Detailed Design of Product Oriented Manufacturing Systems

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ABSTRACT

This paper describes a procedure for the detailed and repetitive design of manufacturing systems within an approach of constantly fitting production system configuration to the varying production needs of products and, therefore, designing Product Oriented Manufacturing Systems – POMS. The detailed design procedure depart from a set of conceptual manufacturing cell configurations and develops from there, through conceptual cell and workstation instantiation, with basis on available methods, the required manufacturing system and control mechanisms for a product or a family of similar products.

1. INTRODUCTION

Product Oriented Manufacturing Systems (POMS) are integrated manufacturing systems based on manufacturing cells and other manufacturing units or resources.

Traditionally a manufacturing cell has been identified as a system dedicated to the manufacture of a family of identical parts. The manufacture based on a setting of such cells is usually referred to as Cellular Manufacturing. A more comprehensive definition of a manufacturing cell points to a manufacturing system that groups and organizes the manufacturing resources, such as people, machines, tools, buffers, and handling devices, for the manufacture of a part family and/or the assembly of a family of products with identical or similar manufacturing requirements. Cellular manufacturing aims at economies of scale through economies of scope, i.e. through increased variety of products manufactured in the same system. This approach of identical or similar processing of similar objects is known as Group Technology (GT) (Gallagher, 1973). It is for this reason that manufacturing systems based on cells are frequently associated with GT.

Although Cellular Manufacturing System (CMS) can have a beneficial impact on manufacturing operations of an enterprise, the full benefits of such product-oriented approach to production can only be realized when overall production is considered. This means that, efficient production of parts or assembly of products alone is not enough to ensure effective advantages for a company as a whole. Customer product orders must be the focus, not parts of products or part of customer product orders. These products must be quickly delivered and, at the same time, good product quality and low cost of manufacturing must be ensured through good use of manufacturing resources.

Traditionally, CMS have been rarely designed having in consideration the need for parts production coordination for effectively and efficiently making complete products and meeting customer orders of end items. Thus, the need for quick response to customer requirements, which is recognized as an important strategic objective under the present market competition paradigm, has not been taken explicitly and appropriately into full account. This limitation however has been addressed in recent years by several authors who propose systems and management approaches focussing on the coordinated manufacturing of parts and components and their assembly towards efficient production and delivery of product customer orders. This manufacturing approach can generally be referred as Product Oriented Manufacturing (POM). Examples of POM systems are what Black (1991) refers as Linked-Cell Manufacturing System and also the Quick Response Manufacturing system referred by Suri (1998). Several authors, including Burbidge (1989), Süer et al. (1995) and Süer (1998) also emphasize the importance of systems integration and synchronized work in cellular manufacturing.

Thus, to effectively respond to the market demand challenges of today, CMS must evolve to Product Oriented Manufacturing System (POMS), frequently reconfigured for fitting and efficiently respond to product demand changes. This approach is radically different from Function Oriented Manufacturing System (FOMS) organization, supposedly adequate for dealing with demand changes and large product variety without needing reconfiguration. This is probably possible only at

expenses of manufacturing efficiency and customer service. In fact, it is well known that systems of this kind are not as efficient or effective to manufacture particular products as are dedicated or POM systems. The main reason is because FOMS is not efficiently adapted to the production requirements of each particular product. In fact they are aimed at the manufacture of the whole range of products within a factory, requiring that, at the same time, a large variety of products share all manufacturing resources available. This creates conflicting interests on the use of resources that are bound to make the system inefficient and non effective. The required fitting of the system to each particular product is not achieved and, therefore, production and service to customer inefficiencies tend to arise. Typical inefficiencies include late deliveries, poor quality, low use of manufacturing resources, high work in process and lack of operators' involvement, motivation and "product ownership". To overcome these inefficiencies POMS should be adopted.

In this paper, in section 2, the concept of POMS is developed. A procedure for detailed design of POMS is put forward in section 3. This procedure describes the detailed design phase of the Generic-Conceptual-Detailed (GCD) methodology for POMS design (Silva and Alves, 2002). In the same section, structures for configurations of cells and workstations are also described. The final section presents some concluding remarks.

