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CONTROL OF PRODUCT/PROCESS REVISIONS IN A CONCURRENT ENGINEERING ENVIRONMENT

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Abstract. *This paper presents the results of the implementation of a software solution designed to control the necessity of process revisions based on a previous change in a product. The system was installed in a large manufacturing company. The influence of this sort of system in a Concurrent Engineering Environment, with special attention to industries that have a complex product structure or frequent revisions in component specifications is also discussed***.**

Keywords**:** Concurrent Engineering, Production Planning and Control

1. INTRODUCTION

The ISO/QS 9.000 specifies the requirements for process documentation in manufacturing companies – particularly in the car parts industry. In fact, the specifications are a great tool available for companies that want to revise and improve their manufacturing processes.

However, some companies have been having problems with the revisions of those documents, especially in the implementation of process revisions based on a previous change in a product.

This problem seems to be more dangerous in companies that have a complex product structure or frequent engineering changes in their BOM (bill of materials). In order to illustrate this problem, the list below presents an overview of an enterprise where this project was originally developed:

- Number of parts described in the company's component database – 50,000;
- More than 54 final products assembled with these parts;
- Each final product can be made up by more than 900 components in its structure.

In addition, the company has been trying to implement a *Concurrent Engineering* environment, aiming at the reduction of the time needed to implement the changes requested by their customers.

As it will be described later, the Concurrent Engineering project found some problems as a result of the characteristics of the systems usually adopted in the manufacturing arena, such as MRP (*Material Requirement Planning*) for example.

In order to deal with these problems, this work describes a special software package developed to improve the *Control Of Product/Process Revisions In A Concurrent Engineering Environment*.

2. CONCURRENT ENGINEERING – TRENDS & PROBLEMS

As defined by Prasad (1996), some efforts have been developed to reduce the time to market of a product, mainly in the following areas:

- ***Business Process Reengineering*** – Which consists in redesigning the activities usually done within a department and across departments in order to eliminate redundant or unnecessary steps;
- ***Co-operative Workgroups*** – Once the business process reengineering has been defined it is necessary to establish cooperative workgroups to bring together different areas of human knowledge and skills. The objective of these multidisciplinary groups is to eliminate a narrow individual understanding of a problem;
- ***Information Modeling*** – In conjunction with the activities described above it is also necessary to integrate all systems used in the product design, process design, administrative tasks and production planning and control.

In fact, as Prasad (1997) pointed out, an effective manufacturing environment involves a carefully orchestrated interplay between teams, software and machines.

Specifically in terms of software solutions, we can observe an increase in the number of applications available to control the project data and their effective implementation on the shop floor.

Among these commercial solutions designed to control changes, for example, the EDS company has implemented the Master Model concept in their systems. In this scenario, a simple revision on a CAD drawing will automatically generate the necessity of a revision in all dependent models which are based on this Master Model. As a sample of the dependent models affected by this change, we could list the CAM model used to generate CNC programs of an injection mold, for example.

It is important to note at this point that this sort of feature is available only in expensive systems, which are not fully disseminated in manufacturing companies. Even in the case of a company that has invested in this sort of systems, it is necessary to point out that these solutions deal with just a part of the problems that are often found in the manufacturing area.

In an attempt to address these outstanding questions the PDM (*Product Data Management*) and the EDM (*Engineering Data Management*) systems were recently developed. These systems were designed to control the information associated with a project or product, tracking the revision cycle and ensuring the integrity of the product structure stored in the MRP systems (Dickerson, 1997).

Although PDM systems are very efficient at managing documents of different formats and controlling the workflow specified for them, it is important to say that most of them still treat these documents without considering their contents. The maximal control level usually implemented in these systems is restricted to some fields that can be customized by the final user.

In spite of the good results that were achieved using business process reengineering, cooperative workgroups and new computerized solutions - like PDM/EDM, we can still observe some important problems that remain to be solved.

In fact, the majority of these problems can be easily detected when we analyze the problems with materials that usually occur in companies with a relatively complex product structure – like cars, tractors, and special machines.

