23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

CNC MACHINE PRODUCTIVITY IMPROVEMENT THROUGH IMPLEMENTATION OF A MONITORING SYSTEM

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Abstract. *Proper use of assets as a cost reduction form and increase production capacity is an issue in the continuous improvement in productivity. This paper has the finality to increase the availability rate of CNC machines in a small industry through the implementation of a monitoring system. The availability index is treated throughout the paper as the ratio of the planned usage and actual usage of the machine providing a reference to managers in order to increase the utilization of such equipment. The proposed monitoring system consists of a programmable logic controller and a custom software with the ability to show report and instant visual aids in the productive sectors. Some specific goals for the company's scenario in study as improving the pointing index of production and the identification of the equipment stoppage causes have also been described in the development of this paper. As a result, it was observed that the use of visual aids in the productive sectors and the first contacts with the reports brought positive changes, where the availability rate, the percentage of pointed hours and the monthly revenue of the company had increased.*

Keywords: *CNC machine, Availability rate, Monitoring machine, Machining, Production process*

1. INTRODUCTION

The productivity of manufacturing systems can be analyzed by observing the relationship between the consumed resource (input) and obtained outputs (output) of the processes that make up these systems. (MARTINS and LAUGENI, 2005). In machining processes, the use of machinery can be considered as one of the key features used to generate value. (BLACK, 1998). The evolution of machine tools and the use of CNC machines allowed the increase in accuracy and repeatability as well as lower production times, but the high cost of investment and the search for competitiveness impose the challenge of constant use of equipment to obtain greater economic gains.

The continuous improvement of processes, either under the cost, productivity or quality necessarily occurs by an effective analysis of the process in question. This analysis and the effectiveness of actions are more easily achieved with the use of tools that provide real and readily updated data for decision-making.

In this context, this paper aims to develop a monitoring system of CNC machines of a production line. Some digital signals will be monitored by PLC (Programmable Logic Controller) and sent to computer. In the computer, a software will be developed for acquiring and archiving data and show it in monitoring screens in production and engineering sector. These monitoring screens are called andom systems. From these storage data, the manager can measure the availability of machines or to calculate the real costs of production.

Others works about machine monitoring of machining process come being developed, as Mourtzis et al (2014) and Wang (2013).

1.1 Availability

According Martins and Laugeni (2005), the availability of equipment or availability index is the ratio between the total operating time and the total time previously scheduled. Equation 1.1 shows how the AR machine availability index, HS total scheduled time OT and the actual operation time.

$$AR = \frac{OT}{HS} \qquad (1.1)$$

1.2 CNC Machines

The evolution of machine tools as well as CNC (Computerized Numerical Control) gave rise to the machining centers. A machining center can perform various machining operations in one piece with a single preparation, in addition, substantially reducing passive machining times.

CNC machines are ideal for low to medium production, as well as medium or high range products. They are used successfully in systems that produce repetitive in batches, in the production of parts with complex geometries with high cost when too much material to be removed from a starting block and when to obtain a piece many operations are required. Still we cite as advantages the increased precision, lower scrap rates, reduced inspection requirements, greater adaptability to design changes, devices and simple fixings, lower run times of production, lower inventories, use less space on the factory floor and less dependent on operator. Among the disadvantages are the high cost of investment, increased maintenance effort, need for programming machining and constant use of equipment to maximize the economic benefits. (GROOVER, 2011).

1.3 Visual management

Installation in an accessible viewing spot, all the tools, parts, production activities and system performance indicators, so that all employees can quickly assimilate the real situation involved.

Andon system is a visual management tool that shows the status of operations in one area and alerts you when something abnormal occurs. Can indicate the status of production (which machines are operating), an abnormality (machine stop, the operator delays, lack of materials) and the necessary actions (need to change). It can also be used to describe the status of the output in terms of the number programmed units compared to the actual results. (MARCHWINSKI, SHOOK, SCHROEDER, 2011)

2. METHODOLOGY

2.1 Description of the current scenario

The company under study is located in the industrial pole of São José dos Campos - São Paulo, with a team of seventy employees split in two shifts, and operates in the supply of parts and devices for the aerospace market using machines with machining technology in three, four and five axis, CNC lathes and conventional machines.

Manufacturing system in the company is the functional layout type or job shop, where the same function machines are grouped into sectors. The average size of the batches produced pieces is thirty, monthly are produced about three hundred lots and all flow to follow a sequence of operations provided in the routes.

