MONITORING FAILURE ON A FMS USING PIMS: A CASE STUDY

Jeferson Roberto Dante, jefdante@gmail.com
Department of Mechanical Engineering (DAMEC), UTFPR, Av. Sete de Setembro 3165, Curitiba, PR, Brazil

Luiz Carlos de Abreu Rodrigues, lcar@utfpr.edu.br
Department of Mechanical Engineering (DAMEC), UTFPR, Av. Sete de Setembro 3165, Curitiba, PR, Brazil

João Antônio Palma Setti, setti@utfpr.edu.br
Department of Mechanical Engineering (DAMEC), UTFPR, Av. Sete de Setembro 3165, Curitiba, PR, Brazil

Luis Paulo Laus, laus@utfpr.edu.br
Department of Mechanical Engineering (DAMEC), UTFPR, Av. Sete de Setembro 3165, Curitiba, PR, Brazil

Paulo Humberto Ferrazza, ferrazza@utfpr.edu.br
Department of Mechanical Engineering (DAMEC), UTFPR, Av. Sete de Setembro 3165, Curitiba, PR, Brazil

Leandro Magatão, magatao@utfpr.edu.br
Department of Mechanical Engineering (DAMEC), UTFPR, Av. Sete de Setembro 3165, Curitiba, PR, Brazil

Abstract. *Flexible manufacturing systems (FMS) rely on automation to promote the integration of CNC, AGV, and robot equipment, which may be connected within an industrial network. Due to integration complexity of flexible manufacturing systems (FMS), availability of monitoring and supervision tools are desired. Plant Information Management System (PIMS) is a software that collects process data from production and transportation equipment within an industrial network, enabling an online monitoring and supervision of production systems. PIMS also enables reports of equipment units' unavailability, of frequency and time elapsed on an equipment unit's failure, reports of critical operations, and other reports associated to an online monitoring and supervision of production systems. The challenges concerning the use of PIMS are on error avoidance and interpretation of data. Errors are caused by bar code misuse and manual input of incorrect data. On the other hand, PIMS provides information on unit's failures but there may be several causes for a failure. Misinterpretation of failure causes may also lead to errors. The goal of this work is to identify the causes of equipment unit's failure within an FMS. In order to achieve this goal, reports of equipment parameters and corrective actions (taken whenever a failure occurs) are analyzed. The question brought by this work is: how can machine failure information become trustworthy, when applied to FMS systems? This work presents an unsuccessfull implementation of PIMS due to ambiguous definition of failures.*

Keywords*: Failure, online monitoring, error avoidance, FMS, PIMS*

1. INTRODUCTION

This work is intended to study the lack of reliability on the information of causes of machine failures in a flexible manufacturing system (FMS). This study is based on data reports on the equipment units operation, reports on machine failure, and the corrective actions carried through for each case. Currently, the data acquisition from machines can be accomplished by Plant Information Management Systems (PIMS) software, e.g. SAM® and ATAN®. If not properly used, these softwares can be misleading on the information that identify the causes of machine failures. Conflicting information can make it difficult to recognize the causes of failures, diminishing the software's efficiency. The question brought by this work is: how can machine failure information become trustworthy, when applied to FMS systems?

FMS systems rely on automation to promote an interaction between CNC, transportation systems (e.g. robots, AGV, and RGV), sensors, and other devices that are connected on industrial communication networks. However, according to Kovacs (1994), FMS systems are vulnerable to failures due to uncertainty factors that may not be foreseen, that may not be programmable, and that are not always controllable by automation. At automated manufacturing processes, the use of PIMS software makes possible the generation of reports that indicate production performance. PIMS also enables on-line monitoring of the plant. These softwares are able to perform data searches and to record data continuously. Such data base has the capacity to store months or years of production-related information (Seixas Filho, 1998). According to Pinto (1999), normally these information only enable the measure of efficiency, and this is not enough for a modern company. Companies need the measure of machine (or workstation) availability, reliability, production cost, and production order fulfillment.