2. PRODUCT ORIENTED MANUFACTURING SYSTEM (POMS)

A POMS is defined as a set of interconnected manufacturing resources and/or cells that in a coordinated and in synchronized manner address the manufacture of a particular product or a range of similar products, including the necessary assembly work. Figure 1 schematically illustrates the concept. In POMS a product may be simple, like a part, or complex, having a product structure with several levels. When the product is simple, POMS may simply take a form of a cell. For complex products several cells and/or resources may be required.

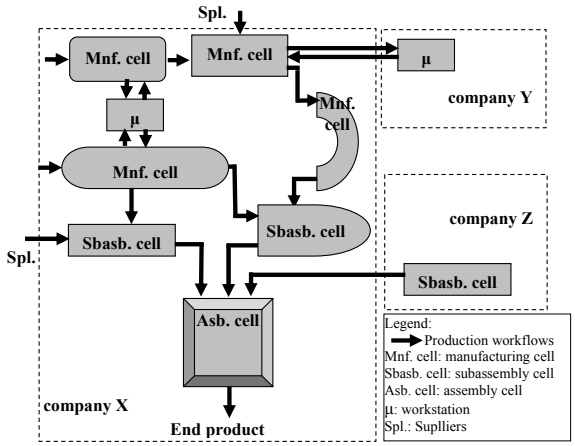

Figure 1: Representation of a POM System

The coordination of work between manufacturing resources or cells is an essential requirement of POMS.

The resources available may exist distributed in space and may be either put together in a localized site or, alternatively, organized into virtual POMS. This approach to virtual configuration of manufacturing systems was initially introduced by McLean, Bloom and Hopp (1982), and studied by several authors afterwards such as McLean and Brown (1987), Drolet, Montreuil and Moodie (1996) and Ratchev (2001), Ko and Egbelu (2003) and Slomp, Chowdary and Suresh (2005). Today, POMS can benefit from intranet and internet based technologies, a prerequisite for the widely discussed Virtual Enterprise concept (Camarinha-Matos and Afsarmanesh, 1999). To be successful, production under this concept must be able to fully and dynamically consider and involve resources available to a company that are locally or globally available, over a time period, either belonging to its own or to potential production partners. Eventually, external autonomous cells or agents offering relevant manufacturing services could be selected for configuring POMS.

At local scale, POMS can be seen as networks of balanced manufacturing resources and cells. This balancing explores flexibility of machines and enlarged skills of operators, which are also requirements of POMS.

One underlying requirement in today's market is the need for frequent adaptation of manufacturing systems to changing manufacturing requirements due to product demand changes. This means that, most probably, POMS needs frequent reconfiguration. This necessity is also justified due to the dedicated nature of POMS to specific products whose demand changing over time requires system adaptation or redesign to ensure high levels of operational performance.

Several factors and parameters, as well as available manufacturing resources data, are inputs to design tools and methods, for generation of operational manufacturing system configurations, which effectively and efficiently achieve company objectives.

Although a POMS lends itself to large quantities and small variety product environments the focus envisaged in this work is on viable POMS for the "Make to Order" (MTO) and "Engineering to Order" (ETO) environments. This viability is ensured by exploring the organizational philosophies, techniques and tools associated with Lean Manufacturing, (LM) (Womack, Jones and Roos, 1990), Agile Manufacturing (AM) (Kidd, 1994) and Quick Response Manufacturing (QRM) (Suri, 1998). Both LM and QRM favour production systems organization in multifunction autonomous units or cells working under integrated coordination for achieving production objectives. AM emphasizes the importance of rapidly changing system configuration for matching processing requirements from product demand changes. AM is also highly dependent on modular production (Starr, 1965) which has been considered essential to product customization (Duray, Ward, Milligan and Berry, 2000). Product Oriented Manufacturing (POM) can also be

associated with concepts such as focused factory, advanced by Skinner (1974), and systems OPIM (One-Product-Integrated-Manufacturing) put forward by Putnik and Silva (1995).

3. DETAILED DESIGN OF POMS

The proposed methodology for POMS design, identified as the GCD methodology, was structured in three design phases or functions, namely the Generic, the Conceptual and the Detailed (Silva and Alves, 2002).

