Article

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Design of a preventive maintenance plan for plastic injection molds

Diseño de un plan de mantenimiento preventivo a moldes de inyección de plástico

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Abstract

In every company it is vital to have strategies and tools that help achieve continuous growth and allow it to be more competitive, obtaining the benefit of the application of these strategies and tools greater productivity, avoiding downtime or unnecessary stops that cause losses. The purpose of this project is to develop a preventive maintenance plan for plastic injection molds in order to reduce failures in them by at least 70% based on the "Reliability-Centered Maintenance Methodology" (RCM for its acronym in English), which is a widely recognized and widely used methodology to develop maintenance plans for industrial equipment based on ensuring the functions of the equipment for the satisfaction of the user or owner (Campos-López, 2018); For the collection of information, tools proposed by the methodology were used, such as the analysis of failure modes and effects (FMEA), the criticality analysis and the logical decision tree.

Maintenance, Molds, RCM

Resumen

En toda empresa es vital contar con estrategias y herramientas que ayuden a lograr un crecimiento continuo y permitir ser más competitivos, obteniendo como beneficio de la aplicación de estas estrategias y herramientas mayor productividad, evitando tiempos muertos o paradas innecesarias que provocan perdidas. La finalidad de este proyecto es elaborar un plan de mantenimiento preventivo para los moldes de inyección de plástico con el objetivo de reducir las fallas en ellos por lo menos en un 70% basándose en la “Metodología del Mantenimiento centrado en Confiabilidad” (RCM por sus siglas en inglés), que es una metodología ampliamente reconocida y de uso extendido para elaborar planes de mantenimiento de equipos industriales basándose en asegurar las funciones del equipo para la satisfacción del usuario o propietario (Campos-López, 2018); para la recopilación de información se hizo uso de herramientas propuestas por la metodología tales como el análisis de modos y efectos de fallas (AMEF), el análisis de criticidad y el árbol lógico de decisiones.

Mantenimiento, Moldes, RCM

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Introduction

Reliability Centered Maintenance (RCM) is a very effective methodology used to identify all the possible causes that can cause a system failure using cause and effect relationships; After identifying all possible causes, the best maintenance strategy method can be determined to eliminate the failures. The chosen strategy must guarantee the operation of the equipment and processes, ensuring safety and reliability. This maintenance strategy was developed in the early 1970s by the commercial airline industry in order to reduce maintenance downtime, maintenance costs, and improve flight safety.

It has also been used with success in the cereal industry, coal mining, oil refineries, gas plants, the paper industry, and this time it is developed for the benefit of a company dedicated to the manufacture of reels. plastic of different sizes and different shapes in the caps, where the process of making the caps is carried out with the help of different injection molds and extrusion machines, where the tubes are generated; in order to create a preventive maintenance plan for injection molds and apply it to reduce possible failures or defects during the injection process by 70%.

Development of headings and subheadings of the article with subsequent numbers

To achieve the implementation of the Reliability Centered Maintenance (RCM) methodology, the following steps were followed:

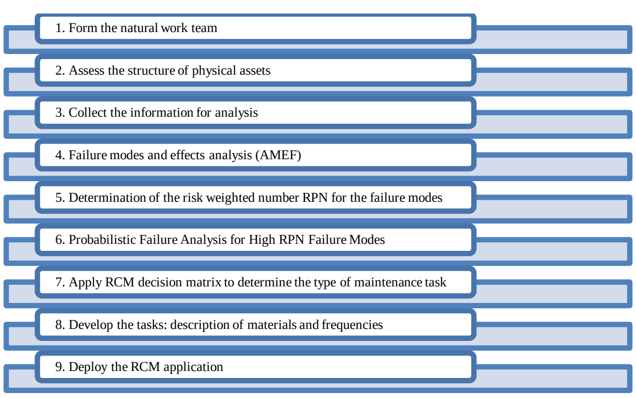

Figure 1 RCM application methodology
Source: (Grimaldo, 2012)

1. Form the natural work team

The first step to start to propose preventive maintenance measures that will be applied to plastic injection molds is to form an adequate work team; For this, it is necessary to have specialists trained in maintenance area issues and who will be helpful for the development of activities; Below is a diagram with the selected work team.