Some of these problems are briefly discussed below:

- ***Obsolescence of parts and raw materials kept in stock***. The cycle of obsolescence starts when items are automatically purchased by the MRP system after a product explosion. Although the "purchase process" seems to be accurate, if the quantity described in the bill of materials is superior to the quantity actually required in the assembly, an "invisible increase" in the stock units will be generated. It is important to note that this increase of quantity will not be listed in the materials reports generated by the MRP, but the "extra" quantity will be stored in the warehouse already. In fact, after some "significant" change is performed by the engineering department in this specific item, or in the product structure that contains it, this stored item will be made redundant. In this case, the component will be scrapped based on the argument that the new version of product does not use it any more;
- ***Excess of stocks of parts and raw materials***. These items would be used in the final assembly of products, but as a result of the problems described above, their stock levels are higher than originally described in the database of the MRP system. The existence of these stocks will increase the risk of obsolescence described above;
- ***Insufficient units of parts and raw materials kept in stock***. When the quantities described in the MRP files are lower than the units actually needed for the assembly, the company will face problems regarding the lack of components. In this case, regardless of the cost of the part, the additional cost of having a line stopped for some hours will have a negative impact on the competitiveness of the whole enterprise.

Although the problems described above seem to be simple, they remain a big issue in many companies across the world. In fact, a careful analysis will indicate that the majority of these problems are the result of poor control of information flow in the *Design / Process / Production* cycle.

It is important to say at this point that the problems described will not be solved by the systems currently available in the manufacturing area. In fact, the majority of these systems were developed with a specific purpose in mind, without considering the possibility of using the controls that there are described below.

As a result of that, we can say that the mere integration of the CAE/CAD/CAM/CAPP systems, even using a *Master Model* concept, or supported by a PDM/EDM system, will not warrant the successful implementation of *Concurrent Engineering* in all stages of manufacturing.

In fact, these solutions when implemented under specific product and market conditions can lead to good results. But this statement can not be made when the final product or the market niche where the company competes is similar to the ones analyzed in this work.

In this case, it is important to analyze all solutions available, identify their blind points and implement a system that will interact with these solutions and allow the implementation of a CE environment.

3. REQUIREMENTS TO INCREASE ACCURACY OF THE BOM

In order to identify the requirements to increase accuracy of the BOM, a complete analysis of the features of the CAE/CAD/CAM/CAPP and PDM systems was initially made. The objective of this analysis was to map operational functions and identify points not covered by these solutions.

Later on, these functions were cross-checked with the problems described above. The results of this work indicated some controls that should be implemented in order to solve the question.

Once the controls had been listed, a study was done to identify the additional functions that should be implemented in the planned control system. The resulting requirements pointed to a system that could manage "*Intelligent Documents*" in the *Design / Process / Production* cycle, and not only archives, as it is usually the case with PDM systems.

The requirements identified are listed below:

- ***Edition control of intelligent documents*** – The system to be implemented will have to provide facilities to the edition for process documents. Although these options are usually available in CAPP systems, the system will have to deal with *Intelligent Documents*, which are documents that can be handled automatically by an external application. In this case, the content of a document will be extracted from a process database and not stored as a text file or a CAD file, as it is usually done in some systems;

- ***Control of tools and accessories*** – In order to support the future implementation of a *Finite Capacity Scheduling System*, the control system will have to control all tools and accessories that are necessary to perform each manufacturing step. As a sample of these tools we could list molds, dies, fixturing, special instruments, machines, etc.

- ***Interface with the Planning and Cost system*** – The control system will have to provide functions to automatically update the cost and planning system. Although these functions are usually available in MRP systems, our research concluded that the majority of process engineers do not update these data after a process revision. More important than this was to discover that they would do it more frequently if their CAPP system provided this option. This functionality will allow the company to control more efficiently the evolution of its manufacturing costs.

- ***Control of process revisions based on changes in the Bill of Materials*** – This control was designed to eliminate differences between the BOM effectively assembled and the BOM listed in the MRP files. The objective of this feature is to ensure that each structural revision performed by the engineering department will be effectively translated in a revised assembly process document.

- ***Control of process revisions based on changes on parts specifications*** – This control was designed to assure that the requirements of ISO/QS 9000 regarding parts process revisions have been effectively implemented in the process documents that will be sent to the shop floor.

- ***Control of prototypes*** – In order to reduce the *lead-time* to implement changes in the product it will be necessary to manage all process documents of parts that are in the pre-manufacturing stage. In this scenario, the *process planning* stage and the manufacturing tests will be done before the engineering department has released the final project. It is important to note that all documents created in this stage must follow the same rules used in normal production;

- ***Automatic prototype implementation of changes*** - Once the engineering department has approved the project, it will be necessary to start, as soon as possible, the production. In this case it will be interesting to use all process documents developed during the pre-manufacturing stage so as to reduce the rework in that area.

