DEVELOPMENT OF METHODOLOGY FOR TOOLING MANAGEMENT ITEMS IN A MANUFACTURING ENVIRONMENT

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Abstract. *Flexibility is the key requirement for companies in the manufacturing systems characterized by diversified and customized products, particularly in the machining area. Developments in automation and manufacturing engineering have contributed to the increase in the versatility of the machine tools and these equipments become capable of processing a wide variety of products. However, the capacity of a machine tool processing several products is limited by the manufacturing strategy, tooling availability and setup time required. The availability of multiple tools is of fundamental requirement for high rates of machine tool utilization in manufacturing environments. Even in relatively small machining companies, a wide tooling variety becomes necessary. In this scenario, the tooling management in the manufacturing environment is needed to minimize disturbance. Among these items are inserts, solid tools, toolholders, collets and adaptors. The objective of this research is to develop a methodology in order to enable the tooling traceability (toolhoders, collets and adaptors), aided by a computerized system, that provides information about the quantity, location and condition of items. The methodology is based on using 2D barcodes (data matrix) and the integration of six steps with a computerized system. Tests in manufacturing environment were carried out in order to a better understand the methodology. Results indicated that the adoption of machining tooling management provides the ability to identify obsolete tooling, avoid redundant information, reduce inventory, minimize the investments when purchase new machine tool and enables focus on critical points.*

Keywords*: tooling management, data matrix, barcode, machining, manufacturing environment*

1. INTRODUCTION

Flexibility is the key requirement for companies in the manufacturing systems characterized by diversified and customized products beyond the short leads time. Developments in automation engineering and manufacturing engineering for mass production, particularly in the machining area, have contributed to the increase in machine tools versatility, and these machines become capable of processing a wide variety of products. The productive efficiency of these machines is strongly connected to the availability of tools, the capacity of the storage of tools devices (magazines), the reasonable allocation of the number of tools on each device as well as fast set up times. Therefore, the use of tooling management techniques is fundamental resource in a productive environment. The advantages of tooling management implementation are the minimization of lead time, products stocks, inventories of devices and tools and, consequently, of the manufacturing costs (KOO *et al.*, 1997; EVERSHEIN *et al.*, 1991).

Machining tooling management involves three major areas: technical, logistical and strategic. The technical area's main responsibilities are the selection, definition, use of tools and performance evaluation. The logistics area's main concerns in buying, receiving, assembly and deployment tools in time and place needed. Finally, the strategic area should assess the resources necessary and provide people beyond the constant demand for optimization actions. With regard to the technical area, the challenges involved are the distinction of existing tools and new needs in the manufacturing environment and the high amount of the technical information offered by the market. Undesirable results for the technical area are: the existence of unnecessary tools, obsolete items, and especially, unjustified investment with these items. Moreover, accurate information about the number of tools and state and repair of toolholding systems for support purchasing decision is an arduous task. Also the activities of the technical area in machining tooling management should consider two types of items: the perishable and toolholding systems. Among the perishable items are inserts, drills, solid mills, reamers – which after a certain cutting time should be disposed or resharpened. Toolholding systems are the fastening of tools like toolholder, extensions, reductions, collets, lock screws and washes. These items have long lifetime since they are properly stored and identified. The toolholding system represents the second largest investment at the time of initial use of the machine tool (STEPHENSON and AGAPIOU, 1997).

Several researches deal with the machining tooling management of perishable items at Brazilian manufacturing environment. Zonta Junior (2007) analyzed the market in order to understand the techniques and trends used. The results showed that the main focus is on logistics planning - which has been treated as outsourcing or application dedicated software. Another relevant point is the lack of technical information on the subject, especially those relating to machining parameters, reasons for failures of tools and unavailability of tools in a productive environment. Favaretto (2005) identifies, in the automotive segment, lack of flow standardization (tools and information), tests for damages detection and analysis of undesirable machine stops. However, two interesting topics identified by the research are high inventories of tools - higher than necessary – and limited standardization of tools in terms of the absence of reliable data base. Matoso *et al.* (2003) defined and implemented a methodology of tooling management based on the Toyota Production System. Among the interesting features of the research are the visual control of the tools, determination of flow for the tools, the definition of three sets for each tool and absence of control based on paper at the manufacturing environment.