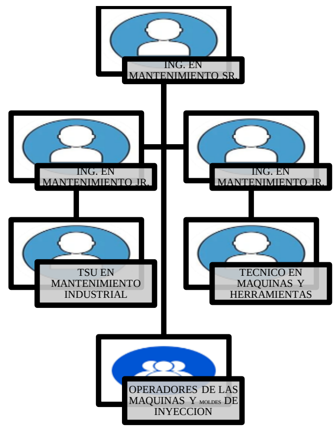

Figure 2 Work team
Source: (project contribution, unpublished)

2. Assess the structure of physical assets

The coding of each injection mold and of each machine in which it is placed is carried out, in order to be able to identify them faster and to be assigned a code. Technical sheets are also prepared for each mold to describe all its characteristics in greater detail.

INJECTION MACHINES CODING			
CODE NUMBER	ALPHANUMERIC CODE	MACHINE	MARK
010100	IN-01	VD-300T-1	VanDorn
010101	IN-02	VD-300T-2	VanDorn
010102	IN-03	VD-300T-3	VanDorn
010103	IN-04	VD-300T-4	VanDorn
010104	IN-05	NB- 75T	New Bury
010105	IN-06	VD-230T	VanDorn
010106	IN-07	VD-150T-1	VanDorn
010107	IN-08	VD-150T-2	VanDorn
010108	IN-09	VD-150T-3	VanDorn
010109	IN-010	VD-200T	VanDorn
010110	IN-011	VD-350T	VanDorn
010111	IN-012	VD-250T	VanDorn

Table 1 Injection machine coding
Source: (Project contribution, unpublished)

CODING OF THE INJECTION MOLDS THAT ARE WORKING			
CODE NUMBER	ALPHANUMERIC CODE	MACHINE	TYPE MOLD
020100	IN-01	VD-300T-1	4 tapas normal
020101	IN-02	VD-300T-2	4 tapas ventana
020102	IN-03	VD-300T-3	1 tapa CNA
020106	IN-07	VD-150T-1	1 tapa papel
020107	IN-08	VD-150T-2	2 tapas rayo
020108	IN-09	VD-150T-3	1 tapa araña
020109	IN-010	VD-200T	8 tubos
020110	IN-011	VD-350T	2 tapas CNA
020111	IN-012	VD-250T	3 tapas normal

Table 2 Coding of molds in operation
Source: (Project contribution, unpublished)

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To carry out preventive maintenance on each mold, what must be done is a technical sheet based on the list of molds that was previously made. The technical data sheet must contain the most important data of the molds.

INJECTION MOLDS TECHNICAL DATA SHEET							
MADE BY:							
MOLD CHARACTERISTICS							
CODE				20100			
DESCRIPTION	Injection mold			TYPE OF MOLD	Normal lid		
				CANTIDAD DE CAVIDADES		8	
DIMENSIONS	Long = 50 cm						
	Broad = 31 cm						
	High = 50 cm						
BOOTS DIMENSION	Long = 19 cm				NUMBER OF BOTTLES	16	
	Diameter = 7 mm						
DIMENSION OF CENTRAL BOOT BAR	Long = 42 cm				NUMBER OF BARS	1	
WATER INLET AND OUTLET NIPPLES							
FIXED PART				MOBILE PART			
MEASURE	01-ago	AMOUNT	8	MEASURE	01-ago	AMOUNT	8
CHARACTERISTICS OF THE MACHINE							
MACHINE IN WHICH THE MOLD IS WORKING	CODE	10100			MARK:	Van Dorn	
	MACHINE	300T-1					
MAINTENANCE MODEL	Preventive				CRITICITY	Critical	
OBSERVATIONS	The mold is working						

Table 3 Example of a mold data sheet
Source: (Project contribution, unpublished)

3. Collect the information for analysis

The primary and secondary functions of injection molds were studied to understand them thoroughly and begin to evaluate which are the main failures they present, with the help of the failure control sheets in injection molds that were implemented to facilitate the identification of major flaws and to keep a record. In addition, possible solutions that can be adapted to avoid or reduce problems were evaluated; Below is the list of primary and secondary functions of injection molds:

Primary functions of injection molds:

1. Receive the plasticized material.
2. Give the appropriate shape according to the cavities.
3. Cool the molten material inside it until it solidifies and forms the part.
4. Keep the piece cooling until it exhibits more contractions.
5. Eject the part.