Production appointment is often not done hindering the feedback from the sales department and processes as the real time of manufacture.

The causes of machine stoppages are not formally dealt with and the average setup time is not registered.

Production team has no information or visual tools to report the correct running of the production: Estimated run time, to-do appointments and other departments to prevent the execution of machining.

2.2 Proposal for implementation of a monitoring system

The company uses a custom software, originally designed for control of applications and issuance of production orders. Use of this software and this form of development present itself as an appropriate cost solution and competitive advantage to the company profile studied and allows the improvement with the creation of new modules.

The proposal is to capture a machine operating signal from the CNC, send it to be combined with other information previously registered in the customized software and provide visual and historical information on the use of equipment, status of production appointments and compliance the estimated production time.

2.3 Implementation of the monitoring system

So that the software could perform calculations and provide information of the expected results this improvement project were created additional entries for entering data.

2.3.1 Script operations and machine register

For each item to be produced is prepared in the department processes, a roadmap of operations to be performed and an internal service order is issued.

To meet the new module in each operation script including machines were previously selected by the department processes to perform the operation, given the estimated time of implementation of operations and time to set up the machines.

2.3.2 Pointing production

To complete a stage production, operators should make the production note. A production record must be opened before starting the operation. This step was added the field "forward end" so that the operator can check the estimated forecast for completion of its operation. The termination of the appointment must be made at the end of the operation.

2.3.3 Opening events aimed at other sectors

The production processes are subject to the occurrence of strikes that hurt productivity. These outages can occur for several reasons. To register and facilitate communication of production outages occurred due to lack of some feature a system of electronic communication was created to record the events and possible improvements from a history. In each of the productive sectors were placed some terminals for the opening of cases. In each terminal operator can effect the opening of the call to another sector requesting the resource or support necessary to continue the operation. All kinds of production problems can be treated by opening call from a doubt found by the operator to perform the operation, quality team support request or even the lack of a productive resource as a CN program. During the opening of the call, the operator indicates whether or not the production was interrupted, in order to allow the correct prioritization. Already in support departments were placed Andon screens on points with good visibility where every employee in the industry can quickly identify the occurrence of a call intended for his department, each employee can respond to calls from their own workstation. All the historical data of each call including the response time of departments are preserved and made available for analysis and elimination of the root causes.

2.3.4 Pointing stoppages

Some of machine downtime are the operator's own responsibility or the sector in which it is allocated. So that operators can register these stops and enable the analysis and eventual elimination of the causes registration machine stop was created. Figure 2.1 shows a list containing a previously registered relationship in the system and when printed becomes available in the productive sectors.

LIST OF MACHINE STOP CAUSES			
ABSENCE OPERATOR	00004	MAINTENANCE	00002
CLEANING	00003	SETUP	00005

FIGURE 2.1 – Codes used to record the reasons for production stoppages.

2.3.5 Signal Capture

The release signal which indicates the operation of each machine is done by using a programmable logic controller. The operating signal of each machine is sent to a specific gateway to the controller.

Within the register of each machine in the monitoring software was created field called PLC address to register the controller input port number that will receive the heartbeat of the respective machine.

The monitoring software receives the reading of the controller input ports and identifies the PLC or port that is not receiving a signal.

2.3.6 Checks and calculations performed by software

The monitoring process of the machines made by the software begins with the making of the manufacturing department in the script processes, the script specifies the operations to be performed, the planned machines and their times set for executing each operation. The second step of the process occurs through the actions taken by the operator opens the pointing production and starts the operation of the machine.

The third stage occurs with the reading of machine operation signal made by the software and verification of pointing data made by the operator. Instantaneously occurs the fourth stage where the software offers data on machine operation and stores the history for future reference. Figure 2.2 shows the steps of the monitoring process.

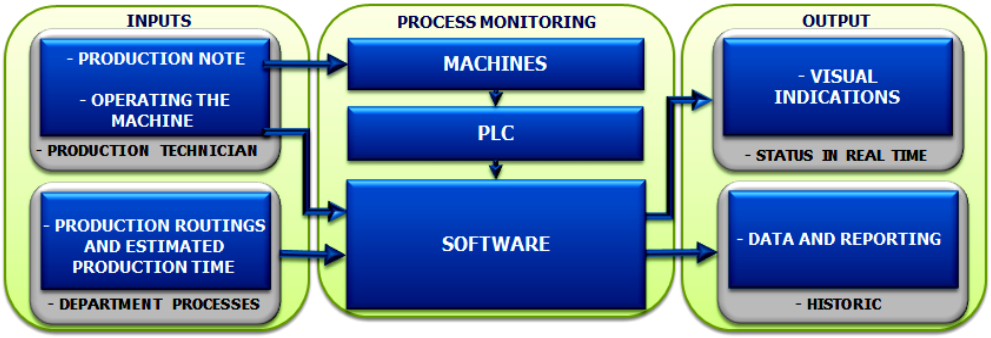

FIGURE 2.2- Steps of monitoring process.