An analysis of the implementation of PIMS software on a FMS was presented by Neve and Plasschaert (1996). It was evidenced that the data monitored for the system corresponded to predefined information, but the system did not indicate precisely which corrective actions should be taken on machines. Thus, using the information from PIMS, the challenge of this work is the identification of proper corrective actions that allow the elimination of equipment failure.

Therefore, one may ask: which are the necessary actions to efficiently monitor production information in order to reduce machine failure and improve FMS operation?

2. PIMS SOFTWARE

PIMS is a software that collects information from production and transportation processes within an industrial network. PIMS allows an on-line monitoring and supervision of production systems. Thus, PIMS may concentrate all relevant information from production cells processes. The information is stored in an on-line database. The advantage of PIMS is in its high capacity of compacting data and its time of response when a user accesses the database. The input of data to PIMS can be supplied automatically and manually. Data is supplied automatically by connecting PIMS to programmable logic controllers (PLC) and machine numerical controllers (NC) through the use of Profibus or Ethernet networks (Neve and Plasschaert, 1996). It is also possible to input data manually through the reading of bar codes. Usually PIMS is automatically supplied with data. But whenever an equipment failure occurs, machine operators are supposed to access machine monitors to check for detailed information of the failure. This information is manually input to PIMS using bar code readers. These bar codes are previously defined. It is up to the machine operators to classify the cause of failure, based on the available set of causes – that have already been printed in bar codes.

PIMS data are mainly used to produce reports. There are many different ways of preparing and presenting reports, including internet. PIMS manufacturers have made graphical tools available to visualize the information on a quite simple and fast way. PIMS is able to interact with popular softwares – such as EXCEL® and ACCESS® – enabling users to customize their reports. Therefore PIMS users can compare the performance of a machine or FMS analyzing present and past information. Users can also perform inquiries of problems, where a situation of normal production is compared to a problematic situation. This comparison indicates which production parameters did not meet preset or typical values. By analyzing information from different operations on FMS equipment, it is possible to identify the real production capacity of individual workstations or of the whole FMS. It is also possible to benchmark the availability, capacity, and performance of different workstations within a FMS.

3. ANALYZED PROBLEM

This work aims to perform an inquiry of a FMS for the machining of car engine components at Curitiba region in Brazil. The informations of manufacturing parameters were obtained from a SAM® PIMS software. When information on equipment failure is analyzed, it is intended to have a clear indication on the corrective actions to be performed on the FMS. This is particularly important when the corrective actions aim to improve the FMS reliability. On this studied case, PIMS is being correctly feed with informations form the FMS but there is a conflicting analysis of failures (Dante, 2004). SAM® PIMS software is being able to provide tables and graphic reports on machine operation parameters and performance, e.g. machine use, availability, and operation interruptions. Alarms and sensors information – that impose operation interruptions – are also available on PIMS.

This study is focused on a specific workstation because its unavailability has been impacting negatively on the overall FMS throughput. This workstation has a Grob® machining center, a Steiff® RGV (rail-guided vehicle) for transportation of production parts, a Grob® part-feeding equipment, and a Grob® cartesian-coordinate robot. According to PIMS reports, this workstation has presented the highest number of machine stops and also the highest amount of time unavailable due to equipment failure.

4. KAIZEN IMPLEMENTATION

4.1 Approaching the problem

Kaizen was implemented – or attempted – to study the causes of failure at this workstation. It has involved persons working at the FMS (e.g. machine operators), from maintenance, from process engineering, from quality management, and a production supervisor. This group started by analyzing the number of stops of the workstation as well as the reported causes of failure from a period of 6 weeks report. From this 6 weeks report, it was evidenced that the indicated reasons and causes of failure were not really identified or had just a generic description.

PIMS software enables users to program production alarms. Based on PLC and NC data, it is possible to diagnose production problems. But these programmed alarms must be carefully devised. As a consequence of Kaizen, the effectiveness and precision of the programmed PIMS alarms was questioned. Some alarm indications were too general and did not enable to identify the effective cause of machine failures. Particularly, there was conflicting information coming from the Steiff® RGV and from the Grob® part-feeding equipment. It was decided that the workstation workers would manually appoint the alarms of failure and the amount of times that they alarmed during a work shift.