Secondary functions of injection molds:

1. Withstand injection and shut-off pressures during cycle.
2. Withstand the high temperatures of plastic material.
3. Ensure that the injection cycle is as short as possible.

Starting from these points, it is known which are the functions of the injection molds, the faults that they present, as well as the causes that originate that fault and the possible solutions.

FALLAS	EFFECT OF FAILURE (CAUSES)	CLASSIFICATION OF FAULTS	POSSIBLE SOLUTIONS
Drum breaker	Wear from continuous work.	Critical	Check the ejector plates from time to time to ensure they move in parallel.
	Ejector plates misaligned		Clean and lubricate the punches.
	Punch bar out of dimensions		Place the dowel bar with the correct dimensions.
	Misaligned mold		Check mold alignment
	Lubrication Free Punch Plate Guide		Lubricate the tappet plate constantly.
Folded pushbuttons	The punches do not retract and the mold is closed with these protrusions.	Critical	Check the ejector plates from time to time to ensure they move in parallel.
	Ejector plates misaligned		Clean and lubricate the punches.
	Longer buttons		Fitting the correct lengths
Rupture of the center rod of the plungers	Wear and tear from continuous work	Critical	Check the ejector plates from time to time to ensure they move in parallel.
	Ejector plates misaligned		
	Punch bar out of dimensions		
Cavity overheating	Bad water flow	Critical	Clean the mold with muriatic acid at least once a month.
	Inputs and outputs covered.		
	Water pumps turned off		
Water leaks	Badly screwed nipples	Significant	Change hoses and nipples from time to time in the mold.
	Broken or worn hoses		
Rupture of pocket bolts	Wear and tear from continuous work	Tolerable	Make a periodic review to check the bolts and change the worn or finished ones.
	Badly aligned plates		

Table 4 Common failures in injection molds
Source: (Project contribution, unpublished)

Following the Reliability-Centered Maintenance (RCM) methodology, a series of calculations are performed to determine important aspects of the injection molds, which are why this methodology is being implemented: Availability indices, Availability, Availability due to breakdowns, MTBF (Mid Time Between Failure, mean time between failures), MTTR (Mid Time To Repair, mean time to repair).

- Total availability

DT=(HT-HPM)/HT (1)

Where: HT= Total hours

HPM= Hour’s downtime for maintenance

D= (720-28)/720

D= 0.96

- Availability for breakdowns

DA=(HT-HPA)/HT (2)

Where: HT= Total hours

HPA= Breakdown hours

D= (720-42)/720

D= 0.9416

- MTBF (Mid Time Between Failure)

MTBF=No.HT/No.A (3)

Where: No.HT= Total number of hours in the period analyzed

No. A= Number of breakdowns

MTBF= 678/21

MTBF= 32 hours

- MTTR (Mid Time To Repair)

MTTR=No.HPA/No.A (4)

Where: No.HPA= Number of hours of stoppage due to breakdown No.A= Number of breakdowns

MTTR= 42/21

MTTR= 2 hours

4. Failure modes and effects analysis (AMEF)

To continue developing this methodology, it is necessary to carry out an analysis of failure modes and effects, based on the information from the previous point to identify which failures are the most important (vital) and which are the least important (trivial)). Here is an example of the FMEA:

FAILURE MODE AND EFFECTS ANALYSIS (FMEA)		PAGE	REV	DATE	PREPARED BY
		1 of 1	1	10/15/21	
PROCESS: Detect faults in injection molds		**RESPONSIBILITY:**			
PROJECT: Maintenance plan for injection molds	**OPERATION:** Detect faults in injection molds	**PREVIOUS DATE:**			
EDITION DATE: 10/15/21	**ACT ON HIGGER RPN**	**REVISED AND APPROVED:**			