Upon receipt of the contributions made by the department processes and the operator, the software performs the processing of this information to define the status of each machine on the operation of the production record of situation, work stoppages records and called records. The software also checks to the status of the operation run-time compared to the forecast of completion. Figure 2.3 shows the flowchart of the sequence of checks carried out by the software to inform the status of the machines. Figure 2.4 shows the flowchart of the sequence of checks carried out by the software to determine delays in operation.

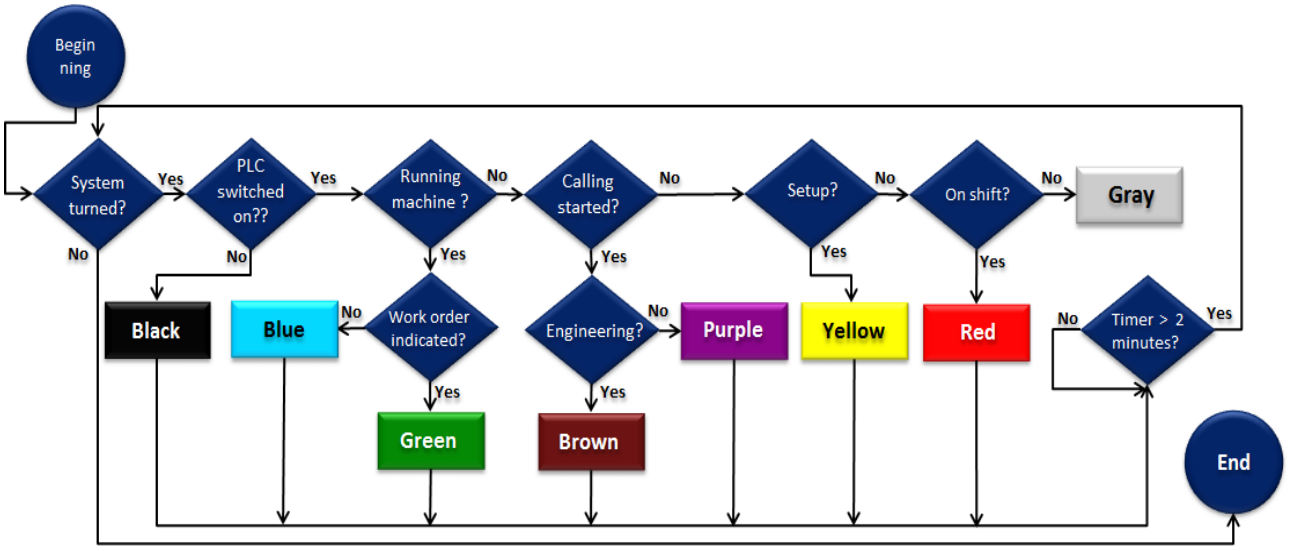

FIGURE 2.3 – Flowchart of checks to inform the status of the machines.

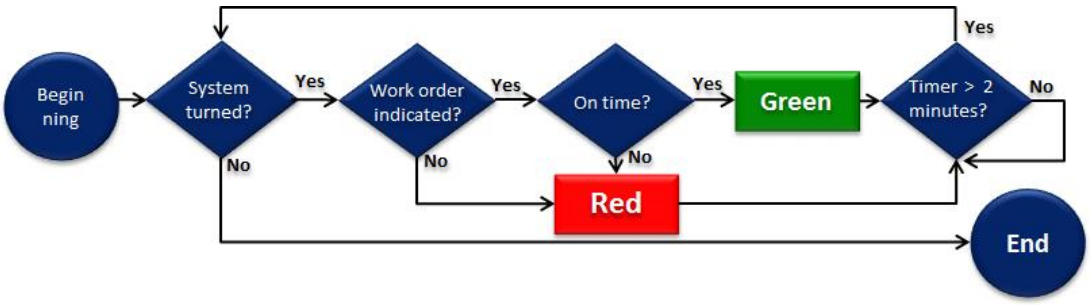

FIGURE 2.4 - Flowchart of checks to inform delay in operation.

