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USING THE SLP METHOD IN THE DESIGN OF FLEXIBLE MANUFACTURING CELLS

Abstract. *Flexible manufacturing systems are becoming increasingly important as customers increasingly want customized products. Also, the trend of the product life cycles to become shorter and shorter causes the proliferation of flexible manufacturing systems. Proper layout is key to making the manufacturing system truly flexible. Novel research and this article show how the Systematic Layout Planning method can be applied to the design of flexible manufacturing systems and, going further, how the design process can be supported by manufacturing process simulation.*
Keywords: *systematic layout planning; simulation; flexible manufacturing systems.*

1. INTRODUCTION

The essence of flexible manufacturing is adaptability - that is, the ability to adapt to changes in product requirements without compromising quality. The Flexible Manufacturing System (FMS) is the manufacturing method that helps to achieve this and can reduce the production time and the number of resources required.

Flexible production systems need to be designed to adapt to changes, such as small (or significant) changes in a product, the addition of production volumes or completely new products. This, of course, requires automation of key manufacturing processes in these systems, including machining and assembly, loading and unloading, and data processing. Because the system is automated, it relies less on human power than traditional manufacturing methods. The Flexible Manufacturing System consists of two to ten machines, including processing workstations and parts management capability [1], [2].

In the case of flexible production systems, it is very important to minimize losses as even the smallest loss per piece becomes a significant loss due to the large number of pieces. The seven main losses in lean are excess activity, handling, inventory, transportation, waiting, overproduction, and scrap. Four of these losses are due to improper layout design; they are inventory, shipping, waiting, and overcapacity as these are directly related to layout design.

2. SYSTEMATIC LAYOUT PLANNING FROM FMS VIEWPOINT

One of the most common and accepted methods of layout planning is Systematic Layout Planning (SLP), developed by Richard Muter in the 1960s.

Systematic Layout Planning is a comprehensive layout planning method that can be used to plan the layout of entire factories, taking into account the material transport and material supply and also the parameters of each machine group [3]. Systematic Layout Planning is mainly used for large projects. It divides layout design into four main parts and defines activity points that determine how material flows in a production area in manufacturing. Depending on the level and depth of the design, an activity point can be a department (e.g. a machining plant) or even a machine (e.g. a CNC milling machine).

For layout planning of smaller projects, such as the layout of a specific department or even a group of machines, Systematic Layout Planning has a simplified version called Simplified Systematic Layout Planning [4]. This methodology can work well for smaller projects where the material flow is less dominant, but the placement of individual devices and equipment is more important. These can be offices, laboratories, tool storage, maintenance plants, but also flexible production systems.

The method is based on three things that define each layout:

- the relationships between each item
- the space requirement, ie how much space is needed for a given department or machine
- the exact location of the machines of each department, ie where the equipment and machines will be located within the given space on the final layout.

Both Systematic Layout Planning and its simplified version work with 5 basic parameters:

- the product,
- the quantity,
- the process,
- the supporting services and
- the timing.

For simplified layout design, we have 6 steps:

1. charting the relationships
2. establish space requirements
3. diagram activity relationships
4. draw space relationship layouts
5. evaluate the alternative arrangements
6. detail the selected layout plan.

In the first step, we create the connection graph, which is a graph that determines the importance of the connections between each piece of equipment. The importance can be divided into six categories, from what must be next to each other, all the way to the distance between machines is unimportant (Figure 1).