Modern machining centers are capable of dozens of tools in the magazine, which require high initial investment with toolholding system (up to 20% of machine tool value). In a manufacturing environment with tens or hundreds of machine tools, the amount of toolholding items needed becomes enormous. Another aggravating factor is that the tooling can be shared by multiples machines tool, which on the one hand, allows a reduction in the inventory value; and other hand, increases the complexity of management tools. Typically, in companies with large number of machine tools, it is implemented a sector responsible for storing, analysis, assembling and making available tools for each preparation machine needed. However, as identified in the literature, this sector still requires stronger integration with the technical and the strategic areas of the company in order to increase efficiency avoiding obsolete items, minimizing the amount spent on inventory and reduce the preparation time for machines. To achieve this goal, machining tooling management needs to consider toolholding items in a manufacturing environment.

The objective of this research is to determine and test a methodology in the manufacturing environment in order to enable the traceability of toolholding items with the assistance of a computerized system that provides information about quantity, interrelation, location and condition of items. Thus, it is necessary to define a methodology for identifying, engraving, reading and transfer of information to a database and a data flow drive.

2. METHODOLOGY

The methodology determination and shop floor tests for machining tooling management of toolholding systems focuses on a company from automotive segment with a number of machines centers over 130 units. Due to the quantity of tooling to support machines centers, this research was carried out experimentally in a specific area of the company in order to facilitate understanding and monitoring of the results. Based on preliminary results, the project will be replicate for the entire production environment.

In order to explain how the system works currently, it is described the procedure of machining tooling management, considering the toolholding systems. Initially, based on production order of a certain product, all tools and toolholding systems necessary - defined by the process engineering - are listed on working procedures at tool preset sector. With the mentioned information, it is taken the components, for each set of tools, in a stockroom. All components must be found out by the operator. The assembly information (e.g. overhang and position of the toolholder in the magazine) will be available on a paper file. After the parts assembled, the operator prints labels with the required information in machine-tool and send the toolholding systems to the production. After closure of the production order, all sets of tools are removed from the machine tool and they follow to the tool preset sector. This sector is responsible for damage analysis, disassembly and storage in the stockroom. At this point, it begins a new cycle.

Several shortcomings are identified in this procedure. First, there is no inventory control, which causes lack or obsolete toolholding systems in manufacturing environment. Second, toolholding assembly mistakes are common by the absence of updated drawings or misinterpretation of information. Third, there is no control how much each toolholding system was used and how many systems are available for new process developments.

It was planned is a new control system for toolholding with the purpose to minimize the shortcomings mentioned. The activities for carry out were divided into six phases: *i)* identification and interrelation of the components; *ii)* definition of the engraving information in the components; *iii)* engraving method in the components; *iv)* definition of the engraving location in components and support device; *v)* definition of the reading system of engraving information; *vi)* definition of information flow for data management. Moreover, the machining tooling management methodology of toolholding system should attend restrictions in order to optimize the system performance: a) whole process must operate with electronic information - no information on paper; b) information should be available for all areas involved (technical, logistical and strategic), despite restrictions modification of information by area; c) codes engraved in each component should not influence on static or dynamic runout; d) in cases the availability of more than one toolholding system, has priority the older in order to minimize the inventory; e) it must occur the liberation of the set of the tool after identification of all components listed by the electronic platform.

Two components are keys to the machining tooling management: the tool (perishable items) and the toolholder (toolholding system). Toolholder is the key element for toolholding system because it is the element of connection between the machine and tool. Therefore, the toolholder has two interfaces of connection: one with the tool – which uses systems based in collet, screw (weldon), hydraulic and shrink-fit; other with the machine tool – which uses a tapered contact interface. Toolholders also may have different types of interface with the machine tool and various sizes for the same model. In particular, the toolholders that fix tools by shrink-fit have a number of assembly cycles - heating and cooling - as the criterion recommended by the manufacturer for disposal. The number of assembled cycles is a variable of difficulty control in the manufacturing environment. For this reason, the shrink-fit toolholders are the items to be discussed during the implementation of the machining tooling management of toolholding system.