2.3.7 Visual outputs provided by the software

To finalize the system checks displays a visual indication of the status of each device. Figure 2.5 shows a visual representation used and the colors of subtitles for each status.

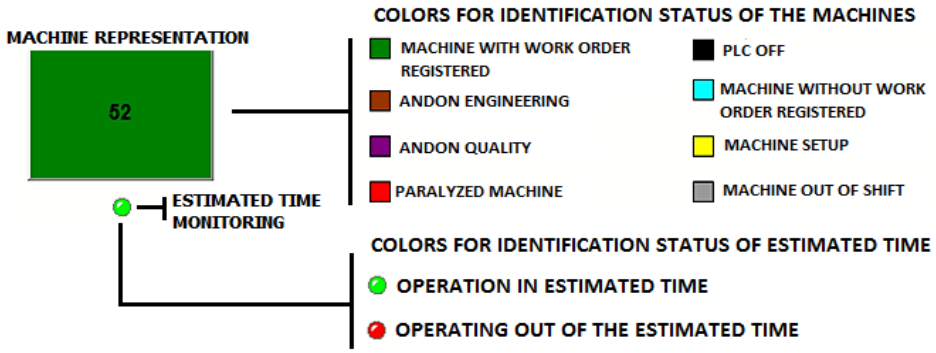

FIGURE 2.5- Visual representation and legend of colors for every status.

Full screen monitoring of machines in the format to be used in production can be seen in Figure 2.6. The layout of the monitoring screen was developed based on the industrial plant of the company so as to facilitate the visual management. The updating of information occurs every 2 minutes.

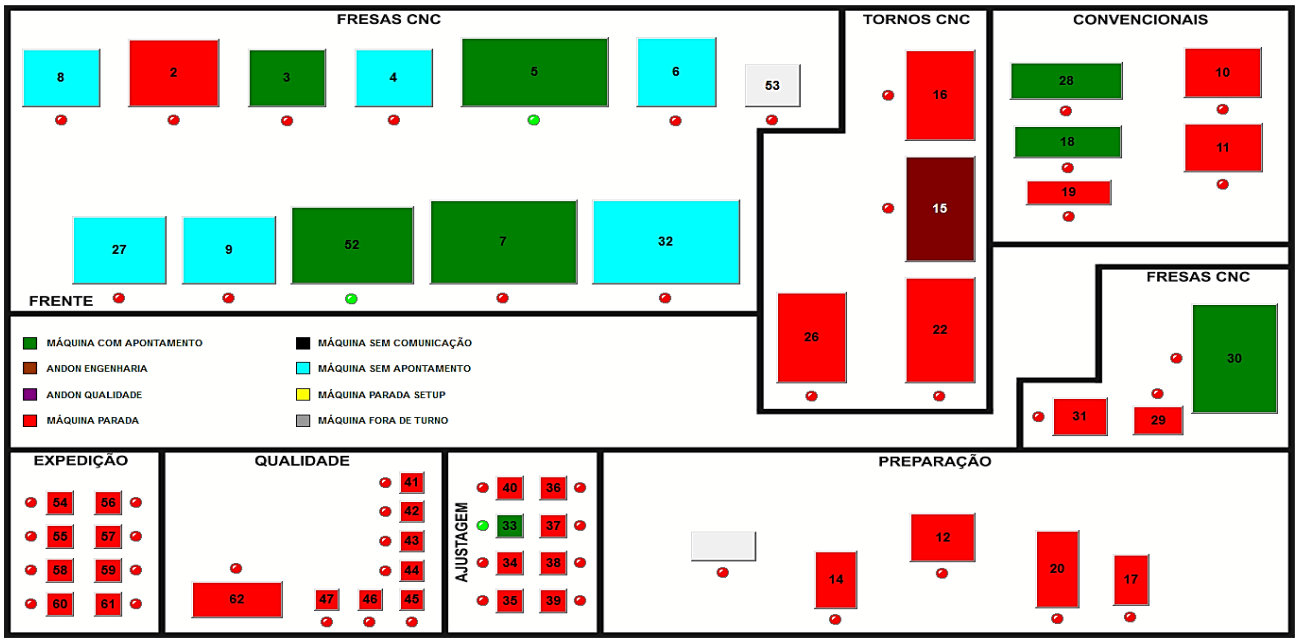

FIGURE 2.6- Complete monitoring screen.