4.2 Temporary actions

From the 6 weeks report, a series of provisory actions of prevention and correction of failures were elaborated. These provisory actions were applied during 6 weeks. Thus, new information related to failures started to be accessed by PIMS. It was identified that PIMS programmer did not have available all the necessary information on the FMS operation, when PIMS alarms were programmed for the first time. Therefore, a process of reprogramming PIMS alarms was started, based on the feedback from manual records of production problems. This reprogramming of PIMS supplied the basis of a last series of actions to prevent failures. An in deep analysis of the actions taken during Kaizen is presented on the next section.

The provisory actions were started as a methodology to reduce production losses and to identify the causes of machine failures. It significantly reduced the number of stops and the time of stops at the workstation. Reductions of 28,83% on the NS (number of stops) and of 25,29% on the TS (total amount of time of stops) of the workstation. Therefore, provisory actions resulted on some production improvement while definitive actions were planned. During first week, a provisory action was performed on the manipulator of the robot that feeds the Grob® machining center. The holding force applied by the robot to different raw materials was fine tuned, in order to eliminate manipulator defects. At the second week, another provisory action was performed. Since there were conflicting informations coming from the Steiff® RGV and from the Grob® part-feeding equipment, both units had their software updated. Four different actions were performed during the third week: *i*) The opening and closure of the Grob® machining center doors were fine tuned; *ii*) the position of a sensor – used to sense the presence of raw materials for loading on the machining center – was reset; *iii*) this sensor was – later during this week – turned off; and *iv*) equipment alarms were also turned off. These actions attempted to check whether the PLC logic – responsible for the machining center loading and unloading – was correct or not. During sixth week, this PLC was upgraded.

4.3 Definitive actions

The results of the provisory and definitive actions have been analyzed based on the data of the type of failure (TP), number of failures (NS), and the amount of time elapsed to correct failures (TS). These data have been obtained form PIMS. Table 1 indicates the different types of failure (TP) nomenclature that have been implemented along the provisory and the definitive actions. Each type of failure was identified using cards with bar codes. Whenever a failure occurred at the equipment, it was up to machining center operators to identify and input the type of failure at PIMS, using the cards with bar codes. Although the kaizen group intended to implement definitive actions after 6 weeks of provisory actions, it will be seen that definitive actions have not indeed become definitive. This was due to the lack of reliable information on failures by the kaizen group and failure misinterpretation problems by the machine operators. In order to describe these problems, the main reported causes of failures along the next six weeks – from week 7 to 12 – are presented on this section. The nomenclature on table 1 is used to report failures.

Table 1. Nomenclature on types of failure (TP).

Notation	Failure
A	electric defect
B	manipulator accessing empty fixture
C	manipulator defect
D	sequence defect at “FC191”
E	anti-return lock failure on entrance 2
F	defect on conveyor exit
G	Profibus network defect / magazine turns off
H	others
I	gantry stopped due to failure on machining center
J	anti-return lock failure on entrance 1
K	fixture defect at table
L	sequence defect at “sep 06”
M	item dimension defect at claw 1
N	mechanical defect
O	defect at claw 1
P	conveyor defect at entrance of operation 15
Q	failure to read identification tag
R	defect at claw 2
S	failure on sensor “E105.3”
T	temperature pre-alarm at axis A

Weekly evolution of definitive actions

As a starting point on the attempt to implement definitive actions, the kaizen group analyzed the data on the number of failures of each TP at week 6 (the last week of the so called *provisory actions*). The main reported causes of failure at week 6 have been TP *A*, *B*, *C*, and D, as indicated on Fig. 1. The TS (total time of machine stop) of failures is not available at fig. 1 because its trustworthiness has been questioned, since the hand appointments of the machine operators did not match to PIMS readings.

