequate training, experience and stability at work, the best productive results were obtained with this team.

When analyzing the machine, a group of abnormal situations was observed: clogged nozzle, improperly functioning valve, malfunction of the electronic valve (it does not open according to operational commands).

A review by the IT maintenance team determined that the machine's software was misconfigured, causing certain bugs during its operation.

The analysis of the raw material used by the machine in the pegging process made it possible to observe that the epoxy product was past its expiration date, which allows us to assume that the quality of the product may be compromised.

To solve the problems raised, a system of maintenance actions was proposed, which aims to develop preventive and corrective actions that can reduce the downtime of this equipment, which, being in a serial line, has a significant impact on the plant's productivity.

These actions were developed considering their inclusion in the existing maintenance plans, they should be developed by the plant maintenance personnel and their frequency will be subject to posterior observation and follow-up of the equipment's work.

To establish the adequate frequency for the execution of these activities it will be necessary to continue this research, as well as to use other maintenance indicators present in Engeman software and thus have a report with more possibilities of developing all the maintenance actions. It is also important that the elements discovered here be addressed during the training activities for the maintenance personnel, as this will contribute to a greater reliability of the maintenance of this equipment.

The results of the proposals and actions are summarized in the table below.

Nro	Problem description	Root Cause	Corrective Action	Preventive Action
1	Blocked nozzle	Does not purge the encapsulation	Change the head hackup and pressure adjustment.	Keeping a head backup prepared for these types of problems
2	Splash	Heater not heating up	Cleaning the contact terminals; Changing connection from head 1 to head 2	Include in the maintenance plan Maintain a backup pump.
3	Excessive encapsulation	Nozzle not heating, bad contact in module connector	Replacement of the heater and rewiring of the connector	Include in the maintenance plan under periodic revision Change the connector to a quick-connect and contact connector
4	Machine caused bubbles and over-encapsulation	Clogged nozzle, cooling air heater hose and purge system clogged with encapsulating materials.	Disassembling the application system/purge of the equipment. Cleaning and unblocking the clogged veins. Replacement of the cooling air hose. Replacement of the resistance that heats the heater	Incluir no plano de manutenção em revisão periódica Desenvolver um head de reposição para troca rápida.
5	Electronic valve system does not purge	Electronic valve does not work	Verificar funcionamento no banco de teste. Ajustar e regular se procede. Troca de válvula	Incluir no plano de manutenção em revisão periódica Analisar relação custo-benefício para obtenção de válvula de reposição. Acionar compras.
6	Bubble creation	Malfunctioning valve	Check operation on the test bench. Adjust the parameters: temperature and pressure mechanically.	Include in the maintenance plan the activity of adjustment and regulation of hydraulic pressure valves. Include in the training of maintenance personnel the process of adjustment and regulation of pressure valves
7	Positioning of the displaced adhesive	De-configured program	Reprogramming the machine, setting up new pattern creation and adjusting the drop size from 5mm to 6.5mm height	Include in the maintenance plan under periodic review the program check of the encapsulating machine.

Table 2. Proposed maintenance actions. Source: Authors, 2022.

CONCLUSIONS

The data analyzed shows that in events of machine stoppages, 50% of available working hours are used for equipment maintenance and there is no exact control of MTTR (Mean Time to Repair Corrective/Preventive).

According to the critical analysis table, the equipment is one of the biggest detractors that suffers as a result of the type of material that is used in the machine.

The proposed maintenance actions should be included in the plant's maintenance plans to avoid future interruptions.

This research should be continued in order to establish the most appropriate intervals for the execution of these actions and their subsequent inclusion in the plant's maintenance plan.

Acknowledgements
Thanks to the PD&I Project Additive Manufacturing and Intelligent Production Processes under the Context of Industry 4.0 offered by the Embedded Systems Laboratory of the School of Technology of the Amazonas State University in partnership with Salcomp Company of the Manaus Industrial Pole.

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