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Machining Operations for Components in Kitchen Furniture: A Comparison Between Two Management Systems

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Abstract

A comparison between two machining of pieces management systems for the manufacture of kitchen furniture is presented. These pieces are characterized by having a morphology based on cuboid shapes and therefore defined by three variables: height, width and thickness. The first management system (type A) is based on the total machining of the pieces in a single process that uses boards of different raw materials (agglomerate, plywood, MDF, etc.). This is done in a single work center cutting the pieces as well as most of the holes necessary for the final assembly and the placement of hinges, handles and other fittings depending on the type of module. In the second system (type B) the process is done in two stages: the cutting of the pieces in the work center described above and the final finish prior to assembly in another work center. This investigation delves into a fundamental part of the process analyzed in a previous investigation in a Galician kitchen furniture manufacturing company. The goal is to demonstrate that the two stages system is the most suitable for a manufacturing characterized by a low standardization and the ability to meet orders with special modules with a customized manufacturing and therefore for the current production system in that company. The main results show that the second system is better: the total machining time used is 38% lower and the development time of machining programs for special parts (non-standard) is reduced to one third in type B system. As a main conclusion in this specific case, it is highlighted that the separation of cutting and machining operations improve productivity and flexibility especially in regard to setup times.

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Keywords: kitchen furniture; modularization; CAM; standard data

1. Introduction

Several studies have contributed to increase manufacturing productivity, reduce work-in-progress and decrease idle time [1] or [2] or to avoid of operators´ mistakes concerning the rejection of the finished product in kitchen cabinet manufacturing facilities [3]. Also modularity is becoming a focus because companies strive to rationalize manufacturing and design processes [4] or [5] or [6].

Next, the study developed in a Galician kitchen furniture manufacturing company characterized by modular manufacturing is shown. The results presented complement those obtained in the first phase of the project [7].

The manufacture of kitchen furniture is a complex process that may require different types of information systems for its management. This is because the production process is characterized by having product structures that serve an X shape with a wide range of raw materials and finished products and a small number of standard modules. In most of cases "kitchen unit manufacturers make standardized bodies to which a wide range of doors and fittings can be attached. These standard modules are represented by the cross of the X. They are combined with a customized selection of features and options, giving a wide range of finished products" [8]. The different X shape structures, with more or less raw materials or final products, depend on the degree of standardization of the offer. On the other hand, these structures allow a sensible reduction of stocks without giving up a competitive lead time.

The firm uses a Dynamic Structure Parametric Bill of Materials (DSP BOM) [9] in a semi-automatic MRP software. This generic BOM enables the management of all product variations by designing a single BOM pattern [10]. A new Bill of Materials (BOM) is created for each order line.

The production management process begins with the reception of a customer's order. Once confirmed, material requirements planning (MRP) is carried out, which, among its main outputs, produces the list of components necessary to assemble a kitchen cabinet. These components are the level 1 products in the bill of materials (BOM) that will be necessary for the assembly and, therefore, the obtaining of the final product that is the cabinet (level 0). The vast majority of modules present a similar structure in terms of the type of level 1 components that are necessary. These level 1 components can be sides, shelves, backs and fronts. In Figure 1 the levels 0 and 1 in a BOM of the generic reference ALTO 50I H45 FMA and an example of kitchen cabinet part names are shown.