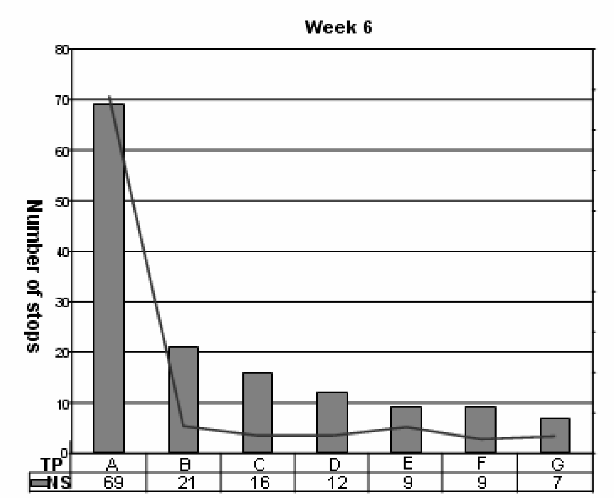
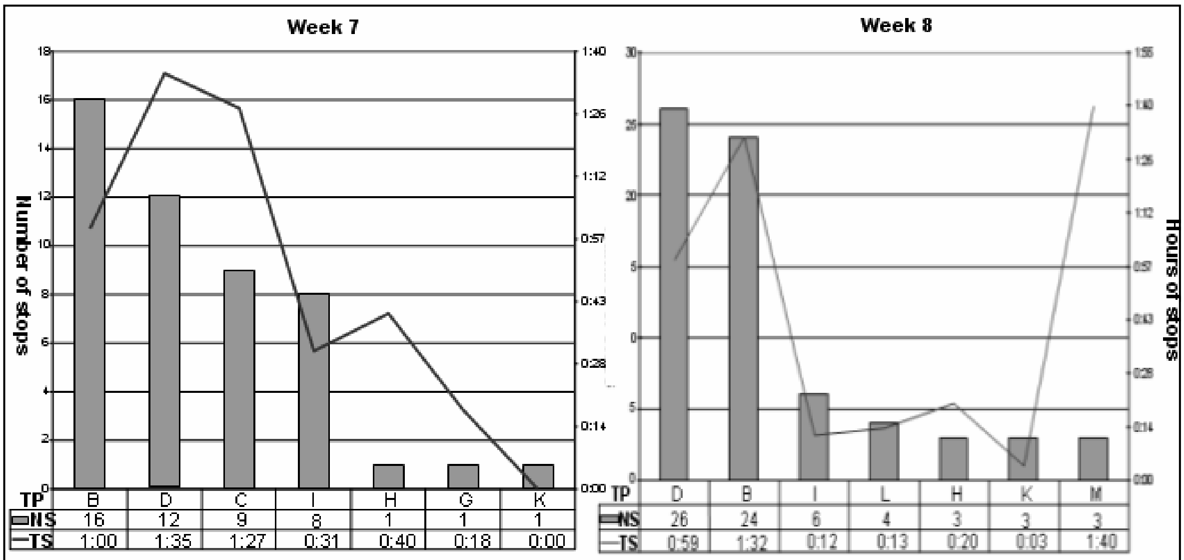


Figure 1. Week 6

Week 7

Two corrective actions have been ordered by the kaizen group at week 7. In order to correct TP *B* and *C* that have been reported at week 6, the PLC software that controls the Steiff® RGV and the Grob® part-feeding equipment has been updated. A back-up of the PLC program was also made. In order to correct TP *D*, a hydraulic valve of the Grob® part-feeding equipment was changed. The results of these implementations have been reported as week 7 at Fig. 2. Notice that the sum of the TS of different types of failure at week 7 was equal to 5.52 h. (or 5 hours 31 minutes). Comparing Fig. 1 and 2, it is possible to see that TP *A* has disappeared at weeks 7 and 8. But different TP (*H, I* and *K*) have emerged. Also as a consequence of the corrective actions done at week 7, TP *B* has presented an increase on its TS at week 8; while TP *D* has presented a significant decrease on its TS. During the same period, there has been a reduction on the total (sum of) TS of 35 minutes (or 0.59 h.).