2.3.8 Calculation of availability

Figure 2.7 shows the percentage of availability shown simultaneously to the machine chart.

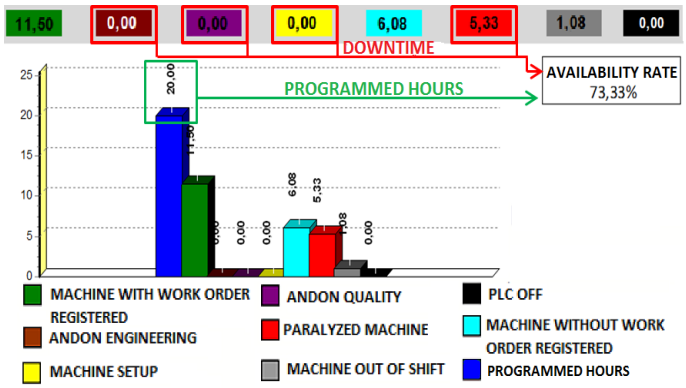

FIGURE 2.7- Percentage machine availability.

2.3.9 Andon and visual management

The use of the outputs provided by the software as visual tools to assist in the correct progress of production will enable the achievement of expected results. It is planned to distribute screens to function as andon and allow visual management throughout the plant. Figures 2.8 shows the screens already positioned in production.

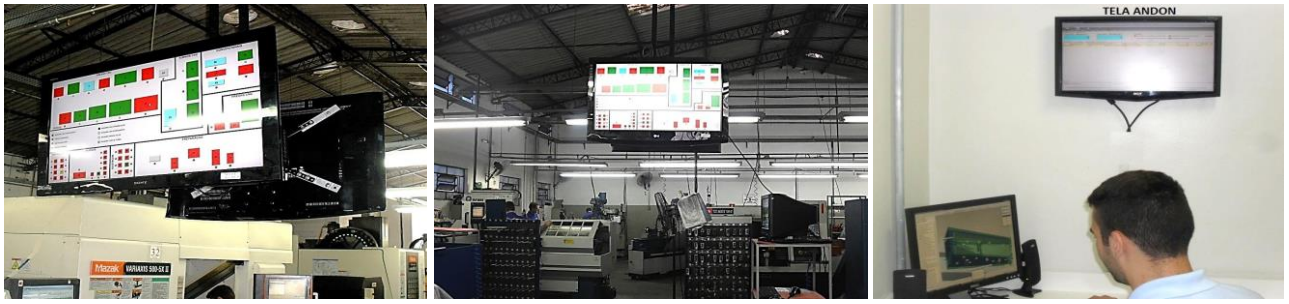

FIGURE 2.8- Monitoring screens of the machines used in production and engineering sector.

3. RESULTS

3.1 Pointing on production

Before the implementation of the project, the production had an insufficient electronic appointment. In April / 2014, employees received training in order to improve the pointing index. The installation of the monitoring screens in the production, in August / 2014, contributed to the pointing index increased significantly as Figure 3.1 shows by percentage of pointed hours.

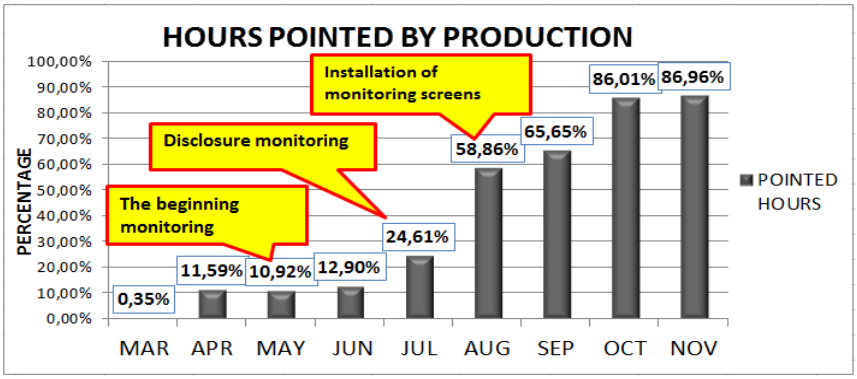

FIGURE 3.1 – Production pointing index.