In fact, the requirements listed above could be divided in 2 groups. The first one contains the requirements that are not available in the CAE / CAD / CAM / CAPP / MRP and PDM systems usually adopted in manufacturing companies. The second one contains the requirements that are partially satisfied by these solutions – like the CAPP, MRP and PDM systems.

Thus, this work identified the necessity of implementing a new system that will interact with the systems analyzed in order to provide a better control in the process flow throughout the *Design / Process / Production* cycle.

However, this is not an easy task, especially when we analyze the characteristics of the majority of MRP systems in use, which were not developed with the idea of performing simultaneous activities. Another problem detected was the fact that the great majority of systems involved in the *Design / Process / Production* cycle can not be customized to meet the requirements detected.

In order to solve this problem our group decided to develop a system to satisfy the ISO/QS9000 requirements and also provide the functionality described.

4. THE IMPLEMENTATION OF THE CONTROL SYSTEM

First of all, it is necessary to specify the systems that were already installed in the company where this work was originally developed:

- The MRP was installed some years ago and its update to a new version is not an easy task due to the high degree of customization implemented by the company on the system;

- The production priorities in the shop floor are defined using *Kanban*, but the company is looking for a *finite capacity schedule system*;

- Projects are made in an I-DEAS CAE/CAD system;

- Only complex parts are programmed in the I-DEAS CAM system;
- The process planning uses the CAPP/PRODMAX system.

Despite the large number of software solutions available, some projects are still made in a conventional way. In fact, it is a formidable task to migrate more than 30,000 part drawings from a conventional system to a computerized system in just a few months, but the number of projects in a CAD system has been increasing little by little.

Apart from that, the company had around 120 people indirectly involved in activities related to product/process revisions, and, almost a quarter from these were directly involved in the process revision activities.

In this scenario, the implementation of a control system was made in line with the conceptual model described in figure 1. Figure 1 also presents the control system interaction with the other systems used in the manufacturing area:

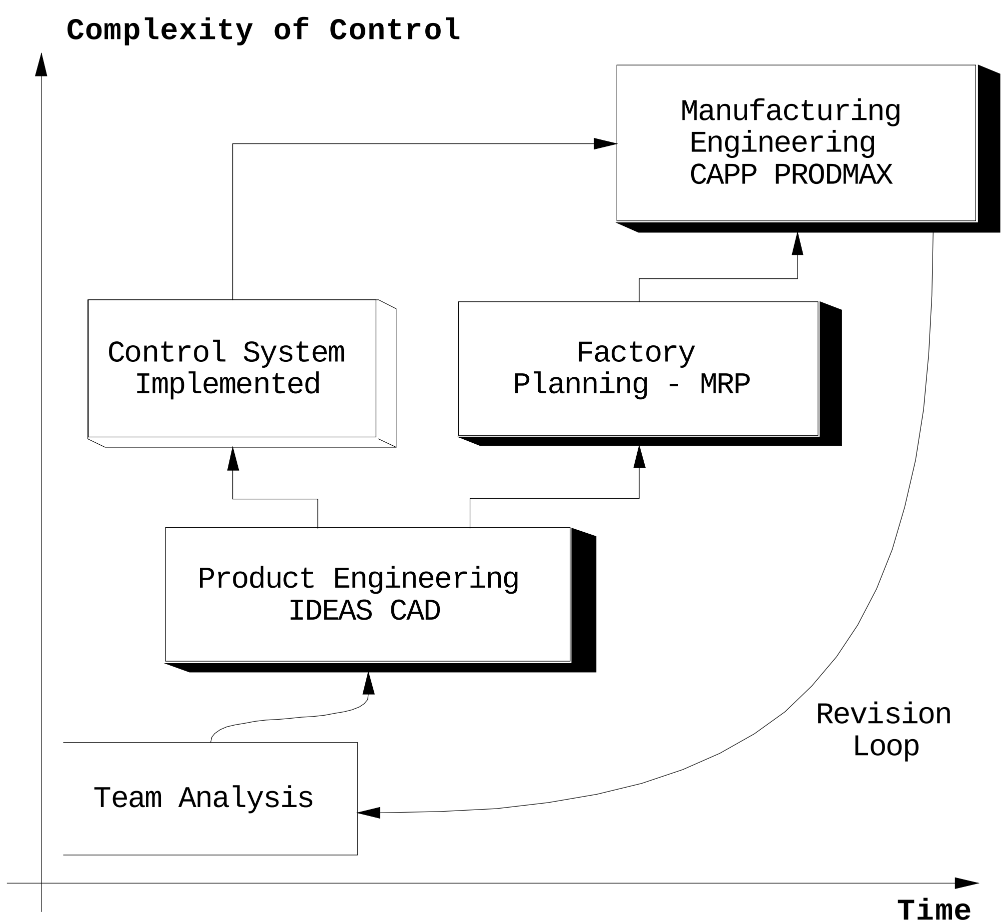

Figure 1: Conceptual model of the control system and its interactions

As figure 1 shows, multidisciplinary teams (marketing, purchasing, quality, engineering, manufacturing and logistics) are structured to analyze the product revisions to be implemented.

This stage is called "*Team Analysis*". Once the revision has been analyzed and approved by the team, the engineering department executes the documentation process and starts the planning stage.

At this point, both the MRP and the control system will be simultaneously activated by the engineering department – *see figure 1.* This action enables a parallelism of events in the revision process.

The activities performed in this step are described as follows:

- The planning department analyzes the parts to be scrapped, items to be purchased, investments, tools required, stock levels, choice of supplier, etc. Based on this information the date of the implementation of the changes in the production line is defined.

- Additionally, the manufacturing department will receive a request for a process revision from the control system. The activities usually performed in the manufacturing stages are process analyses, design of special fixturing sets, project and manufacturing of molds and dies, changes in layout, etc.

The requests for revisions will be generated automatically when changes occur in the product structure or in the parts' revision number. Among the information that are usually sent includes the follow:

- The state of the revision that was affected (ISO requirement), the scheduled date for implementation (this date will be updated when the planning stage is finished), other parts or structures affected by the change, etc.
- After that, the control system will automatically identify all assembly and process instructions that have been directly, or indirectly, affected by the change. All documents found in this process will be bookmarked for a later process revision.

The figure 2 shows the revisions control screen for all documents affected by engineering revisions. It also shows the type of document, the implementation date and other valuable information that can help the technical staff to revise the process instructions.