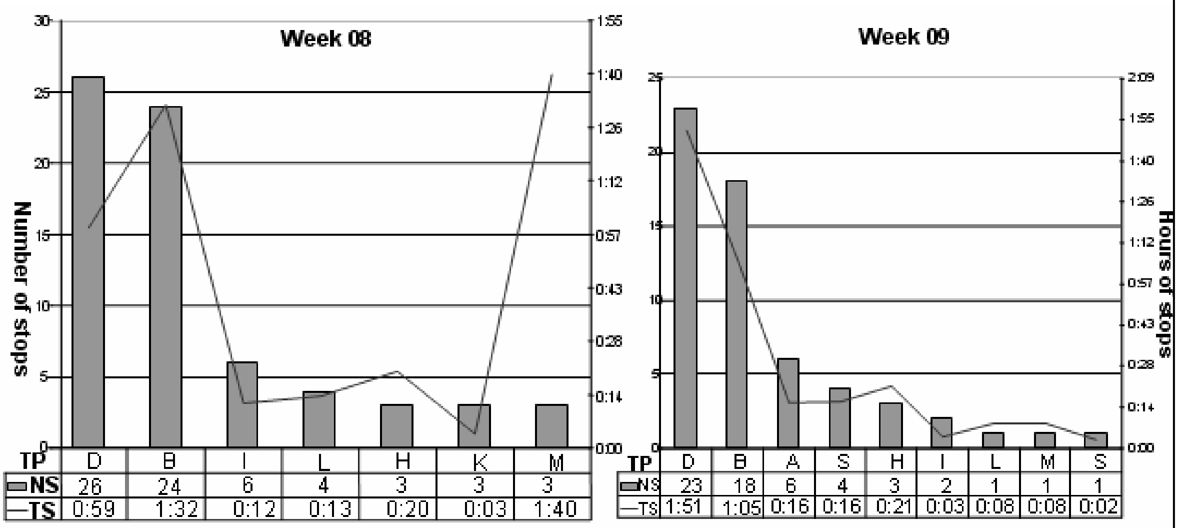


Total TS at week 7 = 5.52 h. Total TS at week 8 = 4.93 h.

Figure 2. Reports of weeks 7 and 8

Week 8

At week 8, TP *D* was analyzed, process simulations were performed, and processing times were corrected. As indicated on Fig. 3, no significant improvement on TP *D* has been measured. But there has been a reduction on the total (sum of) TS of 46 minutes (or 0.76 h.). No explanation was found to the appearance of new TP (particularly *A*) at week 9, except that it was due to the operators' interpretation of failures. This can be explained by the fact that the Steiff® RGV and the Grob® equipment have their own man-machine interfaces, and each interface tended to present different failure messages.