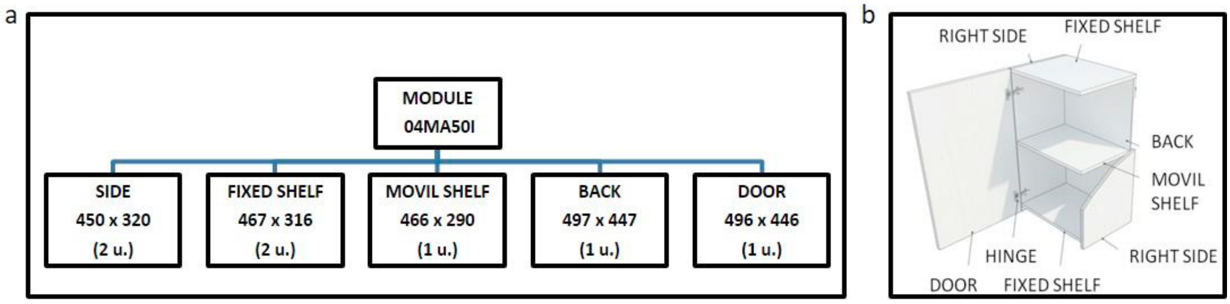

Fig. 1. (a) Example of furniture module BOM detail (levels 0 and 1); (b) kitchen cabinet part names.

The management process key point lies in the manufacture of the level 1 piece. In addition to determining the raw material and the dimensions of the pieces, it is necessary to determine the specific machining program that it requires. Once manufactured, the final assembly phase is executed. It does not present much complication in terms of manufacturing although its control is vital. This is because the absence of a single module in a kitchen can delay the delivery of a complete order. The main objectives of this project are improvement of cutting, milling and drilling of components operations management system, improvement of processing times including setups and reduce the development time of machining programs.

2. Manufacturing management systems

The manufacture of the level 1 parts described above follows a production process that is based on the cutting of a cuboid shape structure in which the thickness is fixed by the raw material. The other two dimensions (height and width) are the key elements in the cut as they define the final measurement of the piece. The different pieces are cut from boards of different sizes and the height and width are not interchangeable in the case that the raw material has vein. Figure 2 shows the 4 stages in the management of these components: definition of measurements and materials in the MRP, distribution of pieces by type of raw material board to cut, drilling and milling of parts and final assembly. After the MRP explosion process of materials, all the level 1 pieces (of different furniture and orders) that use the same raw material are grouped to be subjected to a process of nesting that optimizes the use of the board so that the residue is minimized. As can be seen in the drawing showing the partition of the board, the existence of vein in the board does not allow the alternation between width and height of the piece.