3. RESULTS AND DISCUSSION

The implementation of tooling management of toolholding systems in manufacturing environment was carried out with the adoption of the sequence of proposed activities in the methodology and considering the constraints. The six phases are described below.

3.1) Identification and interrelation of the components

Based on production order of a certain product and, therefore, in the list of necessary tools, the responsible for management tools sector should take the toolholders needed in a stockroom. Every tool used in machining is associated with a type of toolholding system. This stockroom is organized with the technical LIFO (Last In First Out). The use of the technique LIFO enables old toolholders are used more frequently in order to accelerate the wear in older devices. The adoption of this technique fulfills the constraint "d" in order to contribute to the understanding of the need for each type of toolholding system and minimize inventory.

With the electronic reading of a code on the surface of toolholding system - which will be described later - identifies the others required components and access to assembly drawing on the electronic platform. The other components are also found in the stockroom and they use the same technique of organization (LIFO). With information from the electronic assembly drawing, it is possible to perform the assembly of tool in toolholding system. Later, it was release the toolholding system to the carrier, which leads the tooling in the machine tool. The final liberation of the tooling only after the electronic reading of all codes needed. The objective is to avoid lack of tooling in new component preparation for production, and register the number of assemblies performed on each toolholding system. In addition, position information of the tool at magazine of machine-tool and data adjustment offset - which are specific to each assembly - are also available in the electronic system.

Since there are dozens of machine tools in manufacturing environment, it is necessary that the toolholding systems are interchangeable and, wherever possible, with the same interface with the machine-tool and tool. The determination of the minimum types of devices is a critical task, as it also is dependent of the production demand. The reading system and electronic access to computer drawings are intended to meet the constraint "a". For new developments, updated information about the amount of tooling available to the technical and logistic in order to support decisions purchase new items. However, for the efficient operation of the system, the engraved information in the toolholding system should support the decisions mentioned. This information is described in following section.

3.2) Definition of the engraving information in the components

In order to access the assembly information, the sum of two electronic readings should be performed: the tool and the toolholder. This is due to the possibility of a tool, e.g., an insert type could be assembled in different toolholding systems. Regarding the toolholder, the information required are: code, assembly drawings and estimated lifetime.

Toolholder information refers to the type of interface with the machine tool (e.g. BT, ISO, HSK), size (e.g. ISO 30, 40 or 50), interface with the tool (e.g. collet, screw - weldon, hydraulic and shrink-fit) and serial number of the toolholder for the same specification (e.g. 1, 2, 3). The other information required for engraving is the product line that toolholder was originally purchased. Although the toolholding systems can be used in various products, the understanding of the sectors with higher and lower investment is critical to the strategic area of business. The original identification of the product line so that the item is intended promotes an easy access to this information. Finally, the estimated lifetime for each toolholder is important information, especially in the case of shrink-fit, which have a maximum number of assemblies suggested by the manufacturer and possible damages to the cutting edges or machine tool may occur in due to inadequate fittings.

Information such as length and diameter for assembly, products, machine tools, operations and drawing codes are accessed only after reading the code. Furthermore, this information can change over time - with the addition or removal of a product, machine or operation - and it will be updated only in the electronic system. Another important point to note is that the smallest amount of information should be engraved on toolholding system in order to make the small symbol. The types and engraving methods are points discussed in the next section.

3.3) Type and engraving method for toolholding system

Bar codes were the first option when thinking about an engraving type to identify components based an electronic system. However, there were many types of engravings for bar codes. Importantly, the bar code must be alpha-numeric in order make feasible the engraving of the information listed previously. Two initial options were evaluated: linear (1D - code 128B) and two-dimensional (2D – Data Matrix) symbols. Aiming to show the features, the Fig. 1 shows an engraving of the same text using codes mentioned.

1a – 128-B Barcode

1b – DataMatrix Barcode

Figure 1. Barcode examples for the same information (ISO 40 shrink-fit 10 serial 1)

According to Fig. 1, the linear code (128-B Barcode – Fig. 1a) has a rectangular shape with a length greater about five times the height. On the other hand, two-dimensional code (Data Matrix – Fig. 1b) has a square shape and a smaller area than the linear to represent the same information. Data Matrix code can store up to 2,335 alphanumeric characters. The shape and the footprint for the same information were decisive factors for the choice. The goal is to use a bar code with the smallest area possible and adjust to possible places in the mechanical component. For the reasons mentioned, the Data Matrix code was used in this research.