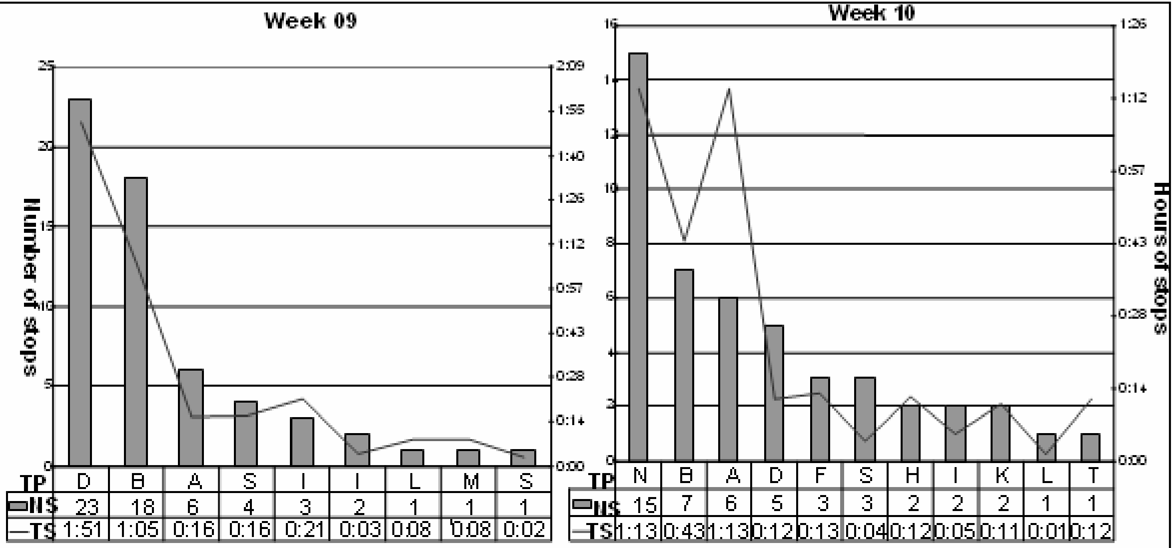


Total TS at week 8 = 4.93 h. Total TS at week 9 = 4.17 h.

Figure 3. Reports of weeks 8 and 9

Week 9

The fixture accessed by the robot manipulator has a sensor to identify the presence of raw materials. In order to eliminate TP *B*, a maintenance/repositioning of this sensor manipulator was made. The PLC programming was also revised, in order to eliminate TP *D* failure. As pointed out on Fig. 4, the reports indicated that these actions have been able to reduce but not eliminate the amount and time consumed of TP *B* and *D* failures, as presented on week 10. But the fact is that there was just a migration on the reported failures, as indicated by the new indication of TP *N* failures. In fact, there was no reduction on total TS from week 9 (4.17 h.) to week 10 (4.32 h.).

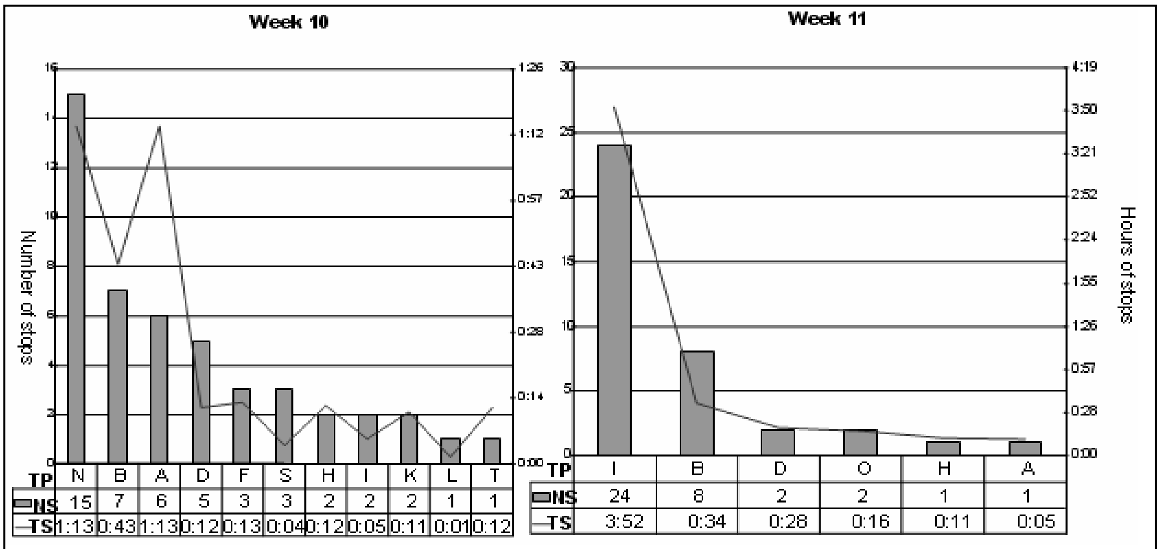


Total TS at week 9 = 4.17 h. Total TS at week 10 = 4.32 h.