Due to today's market competition and market unpredictability there is a need for frequent POMS redesign. This is particularly true at detailed design level where frequency of design is high. In fact, in theory, system redesign or reconfiguration should be carried out every time an ordered product needs to be manufactured, or, in the least, by short planned periods of undisturbed production. This may allow aggregating a few customer orders of the same product, or of similar products, for efficient production during the same manufacturing period.

In order to reach a viable POMS solution it is necessary to structure detailed design through a set of subsequent and interrelated activities aiming at solving different design and operation problems. Such problems are closely interrelated and must be solved together and iteratively. Arvindh and Irani (1994) identified four classes of design problems to be solved in cellular manufacturing, namely: machine group and part family formation, machine duplication, intra-cell layout and inter-cell layout. In addition to these, manufacturing system operation and work organization problems must also be addressed and solved. These are related with cells integration and production control. The Detailed design (A3) of the GCD methodology addresses these classes of problems, and extends design to other aspects, through five activities, namely: products selection and families' formation, (A31); conceptual cells instantiation (A32); workstations instantiation (A33); intra-cellular organization and control (A34) and, finally, intercellular organization and coordination (A35).

Using IDEF0 modeling technique (FIPSPUBS, 1993), Figure 2 illustrates detailed design activities showing important data, control mechanisms, design methods and results.