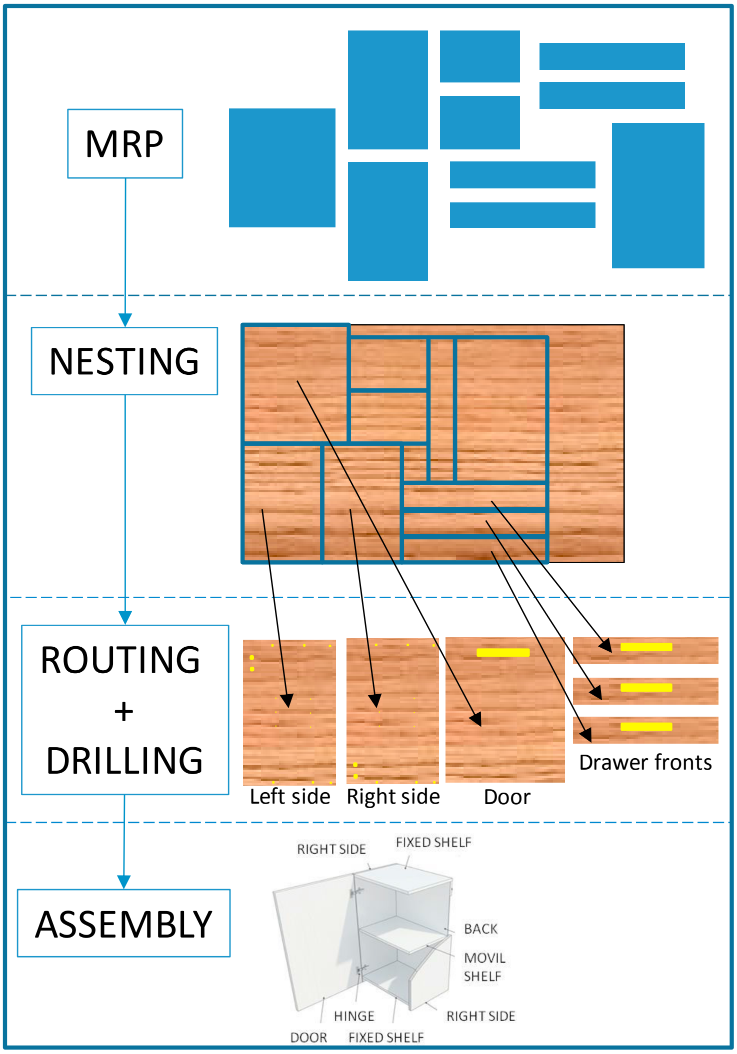

Fig.2. Main stages in level 1 component management

The number of pieces with which the process is carried out directly influences the use of the board (around 80% when the number of pieces is reduced and more than 90% when it is larger). This shows that the standardization of raw materials already offers a significant advantage in cost reduction since it increases the number of pieces. It is also noteworthy that when you cut a few pieces of the same board generates a new process of management of off-cuts that poses an added problem.

The process is done using CAD/CAM tools. The nesting phase is done with the help of a board surface optimization software (BSO) and a cutting programs generation software (CPG) according to the type of piece and material. Before that, a custom database application (MBI) collects the list of materials generated by the MRP and orders the parts according to different criteria: raw material type (melamine, veneer, plywood or agglomerate), the type of the Level 1 part (door or part of the hull) and kitchen model. This operation allows you to send a *. txt file automatically to the BSO software in which, in addition to the parts list, with its particular characteristics of measurement, model, material, etc., if necessary, the specific program of drilling and milling of the piece. Figure 3 shows the main information flow between software tools and machines. As previously commented a text file is sent to the BSO application that makes the distribution of the pieces issuing as many manufacturing orders (joblists) as boards are necessary. In addition, a label is also specifically generated for each piece, which will be automatically placed before the machine is run. This operation is necessary because the label itself acts as a manufacturing order when certain specific operations are required in the post-machining parts (edging, gluing, varnishing, lacquering...) or as the identifier of the module to which it belongs the part that is necessary in the picking process prior to the final assembly.