Product /service name	Operation or function	Failure mode	Failure effect	S		FAILURE CAUSES	O	CURRENT PROCESS CONTROLS	D	RPN	RECOMMENDED ACTIONS	RESP.	ACTIONS TAKEN	ACTION RESULTS			
				I	E									S	O	D	RPN
Plastic injection molds	Give a specific shape to the plasticized material according to the cavities of each mold	Breaking of plungers	The injected part is not ejected	8		Continuous work wear	5	Shutdown alarm	1	40	Perform the tasks to be implemented in the maintenance plan	Maintenance team	Completed	8	5	1	40
		Folded plungers	The injected part is not ejected	8		The springs do not contract, and the mold is closed with these out	5	Shutdown alarm	1	40	Perform the tasks to be implemented in the maintenance plan	Maintenance team	Completed	8	5	1	40
		Rupture of the center rod of the plungers	The injected part is not ejected	9		Continuous work wear	8	Shutdown alarm	1	72	Perform the tasks to be implemented in the maintenance plan	Maintenance team	Completed	9	8	1	72
		Water leaks	Low water pressure	6		Poorly threaded nipples, broken or worn hoses	4	Shutdown alarm	2	48	Perform the tasks to be implemented in the maintenance plan	Maintenance team	Completed	6	4	2	48
		Cavity overheating	The injected part comes out with defects	8		Poor water flow, plugged inlets and outlets	6	Shutdown alarm	2	96	Perform the tasks to be implemented in the maintenance plan	Maintenance team	Completed	8	6	2	96
		Rupture of pocket bolts	The injected part comes out with defects	5		Continuous work wear	3	Shutdown alarm	1	15	Perform the tasks to be implemented in the maintenance plan	Maintenance team	Completed	5	3	1	15

Figure 3 Failure modes and effects analysis
Source: (project contribution, unpublished)

5. Determination of the risk weighted number RPN for the failure modes

6. Probabilistic Failure Analysis for High RPN Failure Modes

The formula used to calculate the NPR for each failure was the following: G x O x D = NPR

In order to determine the NPR value as a border value and to know which failures are the most important (vital) and which are the least important (trivial), the NPR results of the FMEA table were taken as support; where the fault that had a higher value (96) was the number 5 of the cavities overheating, this fault was multiplied by the most recommended border percentage to perform this calculation, which is 20% and resulted in the number that We will use as a border value in the failures of the injection molds it is 19.2. The faults that are greater than this value will be the vital ones, that is, the ones that are most important and that affect the process the most, and the faults that are minor will be the trivial ones that do not affect the process too much, but are still important. Once the previous calculation has been made, we have as a result that the vital faults are: number 1, 2, 3, 4 and 5 and the trivial faults are: number 6.

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7. Apply RCM decision matrix to determine the type of maintenance task

In order to determine the maintenance tasks, a criticality analysis was carried out in order to establish the most indicated activities according to their level of criticality; The guidelines specified by the RCM methodology were followed, also relying on the ISO JA1011 and JA1012 standards. It was classified according to the levels of taxonomy, taking as a reference the levels of the following pyramid:

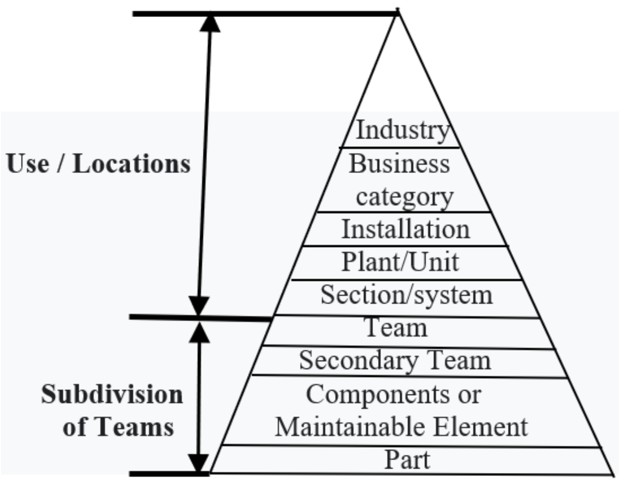

Figure 4 Pyramid of taxonomy levels
Source: (Grimaldo, 2012)

Taking as reference the ISO JA1011 and JA1012 standards, the frequency and consequence factors associated with operational impacts, operational flexibility, maintenance cost, impact on safety and hygiene are established, which are the main factors on which the rules for conducting this type of analysis. The values to qualify each component of the injection molds are shown below:

FAULT FREQUENCY (FF)	WEIGHING
Greater than or equal to 10 failures / month	5
6 to 8 failures / month	4
from 2 to 4 failures / month	3
Equal to 1 failure / month	2
Highly unlikely	1
OPERATIONAL IMPACT (IO)	
Losses greater 75% production per month	5
Losses 50% to 74% production per month	4
Losses 25% to 49% production per month	3
Losses 10% to 24% production per month	2
Losses less than 10% production per month	1
OPERATIONAL FLEXIBILITY (FO)	
There is no other equipment the same or similar	4-5
The system can continue to function	2-3
There is another equal or similar	1
MAINTENANCE COST (CM)	
Material costs greater than $ 10,000	5
Material costs in excess of $ 5,000- $ 10,000	4
Material costs over $ 2,000- $ 5,000	3
Material costs over $ 500- $ 1,000	2
Material costs less than $ 300	1
IMPACT ON SAFETY (IS)	
Affects human security	5
It affects the environment producing reversible damage	4
It affects the facilities causing severe damage	3
Causes minor damage - accidents and incidents	2
It does not cause any type of damage to people, facilities or the environment	1

Table 5 Weighting values
Source: (Project contribution, unpublished)

Formulas to calculate total criticality:

CRITICITY = Frequency of failures x consequence

CONSEQUENCE = (operational impact x flexibility) + costs + safety impact.

Below is an example of the criticality analysis carried out according to each component of the injection molds:

1. EQUIPMENT: Injection Molds

SUB-SYSTEM EVALUATED: Plates (general)

- Failure frequency: 1
- Operational impact: 1
- Operational flexibility: 1
- Maintenance costs: 3
- Impact on security: 2

FREQUENCY = 1

CONSEQUENCE = 6

TOTAL CRITICITY = 6

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The results obtained by component were:

2. EQUIPMENT: Injection Molds

SUB-SYSTEM EVALUATED: Push-buttons

TOTAL CRITICITY = 51

3. EQUIPMENT: Injection Molds

SUB-SYSTEM ASSESSED: Cavities

TOTAL CRITICITY = 60

4. EQUIPMENT: Injection Molds

SUB-SYSTEM EVALUATED: Central bar of pushbuttons

TOTAL CRITICITY = 100

5. EQUIPMENT: Injection Molds

SUB-SYSTEM EVALUATED: Socket Bolts

TOTAL CRITICITY = 4

6. EQUIPMENT: Injection Molds

SUB-SYSTEM EVALUATED: Cooling channels

TOTAL CRITICITY = 48

With these data the criticality matrix is obtained:

FREQUENCY										
5	NC	MC	MC	MC	MC	MC	C	C	C	
4	NC	MC	MC	MC	MC	*coo lina*	MC	C	C	C
3	NC	NC	MC	MC	MC	MC	MC	MC	*tap*	*cavi*
2	NC	NC	NC	MC	MC	MC	MC	MC	MC	C
1	NC	*soc*	*pla tes*	NC	MC	MC	MC	MC	MC	C
	2	4	6	8	10	12	14	16	18	20
	CONSEQUENCE									

Table 6 Criticality matrix
Source: (project contribution, unpublished)

8. Develop the tasks: description of materials and frequencie

In order to carry out the most appropriate maintenance tasks, they must be carried out with the support of the RCM logical decision tree and then the answers that arise from the questions in this tree must be recorded on the decision sheet, which contains all the information of this analysis, this sheet is composed as follows; It is divided into 16 columns, the first three columns are the information reference, which allow to recognize and identify exactly the failure mode that is being evaluated in that row, Function (F), Functional failure (FF), Failure mode (MF). The next four columns correspond to the assessment of consequences.

- H: Consequence of hidden failure.
- S: Consequence for safety and the environment.
- E: Operational consequences.
- O: Non-operational consequences.

Columns 8 to 10 allow you to record tasks as follows:

- H1 / S1 / O1 / N1: It is used to record whether a task could be found in appropriate condition.
- H2 / S2 / O2 / N2: Used to record if a cyclic rebuild job could be found.
- H3 / S3 / O3 / N3: Used to record whether a cyclic replacement task could be found.

Columns H4, H5, S4 are used to record the answers to the three questions “in the absence of” raised above. They select whether to do a fault finding task, a redesign, a combination of tasks or any type of scheduled maintenance. In the last three columns the proposed task, time interval and machine condition are recorded.