Another fundamental point to the research implementation was the engraving method. The bar code should be permanent and it can not influence the performance of the component on static or dynamic runout (as mentioned in constraint "c"). Based on the literature, three methods were identified as potential for bar code engraving on steel surfaces: electrochemical corrosion, micropunching and laser beam. Details of each method are described below.

The electrochemical corrosion uses a low voltage and a template that allows the electrical current flow only in specific areas where is needed to engrave. Two points become critical for this type: the need for template with information and clarity of the engraving. The template shapping for each engraving type would promote additional time for each component beyond discard after use, because the bar code is unique for each component. The electrochemical corrosion engraving is more appropriate in situations that the same information is often engraved in different components. The time required for this engraving and the templates discard after use were not desired by the company. Regarding the engraving clarity, the electrochemical corrosion presents difficulties for reading over time because it is very superficial (usually 3 to 5 μm), according to previous experiences of the company. These were the reasons for discard referred method.

The micropunching consists in the use to a small pyramidal punch with high hardness (usually manufactured in cemented carbide) to make the code engraving by mechanical deformation of the component surface. The punch drive system is electromechanical what makes the engraving fast and without templates. The depth of the engraving is larger than the electrochemical corrosion method. Typical values for depth of micropunching are between 20 and 80 μm. The system cost is another advantage of this method because it is the cheapest among the three analyzed. However, two difficulties were identified: the hardness on the mechanical component surface and the engraving geometry. The mechanical components intended for toolholding system usually have hardness greater than 30 HRC, which makes surface deformation extremely difficult task. Another detail is that the geometry of the micropunching engraving is not absolutely square. The corners should be rounded to avoid nucleation and crack propagation. This fact hampers the optical reading, as it will be describe later.

The laser engraving consists of a non-contact method in which a focused laser beam transfers energy to a surface region. The local absorption of energy leads to a localized increase in temperature followed by phase transformations (melting and evaporation), in which the local material is removed (Dumitru et al., 2005). There are different sources to laser beam energy, however for the use in steel, the highest rates of absorption occurring with beam based in CO_2. Additionally, this is also the cheapest source and widespread in the industry. Depth values can be adjusted depending on process parameters. According Lamikiz et al. (2005), values of depth up to 20 mm are achieved in steel without the need for high energy levels.

With two engraving methods in potential, the company decided for carrying out tests to understand the behavior of each method. Figure 2 shows the Data Matrix code engraved with the micropunching and laser beam performed on a toolholder surface.

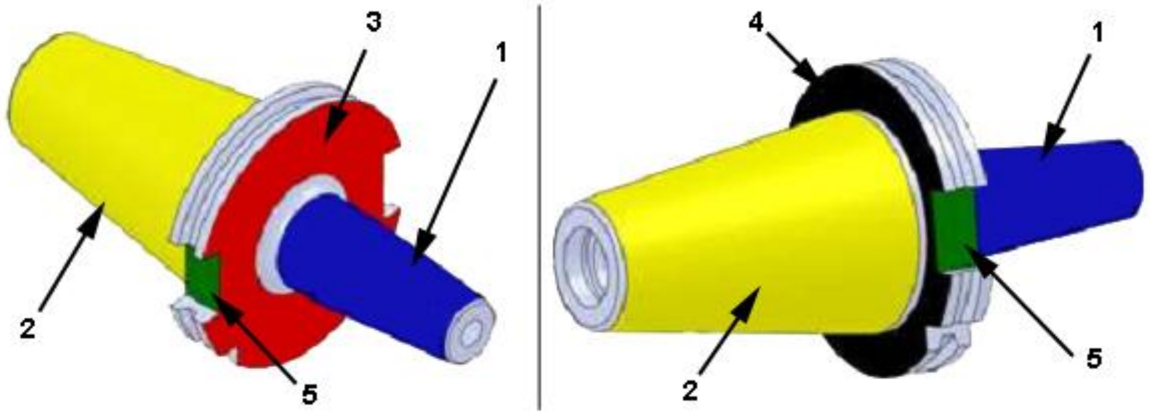
2a – Micropunching engraving 2b – Laser engraving