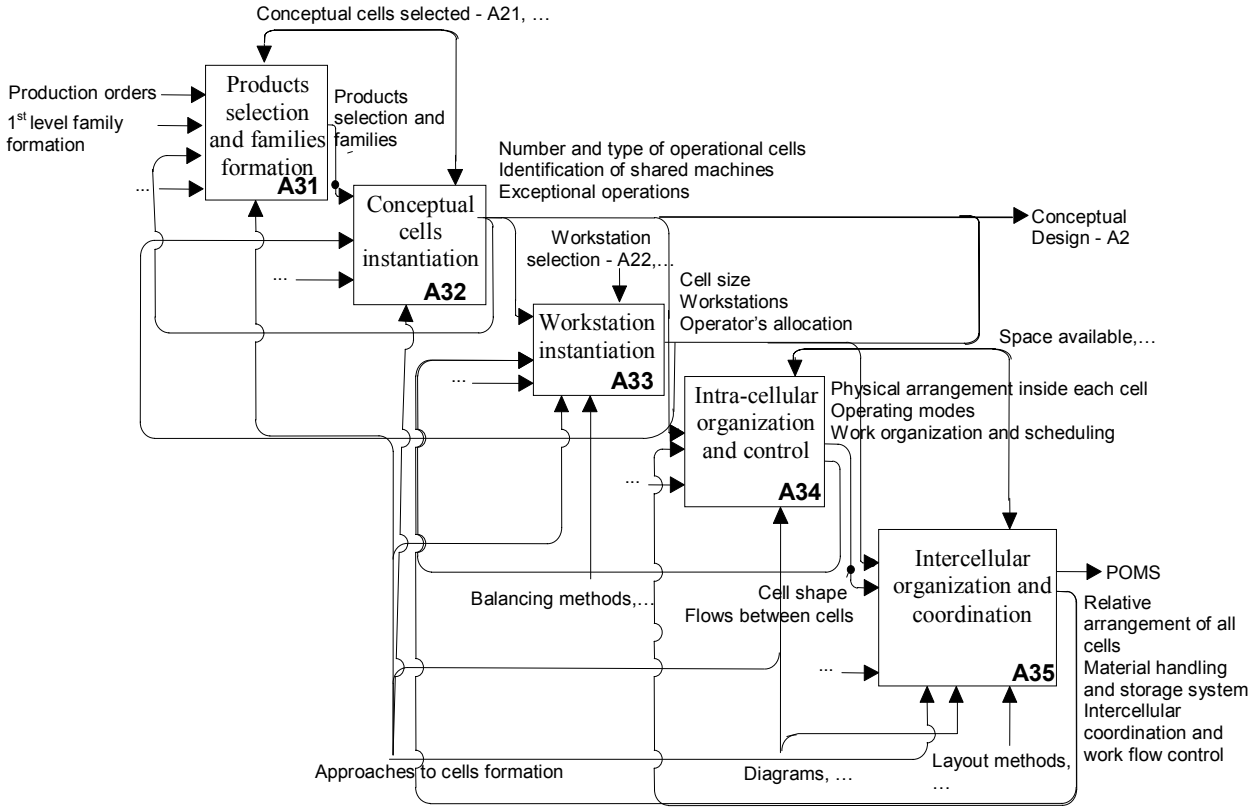

Figure 2: Detailed design of POMS

Detailed design of POMS is dependent on results of Conceptual POMS design (Silva and Alves, 2002). These essentially are the definition of conceptual cell configurations and types of workstations, based on a first level production clustering analysis of product families or models, according market demand. This definition depends on processing requirements of products translated into operation plans. The conceptual cells considered are based on workflow types namely direct, direct with bypassing, inverse, inverse with bypassing and repetitive workflow, (Silva and Alves, 2004), a classification derived from the Aneke and Carrie (1986) view of workflow types. Figure 3 summarizes and illustrates the set of conceptual cell configurations that can be considered. The workstations are assumed to be distributed along the direct workflow path represented. Depending on their processing independence and autonomy conceptual cells are divided into basic and non-basic. Basic cells are self-contained, i.e. are totally dedicated to its products family. Non–basic cells are not self-contained. This means that they share resources with other cells. Basic cells may be seen as autonomous cells and non-basic ones as dependent or non-autonomous cells.

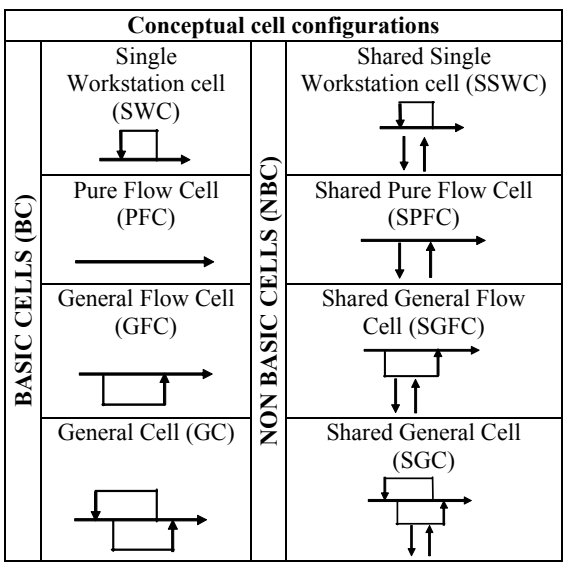

Figure 3: Schematic representation of the Basic and Non-basic conceptual cell configurations

The conceptual cells that can be selected for establishing the POMS systems very much depend on the processing requirements of a product, for which the POMS is thought, or on the degree of similarity among products that constitute a product family. A *product family* is a set of products that share the same processing requirements. This means that in addition to requiring the same manufacturing equipment and use of the same human resources they can be handled by the same materials flow and handling equipment or system and, therefore, manufactured in the same POMS.

A large variety of methods for selecting and forming product families are based on product routings and available manufacturing equipment required for processing. In this case it is common to identify families with basis on a set of machines, which, then, may form a manufacturing cell.

In the approach used in this work, product family formation for POMS assumes a hierarchic analysis based on process plans, operations plans and sequencing plans and, only after this, product routings are taken into consideration (Carmo-Silva, Alves and Costa, 2005).

Families' formation literature is abundant. Since the work by Burbigde in 1963 (Suresh and Kay, 1998) the development of methods, techniques and algorithms have never stopped. Special emphasis has been given to families' formation based on data relating parts to machines required to processing them.

In the GCD methodology, design of POMS' configuration starts with the choice of conceptual cells. Whenever possible, basic pure flow cells are chosen. This tends to happen when a POMS is dedicated to a specific product, and may also happen when the production similarity among products of a family is high. In the extreme general job-shop like cells, here called *general cells*, may have to be adopted for accommodating a diversity of product routings. Both the basic and non-basic configurations must be considered for choice.