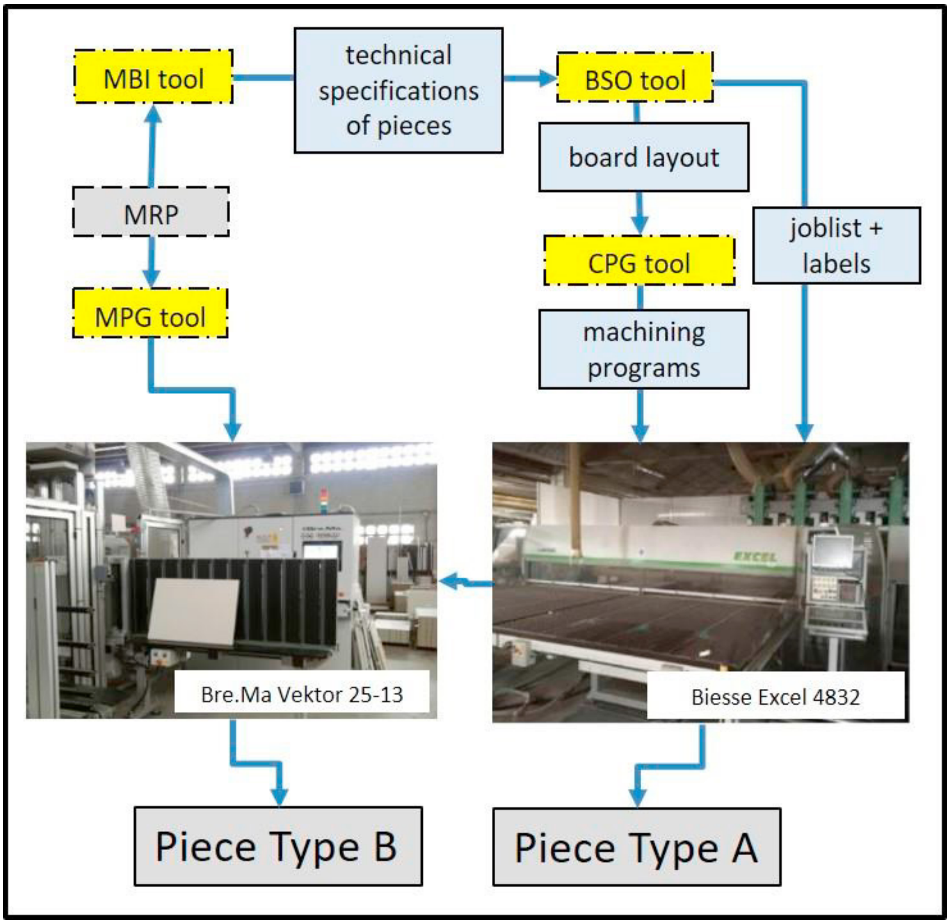

Fig.3. Main software and manufacturing tools in level 1 components management

At this point, the system has two alternatives that coincide with the two management systems subject to analysis. In the first one, called Type A, the piece is fully mechanized in a CNC machining center with a vacuum pump clamping system with sacrificial material or martyr (Biesse Excel 4832 Router). In the second, type B, the piece is cut in the previous system and is subsequently subjected to specific machining in a vertical CNC machining center (Bre.Ma Vektor 25-13). The following are the differential tasks followed by the two systems.

Type A:
- CAD_A1: Part cut program design (using BSO and CPG)
- CAD_A2: Design of Part differential machining program (using CPG)
- CAD_A3: Modification of CAD_A1 according to CAD_A2 (using BSO)
- MAN_A: Cutting and Machining program execution (using CPG)

Type B:
- CAD_B1: Part cut program design (using BSO)
- MAN_B1: Cutting program execution (using CPG)
- CAD_B2: Design of Part differential machining program (using MPG)
- MAN_B2: Execution of machining program (using MPG)

Figure 4 shows the flow diagrams corresponding to both systems in which the design process and the assignment of the cutting and machining programs according to the different CAD-CAM tools are shown.