Figure 2. Data Matrix code engraved with the micropunching and laser beam method on toolholder surface

As can be seen in Fig. 2, with both engraving methods, they have become possible to define a clear picture to human eyes, which does not imply in an easy reading to optical system. In parallel, in order to facilitate the understanding of the test, the random code text (BGM 1234) was also engraved next to the engraved Data Matrix. As mentioned earlier, it can see in Fig. 2a, micropunching promotes the pyramidal geometry with rounded corners. On the other hand, as seen in Fig. 2b, the corners of the geometry in the laser engraving have sharp edges. However, the two key points to define the best engraving method were: feasibility to engraving in the desired area and the ability to optical reading. These points are discussed in items "3.4" and "3.5" sections.

3.4) Place and the engraving support device

An analysis of the geometry of a shrink-fit toolholder - initial focus of research - shows five potential regions for engraving the barcode. Figure 3 identifies each toolholder regions.

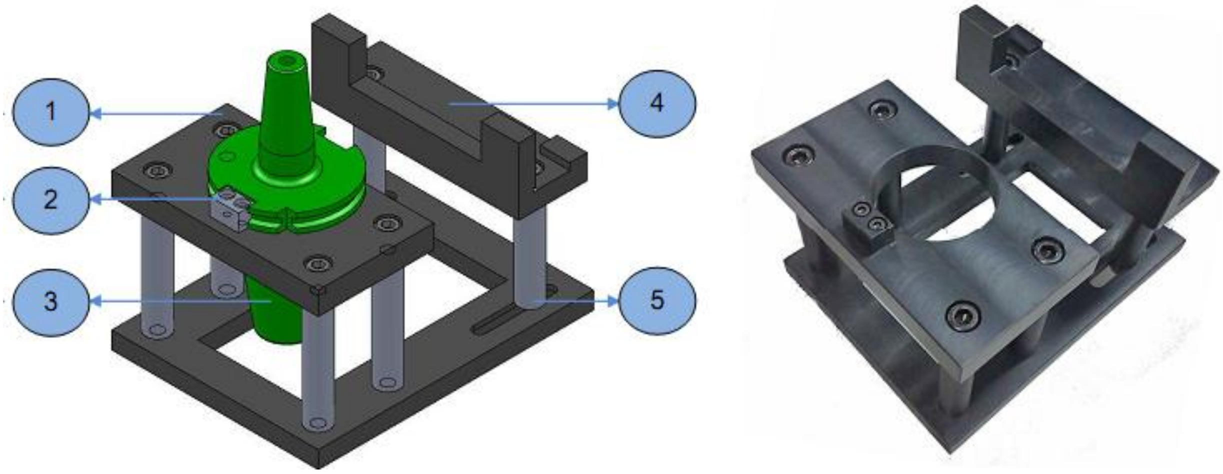


3a - Front View 3b - Back View

Figure 3. Shrink-fit toolholder regions with potential for engraving the Data Matrix code

According to Fig. 3, the region 1 (blue) needs an engraving in a conical surface. The engraving in surfaces like this becomes more difficult when compared to flat surfaces. Others two drawbacks are: a) this region is warming and cooling during assembly and disassembly of tools, which can distort the engraving; b) this is not a region common to all types of toolholders, which in a future time may promote difficulties with the expansion of the method for all toolholding systems. Region 2 (yellow) also presents conical surface, but the drawbacks with temperature variations and differences between toolholders are not present as in the previous case. However, the limiting factor is related to the contact of this region with the spindle of machine tool and any change in surface can damage the stability of the machining process. The region 3 (red) in shrink-fit toolholder is a good option for engraving Data Matrix code because is a flat surface. However, in other toolholders types, this region has different geometries besides be difficult access to an engraving system. Region 4 (black), although geometrically similar for all toolholders types and to be a flat surface, also presents the difficulty of access to an engraving system. Another point of difficulty is that this region is used as reference toolholder during assembly, and contact with other surfaces can distort the engraving. Region 5 (green) is also a flat surface, has no contact during assembly and machine tool in addition to the protection offered by geometrical reentrancy. Even the engraving can be done on both sides toolholder, thus avoiding possible static or dynamic runout. Thus this was the region chosen to carry out the engraving identification code.