Workstations of each cell may have to be considered in different perspectives or arrangements, according to manufacturing resources availability and processing requirements, Figure 4. They may be a) simple, provided with a single machine to carry out a single manufacturing function or be more complex, having b) multi-function processors c) parallel processors and d) multi-resource processors. Taken separately or in combination these arrangements can lead to workstations and cells with several degrees of flexibility, from low to very high. The existence of multi-resource cells adds up additional complexity in control and scheduling.

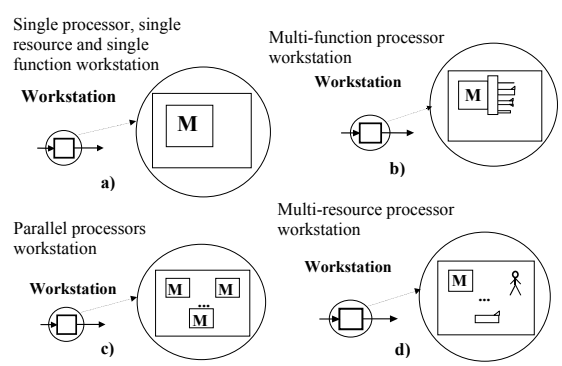

Figure 4: Type of workstations

3.1. PRODUCTS SELECTION AND FAMILIES' FORMATION

Activity A31 – Products' selection and families' formation - is a refining process of the first level family formation made at conceptual design. It can be though of as a detailed product family formation process which actually leads to the manufacturing cells to adopt and implement.

The objective is identifying and selecting products, or family of products, that are going to be manufactured, and which can and should be processed in the same manufacturing system or cells. This activity is based on proposed conceptual cells and requires an in-depth analysis of processing requirements based on actual production orders of specific products and product components. Processing requirements are expressed through operation plans, with a clear identification of operations' precedence. This is critical to form product families that can have identical operation sequencing plans, to fit the conceptual configurations proposed.

3.2. CONCEPTUAL CELLS INSTANTIATION

Conceptual cells are selected and proposed in the Conceptual design phase. The instantiation of each selected conceptual cell is the main objective of this activity.

A selected conceptual cell can be instantiated in several forms, with basis on resource combination and workstation configurations as illustrated in figure 4, dependent on processing requirements and resources availability. Thus the type and quantity of manufacturing resources, i.e. main resources such as machines, or auxiliary resources such as operators and tools, involved in each workstation, together with available quantities of each, may lead to different forms of cell instantiation.

The instantiation of both conceptual cells and workstations, together with integration and control, lead to what can be called *operational cells*. Usually these fit into a number of reported types of cells which include: Toyota sewing system (TSS) (Reece Corporation, 1990, Kalta et al., 1998); modular manufacturing system (MMS) (Black and Chen, 1995, Black and Schroer, 1994, Schonberger, 1996); flexible work group (FWG) and unit production system (UPS) (Chen, 1998); one-piece flow (OPF) (Sekine, 1993); linked-cell manufacturing system (L-CMS) (Black, 1991); and quick response sewing system (QRSS) (JETRO, 1990). These operational cells, because of being based on principles of JIT production (Monden, 1983) are referred as operational JIT cells (JITC). In addition to JITC other operational cells can also be referred, namely the: quick response cells (QRC) (Suri, 1998), flexible manufacturing/assembly systems and cells (FMS) (Tempelmeier and Kuhn, 1993), and virtual cells (VC). UPS cells are particularly used in the apparel industry and have a strong element of flexible automation. For these reason we may, also say that they are a hybrid concept between JIT cells and FMS.

Figure 5 relates conceptual cells with operational cells. The operational cells can be characterized according to several dimensions as shown in table 1. The value 5 means that the dimension is strongly present and the value 1 means that it is weakly present or non-existent at all, according to the authors view.

		JITC	QRC	FMS	VC
BASIC	SWC	--	--	✓✓	✓
	PFC	✓✓	✓✓	✓✓	--
	GFC	✓✓	✓✓	✓✓	--
	GC	--	✓	✓	✓
NON-BASIC	SSWC	--	--	✓✓	✓
	SPFC	--	✓✓	✓✓	--
	SGFC	--	✓✓	✓✓	--
	SGC	--	✓	✓	✓

✓✓ Preferred; ✓ acceptable/possible; -- not recommended/possible

Figure 5: Matching conceptual cells with operational cells

Other operational cells may be generated as the result of combining different operation mechanisms and dimensions most of which imbedded in the operational cells listed.