Figure 4. Reports of weeks 9 and 10

Week 10

No *definitive actions* have been performed at this week. Despite this, there is an increase on TS from week 10 to week 11 reports. The migration on the reported failures continues. Figure 5 indicates a significant increase on the amount of TP *I* from week 10 to 11. At the same period, an increase on the amount of TP *D* and *O* has also occurred. On the other hand, some TP reported at week 10 are not reported at week 11 (e.g. *N*, *F*, *S*, *K*, *L*, and *T*), while other TP have had their amount of reports reduced (e.g. *A* and *B*). At figure 5, it is also possible to notice that total TS has increased by 67 minutes (1.09 h.) during this period. Comparing total TS at week 7 (5.52 h.) and at week 11 (5.43 h.), it is possible to question whether any actions taken during these 4 weeks really benefited production or system reliability.

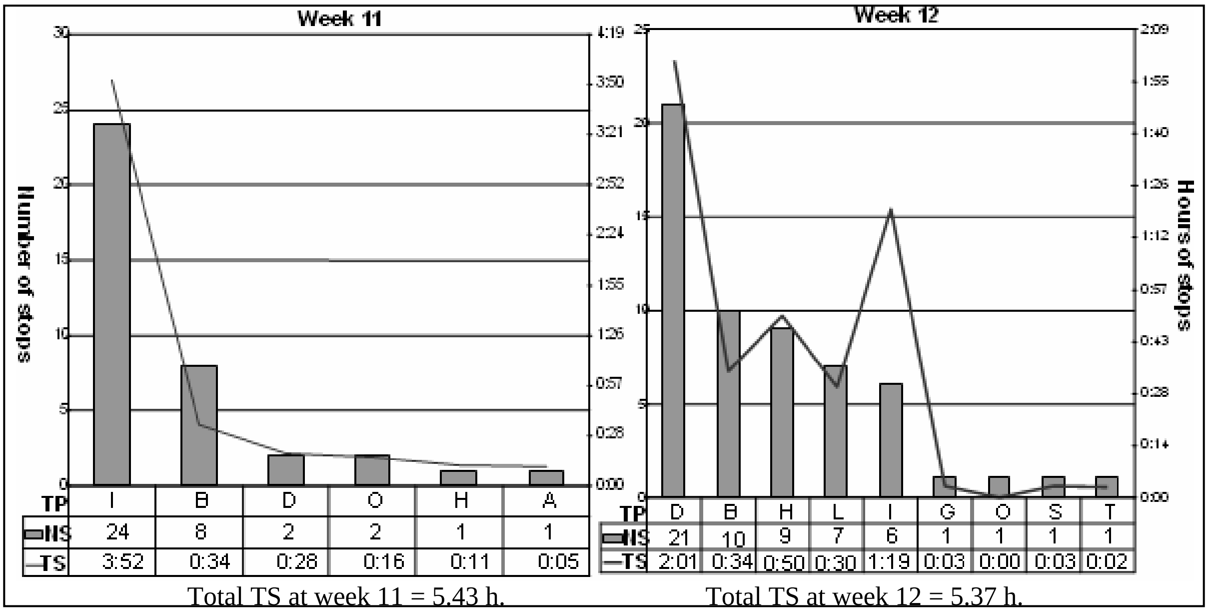


Total TS at week 10 = 4.32 h. Total TS at week 10 = 5.43 h.

Figure 5. Reports of weeks 10 and 11

Week 11

At week 11, software revisions have been made in an attempt to reduce TP *B* and *D*. As indicated on figure 6, there has been no reduction on total TS comparing weeks 11 and 12. But once again there has been a great variation on the indicated causes of failure, with a significant increase on TP *B*, *D*, and *H*. On the other hand, there has been a reduction on TP *I*.



Total TS at week 11 = 5.43 h. Total TS at week 12 = 5.37 h.