3.2 Registration of the reasons stoppages

Operators did not have any tool for the recording of stoppages reasons the machines. Table 3.1 shows the lack of appointment of stoppages reasons the machines during the month of May / 2014. Table 3.2 shows positive results in stoppages of appointment of November observed the migration of hours the column "Not informed" (right column) for the remaining columns of the tables.

TABLE 3.1- Registration Table of stoppages reasons in May / 2014

MACHINE STOPPAGE MEMORANDUM (HOURS) - MAY.								
MACHINES	CHANGE / TOOL SHARPENING	MAINTENANCE	CLEANING	ABSENCE OPERATOR	SETUP	MEAL TIME	PRODUCTION PART MEASUR.	NOT INFORMED
2 - FRESA CNC 2 -								295,6
27 - FRESA CNC 27 -								210,96
3 - FRESA CNC 3 -								166,48
30 - FRESA CNC 30 -								112,08
32 - FRESA CNC 32 -								113,28
4 - FRESA CNC 4 -								203,12
5 - FRESA CNC 5 -								64,72
6 - FRESA CNC 6 -								OFF
7 - FRESA CNC 7 -								67,6
8 - FRESA CNC 8 -								202,88
9 - FRESA CNC 9 -								153,68
52 - FRESA CNC 52 -								OFF
15 - TORNO CNC 15 -								207,4
16 - TORNO CNC 16 -								248,88
22 - TORNO CNC 22 -								204,4
26 - TORNO CNC 26 -								231,12

TABLE 3.2- Registration table of stoppages reasons in November / 2014

MACHINE STOPPAGE MEMORANDUM (HOURS) - NOV.								
MACHINES	CHANGE / TOOL SHARPENING	MAINTENANCE	CLEANING	ABSENCE OPERATOR	SETUP	MEAL TIME	PRODUCTION PART MEASUR.	NOT INFORMED
2 - FRESA CNC 2 -	2,79	53,01			73,23	0,48	0,72	28,33
27 - FRESA CNC 27 -	3,22	1,21			13,93	1,62	5,31	28,12
3 - FRESA CNC 3 -	10,88	3,06	2,38	4,23	38,6	3,96	2,69	44,11
30 - FRESA CNC 30 -	8,93	6,26	5,73	3,45	89,63	6,01	5,3	45,79
32 - FRESA CNC 32 -	2,52	1,77			16,53	4,32	1,86	42,76
4 - FRESA CNC 4 -	6,12		2,07	0,87	29,83		1,11	27,38
5 - FRESA CNC 5 -	12,46			1,04	18,27	1,23	0,97	22,11
52 - FRESA CNC 52 -	6,42	7,98	0,42		20,67	4,44	3,84	24,61
6 - FRESA CNC 6 -	3,03	4,66	3,42		13,47		1,23	45,23
7 - FRESA CNC 7 -	7,02	2,19			20,7	0,93	1,11	23,08
8 - FRESA CNC 8 -	16,47	2,97	2,16		28	11,46	4,56	49,88
9 - FRESA CNC 9 -	13,38	0,69	0,33	2,37	49,17	7,02	2,73	69,66
15 - TORNO CNC 15 -	0,57	19,83	8,79	4,59	25,73	15,75	4,47	75,59
16 - TORNO CNC 16 -	0,69	7,98	4,71	39,21	31,73	17,88	2,49	78,05
22 - TORNO CNC 22 -	3,93		2,1	8,64	33,57	17,7	5,07	79,32
26 - TORNO CNC 26 -	0,66	1,77	2,34	30,75	23,07	21,06	9,06	73,59

3.3 Machine availability

Real percentage of operating machines in the scheduled period (availability) could be improved from actions taken on the causes of machine stoppages, detailed above. However, only with the installation of monitoring screens in the production and dissemination of reports there have been an initial improvement in average monthly availability rate of the machines as shown by Figure 3.2.

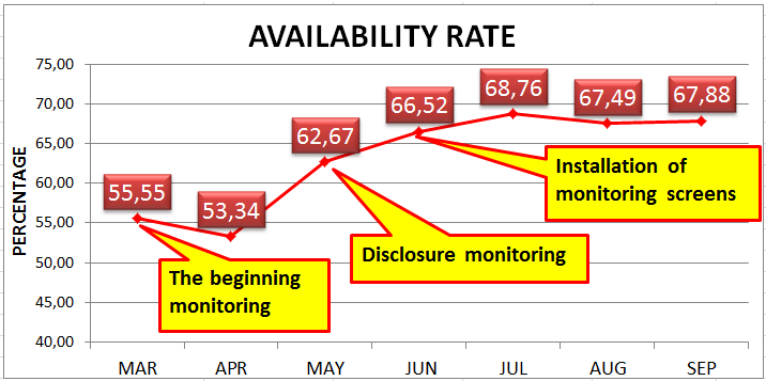

FIGURE 3.2 – Average monthly availability of Contents.