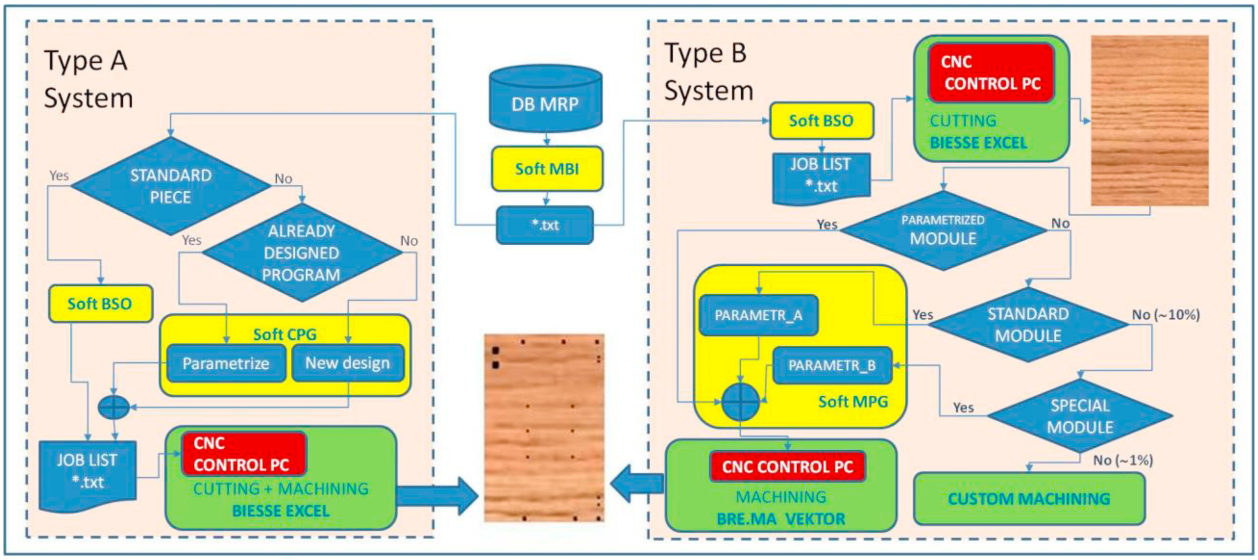

Fig.4. Type A vs. Type B systems

In the same figure, an example of a finished part is shown. It is a side of cabinet that incorporates 1 movable and two fixed shelves and a door with two hinges. This side has group of 6 diameter 5mm drills for the positioning of the supports for the mobile shelves, two groups of 3 diameter 8mm drills for the fitting of the dowels for the fixed shelves, two groups of 2 drills of 8mm diameter for the placement of the hinge bases, a group of two 10mm diameter drills for placing the furniture hanger and optionally a milling for certain models (using special handles).

Using the Type A system, the MBI software would generate a text file that would feed the BSO application and propose a job list that will include the side to be cut. Due to the characteristics of the cabinet of which it is part, the groups of drills are assigned by a specific machining program designed with the CPG application (in case that piece had already been manufactured, the program would already be designed) that would be indicated to the BSO application. Then BSO through CPG send the modified job list to the control pc of the Biesse Excel machining center where the piece would be finally manufactured (cutting and machining process). Using the Type B system, the process is similar with regard to the execution of the cutting in the Biesse Excel machining center, except that there is no need to indicate the machining program. Once the piece is cut, it is finished in the vertical machining center Bre.Ma Vektor. The MRP database itself contains the necessary information for the MPG application to select the machining program (only about 1% of the parts can´t be machined due to their special characteristics).

It can be seen that, independently of the chosen system, the cutting and machining operations involve two different parts, the preparation time and the operating time. In the analysis proposed below, these times are differentiated according to the management system used.

3. Case analysis

For the comparison, the real production is considered between January 2015 and September 2016. The total amount of manufactured parts is 42,944 units. Figure 5 shows the distribution of parts by type.

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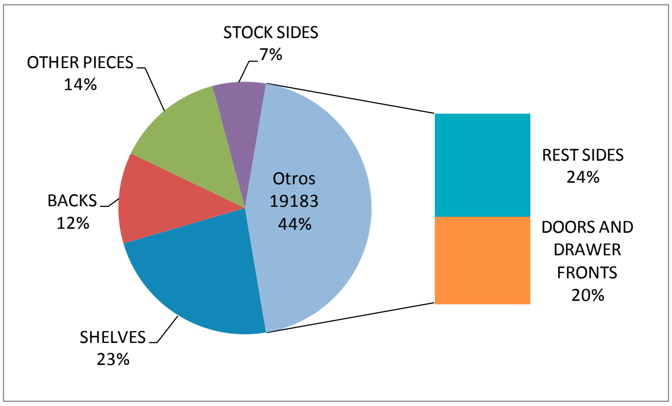

Fig. 5. Piezas fabricadas durante el estudio

Only the sides and doors were included in the study, because they are the pieces that need to be cut and also machined on their inner and / or outer face to be able to insert the necessary fittings, handles, etc. in the final assembly. Of these, a significant amount of cut sides that are acquired from an external supplier have been rejected and therefore they do not follow the cutting process (called stock sides and which are managed through a kanban system). Neither has been considered certain types of fronts (strips and showcases) that by their special dimensions also do not follow the standard cutting process. The rest of the pieces (shelves, backs, etc.) can´t be machined in the Biesse Excel pantograph since they have holes in the edge and / or through holes that would damage the martyr or sacrificial material with the consequent loss of strength in the vacuum system.