Figure 6. Reports of weeks 11 and 12

4.4 Results of *definitive actions*

Figure 7 indicates the variation on NS and TS at a period of 12 weeks. On the first 6 weeks the company adopted (what was called) *provisory actions* and *definitive actions* have been taken on the last 6 weeks. Figure 7 indicates a 52,58% reduction on the NS and 54,46% reduction on the TS when the *provisory actions* period is compared to the *definitive actions* period. Despite the overall reduction of failures, it is possible to see that there has been no significant reduction of failures after week 7. Therefore it is possible to identify that the action (PLC upgrade) taken at week 6 (that impacted on week 7) was the most effective one during the 12 week period. The fact that no *definitive actions* have been effective in significantly reducing NS and TS indicates that the kaizen group has not been able to identify the causes of failures. During all the analyzed period, the indicated TP (causes of failure) have always been changing. It was up to the machine operators to indicate the TP whenever a failure occurred and the ambiguity on TP definitions enabled operators to select one of the (sometimes several) possibilities.

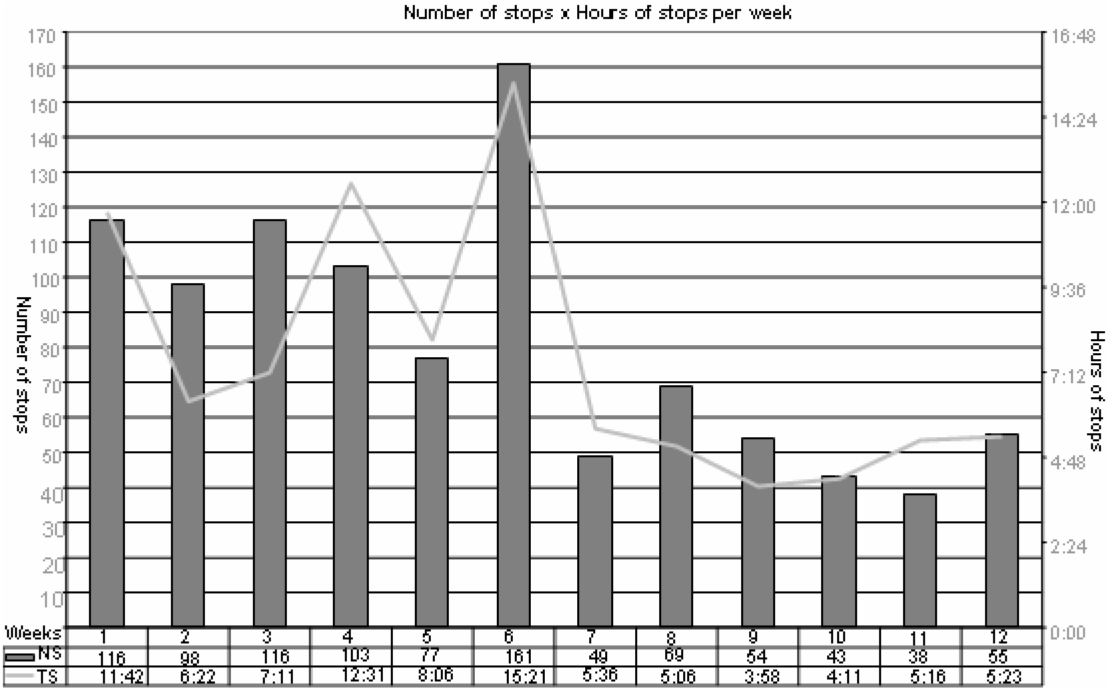


Figure 7. Total reports of NS and TS per Week

5. CONCLUSIONS

Plant Information Management System (PIMS) is a software that collects process data. It enables reports of equipment units' unavailability, of frequency and time elapsed on an equipment unit's failure, reports of critical operations, and other reports associated to an online monitoring and supervision of production systems. The challenges concerning the use of PIMS are on error avoidance and interpretation of data. At the analyzed problem - during the implementation of actions - the identification of failure causes was not efficient. This was due mainly to the ambiguity on the nomenclature of failures causes (TP). Machine operators often had more then one TP to choose whenever a failure occurred. For example, a failure due to different software protocols (between the Steiff® RGV and the Grob® equipment) has been indicated by the operators as TP *A* (electric defect), C (manipulator defect), and *H* (others). Therefore the kaizen group became an erratic and misleading search for solutions. The conclusion is that it is not enough to use PIMS to report failures and the performance of any workstation if the data input to PIMS is not trustworthy.

4. REFERENCES

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