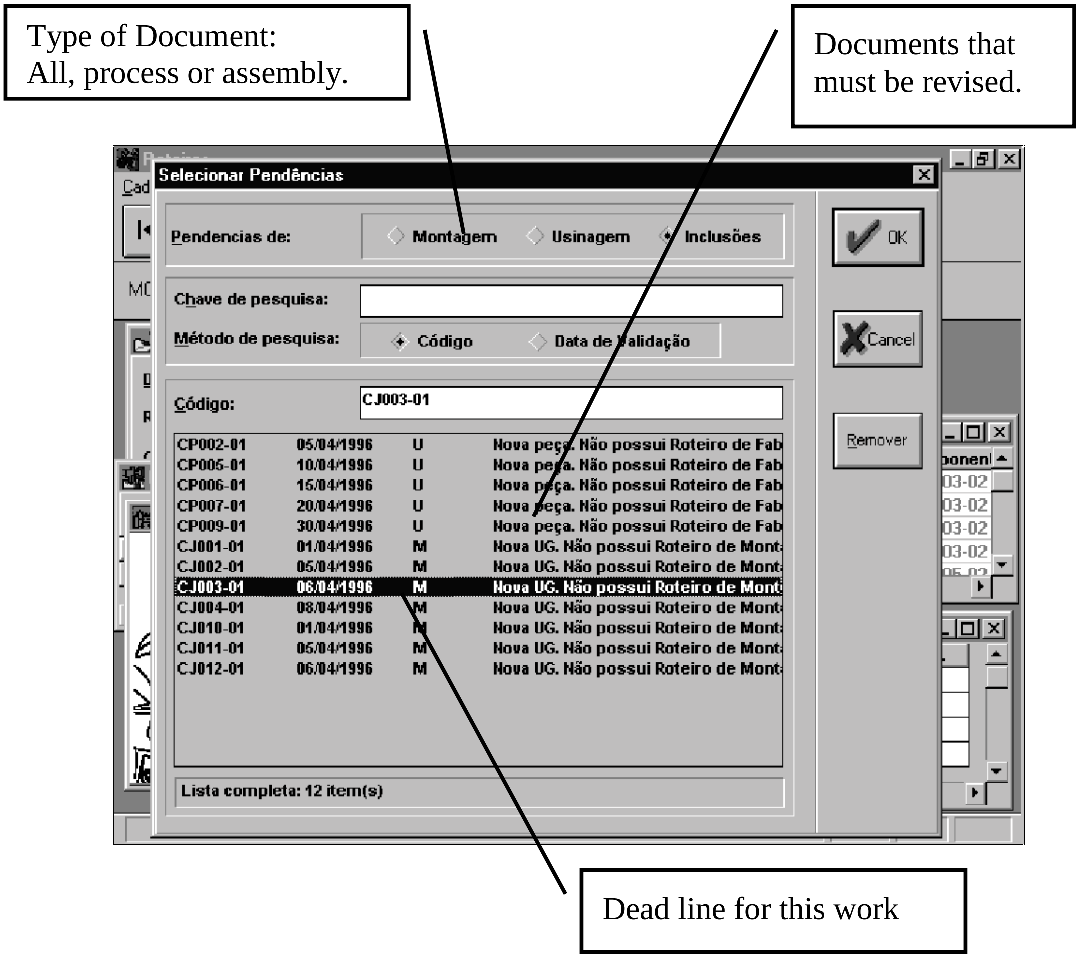

Figure 2: Control of documents that must be revised

It is important to note that the *bookmarks* of an assembly instruction will not be eliminated until the documents involved are free of structural inconsistencies. In fact, this action will warranty that only valid parts are listed in this sort of instruction.

It is also relevant to say that this control alone will not guarantee the complete eradication of the BOM errors, but a great part of them will be eliminated. In fact, the total eradication of these problems will be only possible with a *virtual disassembly* of the product structure.

This *virtual disassembly* will check the contents of the assembly instruction with the structural database of the MRP system. The resulting report will list parts of the BOM that were not used in the assembly instructions and quantities used that do not agree with the ones listed in the MRP files. (*This function is under implementation*).

In addition to this, the control system identifies other process documents (like milling, turning, forging, etc) affected by the change and will *bookmark* these for a later process revision. The control of *bookmarks* will guarantee that all documents affected by engineering changes are effectively analyzed before their next release to the shop floor.

As observed in the shop floor, the problems in the project usually appear in the manufacturing stage. When this is the case, if a change in the original project is requested, a loop in the *Design / Process / Production* cycle will be generated. This unplanned revision loop may increase the lead-time estimated for the implementation process, which will result in an undesirable delay in the revision cycle.

In spite of this, in a Concurrent Engineering Environment supported by the control system described here, this revision loop will occur simultaneously with the planning stage, which will reduce the negative impact of the reworking. It is also important to note that the control system will manage all priorities defined for this cycle, ensuring that the efforts of the technical staff are used in the most urgent task and that all details involved in the change will be analyzed and included in the process specifications.

The control system was conceived to automatically eliminate all *bookmarks* associated to a revision request that has been made redundant. This redundancy, for example, may be generated after a product change executed inside a revision loop.

In fact, one of the most important features of this control system is its ability to keep the control throughout the original *Design / Process / Production* cycle, especially when we consider the increasing complexity of the product/process information to be managed through this cycle and its huge influence on the undesirable loops described.

Figure 3 presents the bookmarks assigned to an assembly instruction.