Table 1. Differences between operational cell configurations

Characterization dimensions	**JITC**	**QRC**	**FMS**	**VC**
Direct flows	5	4	2	1
Production rate	5	3	3	2
Product variety	3	4	3	5
Manual handling	5	4	2	3
Wait times	1	3	3	3
Set-up times	1	2	3	1
Operators involvement	5	4	2	3
Multi-skills	5	4	2	1
Reconfiguration easiness	4	3	2	5
One piece flow	4	3	4	2
Automation	2	2	5	2

Normally, there has to be a few iterative design loops between conceptual cells proposed and their instantiation, at detailed design, before the set of the POMS cells to adopt is finally settled. This is because, at detailed design product selection and detailed family formation, together with company available resources, might point out advantages of exploring conceptual cells different from those already proposed. If this happens, conceptual design is revised, in an attempt to simplifying workflows and POMS' configuration. This simplification effort may call for measures which may include product processing plans adjustments, choice of alternative manufacturing resources and, also, replication of machines in positions dependent on processing sequence of products. For example, the availability of two or more identical

machines may allow processing in direct flow and use of basic flow cells, instead of having to accept inverse flows, and, eventually, non-basic cells too. Operational JITC cells are mainly identified with direct flow cells and QRC, FMS or VC with other cells.

POMS simplification may also derive from integrating or joining together two, or even more, non-basic cells to obtain a basic cell, manageable and balanced, in spite of being larger than each of those joined.

The results from conceptual cells instantiation are a number of cells whose configuration matches the conceptual cell configurations selected. In this process, sequencing plans for each product in a product family are defined based on operations plans, having into account operation precedence constraints.

Further important information retained at this activity for later use, is the identification of shared workstations between non-basic cells. This sharing is due to exceptional or "outlier" operations of some product families. This information is critical for later solving the problem of the work flow interaction and coordination between and within cells as well as for establishing the inter-cells layout arrangement.

The next step of detailed design is workstations instantiation.

3.3. WORKSTATIONS INSTANTIATION

This detailed POMS design activity (A33) aims at precisely establishing the number of workstations and machines per workstation, which have been roughly estimated at the previous conceptual design level, and also other production resources that may be required to operate workstations.

Workstation instantiation involves a detailed knowledge of the quantity and processing capabilities of available main and auxiliary processing equipment and operators. The number of operators and the level of replicated auxiliary equipment, such as tools, together with their dynamic utilization within cells may substantially affect, not only the cell capacity and manufacturing flexibility, but also the manner how cells can be operated. Therefore the availability of auxiliary resources and operators highly restrict the performance levels that can be achieved (Silva, 1988, 1997).

There is also the objective of preliminary allocation of operators to workstations, according to their skills. Detailed cell balancing is also carried out having into consideration not only existing manufacturing resources but also skills of operators. The existence of multi-skilled operators eases the operators' allocation or reallocation to workstations within cells, which might occur due to changing production requirements, allowing quick and effective cell rebalancing. In this manner adjustment or reconfiguration of cells due to, for example, product demand changes, becomes easier. Demand rate, processing times per operation, planning levels of machines and operators' utilization are essential data to cell balancing.

The survey of Bidanda et al. (2005) emphasises that important issues to be treated when implementing cells include operators allocation strategies, skills identification, training, communication, reward/compensation systems, definition of operators roles, teamwork and conflict management.

The nature of workstations highly influences the number and role of operators required within a cell. Thus, for example, automated workstations tend to require operators essentially for load/unload tasks, while intensively attended workstations requires a much larger operator involvement on the production process. In this latter situation, in addition to the allocation of machines to workstations, allocation of operators to workstations and team selection for operating the cells are important problems to solve. This importance directed several authors to look into the integrated problem of operators and machines allocation to cells, when establishing manufacturing cells [(Min and Shin, 1993), (Molleman and Slomp, 1999), (Askin and Huang, 2001) and (Norman et al., 2002)].