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DECISION SHEET RCM													EQUIPMENT: Plastic injection molds		
Reference information			Assessment of consequences				H1 S1 O1	H2 S2 O2	H3 S3 O3	Default actions			Proposed tasks	Frequency	Machine condition
F	FF	FM	H	S	E	O	N1	N2	N3	H4	H5	S4			
1	A	1	S	N	N	N	H1	N	N	H4	N	N	Check the punches, clean and lubricate them	Weekly	Off
													Check Ejector Plate Alignment	Monthly	
													Place the dowel bar with the correct dimensions.		
													Check mold alignment		
													Lubricate the tappet plate constantly		
2	A	2	S	N	N	N	O1	N	N	H4	N	N	Check the punches, clean and lubricate them	Weekly	Off
													Check Ejector Plate Alignment	Monthly	
													Fitting the correct lengths		
3	A	3	S	N	N	N	N	O2	N	N	N	S4	Check bar tightness	Weekly	Off/On
													Check Ejector Plate Alignment	Monthly	
4	A	4	S	N	N	N	H1	N	N	N	H5	N	Change nipples and hoses	Every 6 months	Off
	B	5	N	N	S	N	N	N2	N	H4	N	N	Clean the mold with muriatic acid.	Monthly	Off/On
5	A	6	S	N	N	N	N1	N	N	N	H5	N	Check bolt wear	Monthly	Off

Table 7 RCM Decision Sheet
Source: (Project contribution, unpublished)

9. Deploy the RCM application

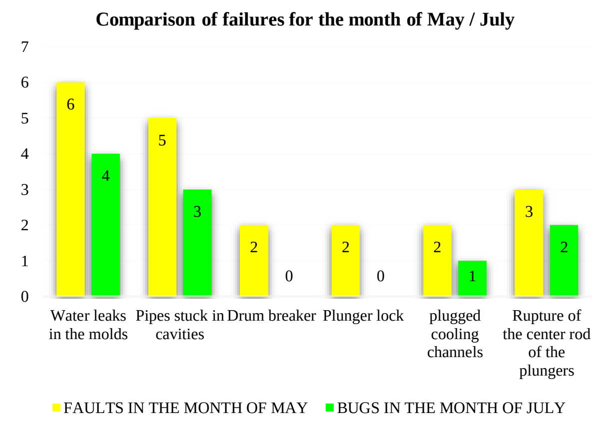
As the last step to carry out the correct application of this methodology, the preventive maintenance plan for the injection molds was drawn up based on the RCM methodology, obtaining the solutions that are best adapted to be able to reduce or eliminate the problems that arise. frequently in molds.

PREVENTIVE MAINTENANCE PLAN						
ELEMENT: Plastic injection molds		Date of realization:		Made by:		
TASKS TO BE DONE		FREQUENCY		IN CHARGE		
		Weekly	Monthly	6 months	Annual	
1	Check the punches, clean and lubricate them	X				Operators
	Check Ejector Plate Alignment		X			Maintenance Technicians
	Place the dowel bar with the correct dimensions.			X		Maintenance Technicians
	Check mold alignment		X			Maintenance Technicians
	Lubricate the tappet plate constantly.	X				Operators
2	Check the punches, clean and lubricate them	X				Operators
	Check Ejector Plate Alignment		X			Maintenance Technicians
	Fitting the correct lengths			X		Maintenance Technicians
3	Check bar tightness	X				Tecnico in machines and tools
	Check Ejector Plate Alignment		X			Maintenance Technicians
4	Change nipples and hoses			X		Maintenance Technicians
	Clean the mold with muriatic acid.		X			Tecnico in machines and tools
5	Check bolt wear.		X			Tecnico in machines and tools

Table 8 Preventive maintenance plan
Source: (Project contribution, unpublished)

Results

With the implementation of the maintenance plan it was possible to reduce failures.



Graphic 1

Conclusions

The application of the Reliability-Centered Maintenance (RCM) methodology is very important, because to achieve its elaboration requires the collection of enough information to understand the problem and lead it to a correct solution; Within these procedures, those that had the most impact on the project were failure modes and effects analysis (FMEA) and criticality analysis, because from these it was possible to assess which failures occurred frequently, which part of the molds were the most affected and what was the criticality of each element; In other words, which had the most impact on the process if a failure occurred and which had the least impact.

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