Another challenge for the code engraving was to development of a mechanical device that supports engraving code on the chosen region of the toolholder. Note that device design should be modular in order to consider the different types of toolholders (BT, ISO, HSK) and their different sizes. Figure 4 shows the device designed.



4a – Conceptual design 4b – Manufactured modular device

Figure 4. Modular device to support the engraving of the Data Matrix code

As can be seen in Fig. 4, the modular device design involves 9 pieces and 14 screws. This device allows all types toolholders mentioned previously are engraved, although at research stage only the shrink-fit toolholders are considered. It is noteworthy that the part number 4 in Fig. 4a is the support to the engraving head and its attachment is adjustable to promote the engraving with the micropunching as well as laser system. Figure 4b shows the manufactured modular device. Therefore, from the viewpoint of the toolholder engraving place and the device for micropunching or laser, the same device can be used. Thus, the definition of the better engraving method depends only of the reading system in each type. This approach is carried out in the next section.

3.5) Definition of the reading system

Identification code (Data Matrix) reading of each toolholder was performed with a system based on portable optical readers. The system allows the reading is performed at a relative distance of the engraving. This aspect facilitates the reading process because the reader moves while the toolholder is on the table installation. Readers assembled at fixed points (readers of table) were not adopted due to the difficulty of reading on specific components of toolholding system. Thus, reading tests were carried out with that system. Figure 5 visualizes the operation of code reading.

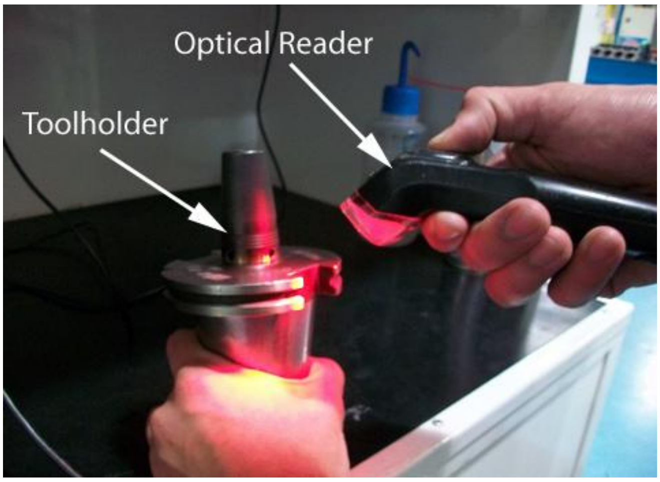


Figure 5. Portable optical reader for data matrix code

As shown in Fig. 5 for to performed the reading, it is only need to position the focus of an optical reader on the engraving place and press the button at the top of the equipment. Thus, the reader software interprets the engraving and provides the information available in digital format. With the aid of software - created by the corporate IT team - information is available in the electronic system.

Regarding the reading tests, the differentiation criterion between the engravings is the amount of attempts to provide the information in the software. After numerous systematic engraving reading tests, similar to those showed in Fig. 2, the results indicated that it is easier to perform reading code such as engraved by the laser method. However, engravings made with micropunching could also be read, but in most cases, more than one attempt to read needed to be done. Thus, the engraving method chosen by the company was the engraving laser.

Therefore, it was developed for tooling management of toolholding systems items in an industrial environment, the identification and interrelation of the components, definition of the engraving information in the components, a type and engraving method for toolholding system, a place, the engraving modular device and a reading system. This shows the feasibility of the implementation of methodology. However, the modes how the items relate information and are provided for areas of the company are the key element. This point is demonstrated in the next section.

3.6) Definition of information for data management

The user interfaces for machining tooling management of toolholding items have been developed by corporate IT team and considered the integration of three areas: technical, logistical and strategic. However, a sub-division of the technical area needed to be done: process engineering and manufacturing environment. The justification for the division is that there are different needs between these sub-areas, because while the process engineering registers and defines drawings, the manufacturing environment uses these informations and reports production data. Another important aspect at this stage is that the information in software could not be redundant and each update by an area should reflect to the others areas to satisfy the constraint "b".