Operators' definitive allocation to cells and working roles are established in the next design activity, together with the definition of working teams. Working teams, which are closely related with cell operating modes, can take several configurations, such as semi-autonomous workgroups, self-directed or self-managing work teams and lean teams [(Badham and Couchman, 1996), (Niepce and Molleman, 1996), (Amelsvoort and Benders, 1996), (Van Hootegen, Huys and Delarue, 2004) and (Jonsson, Medbo and Engstron, 2004)].

The workstation instantiation activity requires some iterative loops with the previous activities of detailed design, justified by the eventual need for readjustment of conceptual cells instantiation and/or product families' formation.

The results of the workstation instantiation activity are the cell size, i.e. number of workstations and machines, the operator's allocation to cells and clear identification of each cell for manufacturing each product.

3.4. INTRA-CELLULAR ORGANIZATION AND CONTROL

The main objective of this design activity is to establish an arrangement of the machines and other resources in order to minimize the movement people and the handling of materials ensuring good levels of performance. Additionally forms of cell production control including strategies for solving several dimensions of the scheduling problem are defined. So, operational cells are finally settled.

Although conceptual cells instantiation restrict cell arrangements that can be made, there is still a need for clearly defining intracellular detailed organization and control at each cell. This involves location of workstations, machines and auxiliary devices, including

workstation *decouplers* (Black and Chen, 1995), and also the evaluation of several physical layout configurations (Arvindh and Irani, 1994), such as the well known and popular U shaped one (Miltenburg, 2001). The mode how work and people flow within a cell must also be defined. Moreover, cell operating modes must be studied for implementation.

The intracellular physical organization problem must be treated in a systematic and integrated way with the material handling and storage system. This requires information about resources, space available, quantity, size and weight of unit loads to be handled, frequency of handling, and eventually unit costs of handling. Ergonomic and safety considerations must also be considered at this design stage. Input and output locations of both cells and of each workstation or machine must also be clearly defined here, as well.

Once physical arrangement of each cell is solved, the problem of distribution and organization of operators within a cell according suitable operating modes must be solved. Of course decisions made previously, such as preliminary allocation of operators to workstations, are taking into account in solving this problem. Additionally we should take into consideration guidelines put forward by many authors on this matter. For example, mainly for the U shape cell layouts, several authors recommend the following operating modes: *working balance* (Black and Chen, 1995), *rabbit-chase* (Black and Chen, 1995) or *caravan* (Baudin, 2003), *toyota sewing system* (Black and Chen, 1995) and *baton-touch* (Baudin, 2003). Maters of teamwork and time-sharing resources (Suri, 1998) are also important to consider.

The Bucket Brigades (BB) (Bartholdi et al. 1995) is a novel, powerful and flexible cell operating mode for the dynamic allocation of operators to workstations within a cell. The BB mode resembles the work organization and behaviour of bees and ants [(Bartholdi and Eisenstein, 1996, 1998) and (Bartholdi et al., 1999)]. The TSS mode is considered by the authors of the BB mode as one of its possible implementations.

The last problems to solve within this design activity have to do with loading and scheduling of jobs in the POMS. When several different, although similar, products are manufactured in the system, product releasing, sequencing or dispatching must be defined based on scheduling strategies, rules or algorithms directed to minimize some criteria of performance. Batch splitting and overlapping may have also to be considered. Scheduling decisions are likely to be influenced by the need of coordinating assembly and production of components, of the same product order, manufactured in other cells of the POM system. This is a problem of intercellular organization and coordination object of the next POMS detailed design activity.

Due to the workstations proximity in cells, distances are small between successive workstations of a given product routing in a non-virtual cell. This allows the handling of small lots and, in same cases, even one piece flow production. This flow approach is usually implemented in JITC, QRC and frequently in FMS as well.

In JIT cells work coordination and scheduling is based on the repetitive uniform flow of production, with product models manufactured together, in a mixed manner, during a given planned production period, at a uniform flow rate. This rate matches and is synchronized with forecasted demand rate, and the planned period usually varies from a few days to a few weeks, dependent on the processing requirements and complexity (Carmo-Silva, Alves and Moreira, 2006).