The method followed in the research is based on a time study using standard data technique [11]. The job a work study person is made much easier if a set of data were to be available from which standard times could readily be derived for these common work elements without necessarily going into the process of timing each one. The standard data bank has been obtained using two complementary ways so that a specific manufacturing time is assigned according to the piece: by means of simulation using CAD tools (NC-Studio and Edicad) and from the manufacturing control system of the company. These standard times would include both the setup time and the operation time.

Due to the great variability in the type of machining (milling and drilling) the standard data bank has been established for 12 groups of parts. These groups depend on the cut made (cutting nesting, piece by piece special cutting and cutting with flipping of the board) and the complexity of drilling and / or milling (D/M I and D/M II), It is considered that D/M II pieces are more complex than D/M I. Table 1 shows the estimated total times for each of the selected groups of pieces for the total pieces of the sample.

The initial number of pieces of the study (19,183 units) has been reduced because not all of them are capable of being machined according to the Type A system (approximately 30% of them can´t be compared).

In addition to the execution and setup times, qualitative [12; 13] reasons have been considered for functionality, flexibility, occupational health [14] and absence of errors.

Table 1. Estimated total time (minutes) according to the group of pieces.

	Type A machining		Type B machining	
Type of Cutting	D/M I	D/M II	D/M I	D/M II
Nesting cutting	11742	7891	7657	3713
Special cutting	5631	2061	4803	1619
Cutting with flipping of the board	not applicable	5797	not applicable	2576

The main results obtained are:

- The total machining time used, using the Type B system is 38% lower.
- the development time of machining programs for special parts (non-standard) is 325% faster in the type B system (in addition machining is not possible only in the Type A system in most of them)
- In the period under consideration, no incident / accident has occurred, so none of the systems is considered preferable in aspects of occupational health and safety [15].
- No influence was seen in the comparison depending on the type of raw material.
- The use of the mirror image in the design of machining in the Type B system improves the quality of the sides (possible errors are absorbed in the final measurement of the piece). Although the dimensions are within the tolerance margins in both systems, a greater precision is observed in the B-type system although it has not been controlled quantitatively

The two systems comply with the rules on product quality [16, 17] and also, the rules on the environment [18, 19, 20]. However new ideas [21, 22] are always welcome, in a time when consumers are increasingly demanding [23, 24] looking for a better quality of products and life life [25,26,27], with more education [28].

4. Conclusions

A comparative study of two component manufacturing systems in an SME manufacturing kitchen furniture has been presented. Both systems use a common CNC machining center to perform the cutting of parts and use alternative systems for the rest of machining operations (drilling and milling).

The results obtained in terms of process times indicate a significant improvement in separating the cutting and machining operations. Flexibility also improves with the use of the separate system (the parametric system used reduces the preparation time of machining programs). This is basically due to the fact that type B system allows to introduce last minute modifications in the machining operations (even once the cutting operation has been carried out).

Another of the advantages detected are the improvements in terms of reliability and absence of errors. This is due to the fact that the machining programs for non-standard parts in type A system require a custom programming process that could generate errors.

The main disadvantage is the necessary investing cost in two machining machines instead of one. However, the amortization cost in the case of the analyzed company is practically compensated with the saving of personnel. Neither is design knowledge necessary in the operators in charge of carrying out operations, which improves the staff's versatility index. Therefore, it can be concluded that the Type B system is better than Type A.

As a final reflection, it can be said that for a repetitive manufacturing of the same piece, the manufacture in a single step is more convenient because although the setup time is longer, it is distributed among a greater number of pieces. However, when there is a lot of variability in production and changes can occur that require greater flexibility, it is more convenient to separate the process into two stages.

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