Therefore, it was created 8 interfaces for registration and access to information in the software. Table 1 shows the interfaces name, information and access permissions for each area.

Table 1. Information to support the creation of the tooling management of toolholding interfaces software

Interface	Informations	Company Area	Access Permission
General information	Code, quantity, serial numbers, acquisition date, estimated lifetime	Technical – Process Engineering	Creation and modification
		Technical – Manufacturing Envir.	Reading
		Logistical	Reading
		Strategic	Reading
Drawings	Items needed for assembly, assembly dimensions and review date of the drawing	Technical – Process Engineering	Creation and modification
		Technical – Manufacturing Envir.	Reading
		Logistical	Reading
		Strategic	No access
Code reading	Form to optical reading (tool and toolholder)	Technical – Process Engineering	Reading
		Technical – Manufacturing Envir.	Creation and modification
		Logistical	No access
		Strategic	No access
Liberation and receiving of tooling sets to machine tool	Date, time and quantity of delivered tooling sets according to production order	Technical – Process Engineering	No access
		Technical – Manufacturing Envir.	Creation and modification
		Logistical	Reading
		Strategic	No access
Maintenance status	Physical status of each item, maintenance carried out, justifications and utilization historical	Technical – Process Engineering	Reading
		Technical – Manufacturing Envir.	Creation and modification
		Logistical	Reading
		Strategic	No access
Request for toolholding	Code number, quantity, date, responsible and justification	Technical – Process Engineering	Creation and modification
		Technical – Manufacturing Envir.	Creation and modification
		Logistical	Reading
		Strategic	Creation and modification
Investment	Cost of each component, justification and the sum by product line	Technical – Process Engineering	Reading
		Technical – Manufacturing Envir.	No access
		Logistical	Creation and modification
		Strategic	Reading

Interface	Informations	Company Area	Access Permission
Minimum stock and suppliers of toolholding	Minimum amount of stock for each item and the main suppliers	Technical – Process Engineering	Reading
		Technical – Manufacturing Envir.	No access
		Logistical	Creation and modification
		Strategic	Reading

It is not the aim of this paper to discuss the programming language used to create the database management tools, since different platforms are available on the market. Similarly, characteristics of each screen can be customized by developers and does not apply to this scope.

As seen in Tab. 1, the process engineering area is responsible for defining, creating and modifying the general information (e.g. code, quantity, serial numbers, acquisition date, estimated lifetime) addition to providing assembly drawings (electronic) used in assemblies. At first, as there are numerous components in a manufacturing environment, an activity must be performed in conjunction with the manufacturing environment area in order to support the creation of the database. Also, the requisition of new of new components is the responsibility of the process engineering. On the other hand, in the aim of support the design of new processes, process engineering has access to reading the information of the tooling physical state in a manufacturing environment. The responsibilities of the technical area in the manufacturing environment are to support the database in write code for the tooling (following the criteria), release and receive the tools used in each production order, evaluate the tooling physical condition after the process. However, it is necessary to have reading access in interfaces as general information, drawings and tooling required. The logistics area support to the database with information on tooling cost and the total investment by product line. Moreover, the strategic area shall approve the requisitions performed to purchase new tools based on database available information.

After a certain running time management tools, it becomes clear the possibility to understand the presence of obsolete tooling, avoid redundant information, reduce inventory, minimize the investments when purchase new machine tool and enables focus on critical points, even in the face of production variations

4. COCLUSIONS

Based on the results obtained during the development of methodology and experimental tests for tooling management items in a manufacturing environment, it can be concluded that:

a) using a engraving method based on laser beam and 2D bar code (Data Matrix) enabled the identification of the tooling in a place without impact to the machining process;

b) optical reading system based on portable readers integrated with a specific software promotes reading and tooling identification without the need for paper documents, which avoids the redundancy of information;

c) the adoption of a specific program for tooling management using the computer network allows the company to provide information to interested areas (technical, logistical and strategic) to form quick and agile;

d) the use of tooling management for a certain time allows to understand the obsolete tooling, avoid redundant information, reduce inventory, minimize the investments when purchase new machine tool and enables focus on critical points, even in the face of production variations.

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