3.4 Monthly Billing

The monthly turnover index is an important indicator of business result, however the proper use of the machines in production is only part of this index. There are other factors that also influence the variation of the final performance of billing. Figure 3.3 shows the improvement in the company's turnover index in the past five months and the increased availability of the machines in the same period contributed to the positive results presented.

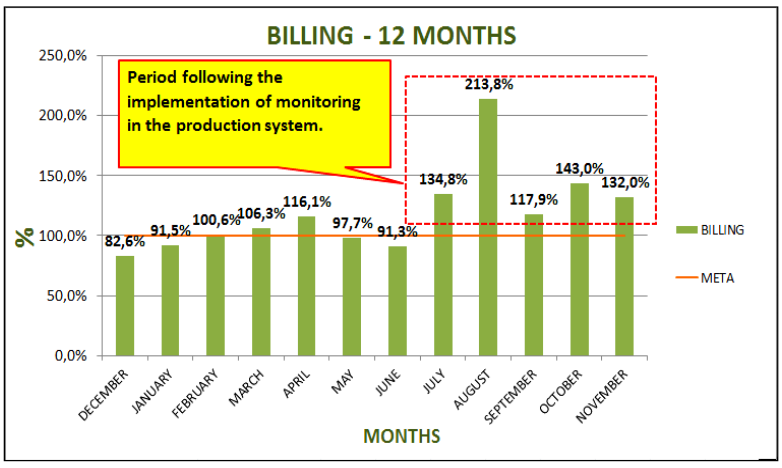

FIGURE 3.3 – Monthly billing Index.

4. CONCLUSION

The company has received positively the implementation of the monitoring system and at all levels - operators, leaders and engineers - this was the desire to improve the productive results.

The increase in the percentage of hours indicated by the production documented an existing production level prior to system deployment, but will enable the department processes a better determination of the actual times of production and the commercial department costs.

Monitoring screens installed in the production and generated reports allow managers to track instantaneously occurrences in the production and served as a visual aid to operators throughout the duration of notes.

The use of stoppages records machines by managers and operators was instrumental in the identification and subsequent correction of root causes. Quality in work stoppages of notes and correcting its causes will be important for productive results.

The implementation of visual aids and reports, conducting trainings with the operators and the daily monitoring of managers resulted in a 22% increase in the average machine availability, which contributed positively directly in monthly revenues of the company.

The monitoring system helped increase the availability of machinery index, presenting information in real time and providing increased production notes. However, this system requires constant critical analysis of information generated and reaction through the action plan of culture setting goals, in addition to the commitment of the entire team and follow up by management.

5. REFERENCES

BLACK, J. T.. O projeto da fábrica com futuro. Porto Alegre: Artes Médicas, 1998.

GROOVER, M. Automação industrial e sistemas de manufatura. 3ª ed. São Paulo: Pearson Prentice Hall, 2011.

MARCHWINSKI, C.; SHOOK, J.; SCHROEDER, A. Léxico Lean – Glossário ilustrado para praticantes do Pensamento Lean. 4ª ed. São Paulo: Lean Institute Brasil, 2011.

MARTINS, P. G.; LAUGENI, F. P. Administração da produção. 2ª ed. São Paulo: Saraiva, 2005.

MOURTZIS, D.; DOUKAS, M.; VLACHOU, A.; XANTHOPOULOS, N. Machine Availability Monitoring for adaptive holistic scheduling: A conceptual framework for mass customization. Procedia CIRP, Volume 25, 2014, Pages 406-413.

PRESSMAN, R. S. Engenharia de Software – Uma Abordagem Profissional. 7ª ed. Brasil: Mc Graw Hill, 2011.

TUBINO, D. F. Planejamento e Controle da Produção: teoria e prática. São Paulo: Atlas, 2007.

WANG, L. Machine availability monitoring and machining process planning towards Cloud manufacturing. CIRP Journal of Manufacturing Science and Technology, Volume 6, Issue 4, 2013, Pages 263-273.

6. RESPONSIBILITY NOTICE

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