3.5. INTERCELLULAR ORGANIZATION AND COORDINATION

This is the final step in the detailed design of POMS and is the activity which ultimately guarantees that the POMS concept can be implemented. Because of this, and according POMS definition and general objectives, it must ensure that good levels of production and customer service performance are achieved. Because of this, production related with each individual product order must be synchronized throughout the several production stages, at each cell or resource of the POM system.

This design activity is less complex when parts are manufactured and ordered by customers. However, it can be very demanding when complex products with several components with parallel and subsequent manufacturing and assembly processes are involved. Production in POMS generally assumes the existence of connected cells [(Süer et al., 1995) and (Süer, 1998)] and interlinked cells Black (1991), being the output of one cell the input to one or more subsequent ones.

The intercellular organization and coordination design activity may be divided into two interrelated tasks. First, the relative arrangement of all cells and workstations, and also the selection of the integrated material storage and handling system must be carried out. This is very much dependent on intercellular dependence between cells, either due to resources sharing among products or product families, or due to the need for synchronized flow of production of components and assembly work. This aspect is absolutely critical to POMS design. Second, the POM intercellular coordination and work flow control procedures and mechanisms to adopt must be identified.

The first task call upon the use of design methods of layout and materials storage and handling systems based on alternatives whose performance behaviour is already known or can be evaluated. Cost information together with frequency of handling and amount of work to move and store within and between cells are critical data to use in the design process. Several alternative handling systems that can be used should be known. Safety and ergonomic factors should also be taken into account.

The second task solves the problem of coordination and control of work throughout the cells and resources of the POM system. Synchronized production required in POMS should explore, as much as possible, the concept of simultaneous manufacturing (Silva and Putnik, 1995).

This is based on the production control strategy of giving priority to the production on the shop floor of jobs on a FCFS basis and of widespread implementation of batch splitting and overlapping. The concept of overlapping is here enlarged to mean overlapped manufacture of different components, of the same product, for simultaneously and synchronously feeding an assembly stage. Splitting and overlapping strategies under this enlarged view have been studied and evaluated by Lima and Silva (2002), Lima (2003). Coordination and control should also explore the *push* and *pull* paradigms and Production and Materials Flow Control (PMFC) mechanisms resulting from novel combinations of them such as GPOLCA (Fernandes and Carmo-Silva, 2006), POLCA (Suri, 1998), DBR (Goldratt, 1986), CONWIP (Spearman, 1990) and SYNCRO-MRP (Hall, 1981), to mention only a few.

Period batch control (PBC) (Burbidge, 1989, 1993) is one classic control mechanism that appears to be useful for production activity coordination in POMS. The performance of this mechanism in cellular manufacturing has been investigated by several authors including Steele and Malhotra (1997) and Benders and Riezebos (2002).

Once this last activity is finished a POMS systems is defined together with its operational cells and coordination of work flow and production control, within and between cells clearly identified.

4. CONCLUDING REMARKS

Designing production systems to fit production requirements of a specific product or a family of similar products whose demand varies continuously is a way of exploring both scale and scope economies and, at the same time to adapt production to today's market unpredictability. This fitting leads to what we call Product Oriented Manufacturing Systems (POMS). To achieve this purpose, tools are required to easy the design process and make it acceptable and quick. Considering the complexity of this design there is a need for a methodology that in a systematic, well organized and structured way takes into account all the important design steps and aspects that must be considered. In this paper the GCD-Generic-Conceptual-Detailed hierarchic methodology is referred and the Detailed phase thoroughly described. We show its five activities and their interrelationships with Conceptual design phase.

One important underlying strategy to POMS design and redesign is system dedication to specific products or to families of similar products, let them be simple or complex, ensuring synchronized production of components and assemblies. Moreover, for cells formation based on product families, a hierarchic analysis of processing requirements of products based first on process plans, followed by operations plans and sequencing plans is carried out. Product routings are considered only at the last stage of analysis for adjusting cell configuration and finally settle cells' configurations, cells manufacturing resources to use, main and auxiliary, and products or parts to be manufactured in each cell of the POMS in a synchronized manner.

The authors are in the phase of developing a Computer Aided Design System for POMS based on the GCD methodology. Part of this has already been reported (Carmo-Silva, Alves and Costa, 2005), although a substantial part of it, to integrate design methods and data bases, is still under development.

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