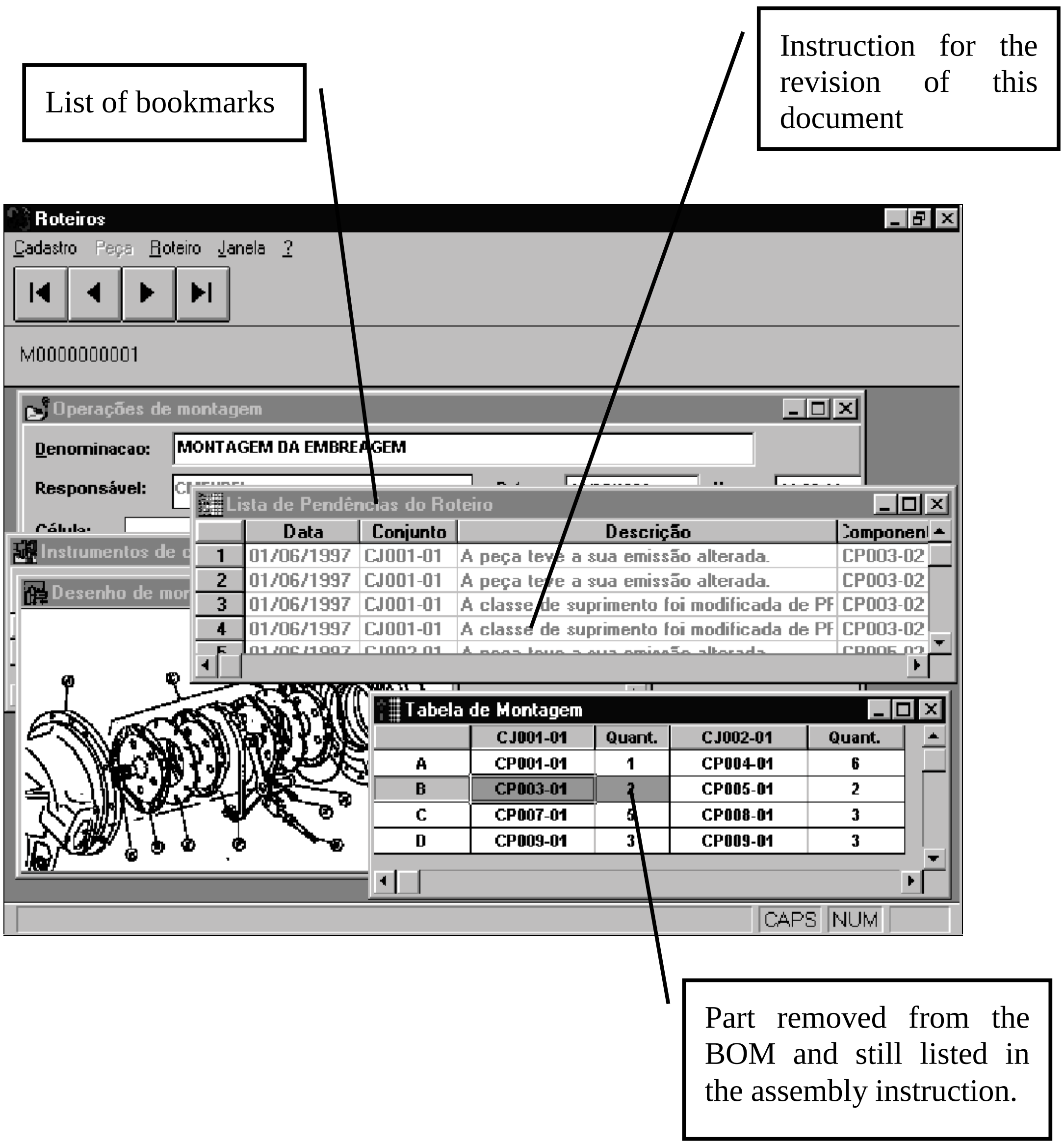

Figure 3: Control of inconsistencies in an assembly instruction

5. CONCLUSIONS

This work started by describing the trends observed in the implementation of a Concurrent Engineering environment and presents a case of a large tractor manufacturer that has implemented it.

The problems faced by the majority of manufacturing companies regarding the control of product/process changes specified by the ISO/QS 9000 were also discussed. In fact the lack of control in the *Design / Process / Production* cycle can lead to a serious problems regarding the accuracy of the records of materials kept in stock.

In order to solve the problems described software solutions like PDM and EDM were developed. Unfortunately, these solutions have not solved all outstanding questions discussed.

In an attempt to solve these problems the results of a research study that identified the points not covered by the systems in use in the manufacturing areas and by the reengineered workgroups were presented.

The results of this study pointed at the development of a control system that should manage the necessity of revisions in process instructions based on a previous change executed in the part/product configuration. The conceptual model of this system was presented alongside the information flow implemented in this new scenario.

It is important to point out that the number of undesirable loops has been reduced after the implementation of the system. The amount of parts and components scrapped has also decreased.

In addition, all engineers agree that the system has improved the controls of the revision tasks that must be performed, as well as the prioritization of activities and the assignment of groups.

Finally, the facts described above allows us to conclude that the control system has already improved the accuracy of product integrity and the manageability of the documents to be revised in the *Design / Process / Production* cycle.

In spite of this, full accuracy of the BOM will only be achieved with the project *Virtual Disassembly* that this group has been developing since last year.

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