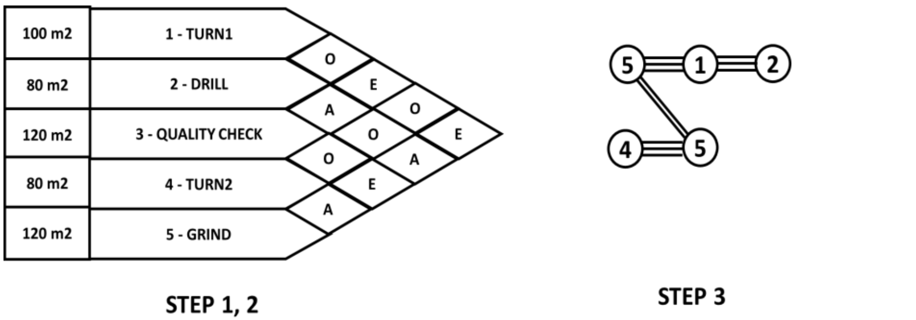

Figure 1 – The first three steps of the Simplified Systematic Layout Planning

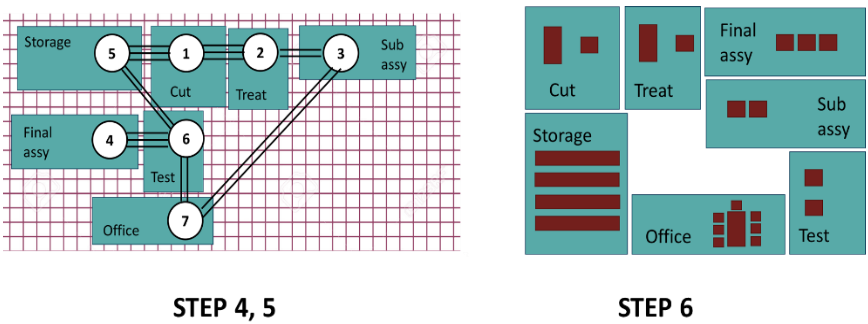

Figure 2 – The last three steps of the Simplified Systematic Layout Planning

In addition, the graph can also be used to indicate the reason why we decided to classify the distances of the two machines and equipment into the given category. Such reasons can be, for example, material flow, maintenance or quite simply a practical reason why it is worth keeping two devices close to each other.

The second step is to specify the space requirements for specific departments or specific equipment. The calculation of space requirements shall consider not only the space directly required by the machinery but also the space requirements around it which belong to the same category or to the same machinery. For example, if a container or a buffer is required for a given machine, the space requirement for that machine must also be included in the machine's space requirement. Separate storage areas should be included in the graph as separate units (Figure 1).

The next step is to draw a graph of activity relationships that shows how important the relationship is between each machine. This can be represented in a graph where the required proximity is typically represented by one, two or three connecting lines (Figure 1).

We can supplement the graph made here with the need for space, as we can draw the size of the required space for each activity point. Regarding the size of the space required, it is worth examining the extent to which it’s possible to deviate from the size of the space requirement on the one hand and its proportions on the other. In some cases, an elongated shape is required, whereas, in other cases the proportions of the rectangle determining the space requirement can be changed (Figure 2).

As a result, multiple layout variations can be created that need to be evaluated. Evaluation considerations go beyond simple layout design and may consider parameters that include economics or other practical considerations. Such parameters may include the logistics of the material supply, adaptability within the existing structure, costs, constraints due to the characteristics of the building, and, for example, maintainability or cleanability (Figure 2).

Based on these, the final so-called block layout can be selected, which must be detailed in the last step. During the detailing, the machines and the parameters, storage devices and other objects that are important for the given activity point and that determine its operation, must be drawn (Figure 2).

In the case of flexible manufacturing systems, it is important to highlight that of the five basic parameters, product, quantity, and routing can change quite often. It is also important to see that the life cycle of flexible manufacturing systems can be extended, in most cases with the introduction of a new product, which means that the system must be prepared for the introduction of new elements and new machines during its life cycle.

3. SAMPLE APPLICATION OF THE METHOD

Apparently, this framework provides an easy-to-use and easy-to-understand method for designing production layouts and, as such, can be used for flexible production systems [5], [6].

Figure 3 shows an example of a simple flexible manufacturing system that examines the use of Systematic Layout Planning in a simulation environment. Digital manufacturing support was used for the Plant Simulation discrete event-based simulation system.

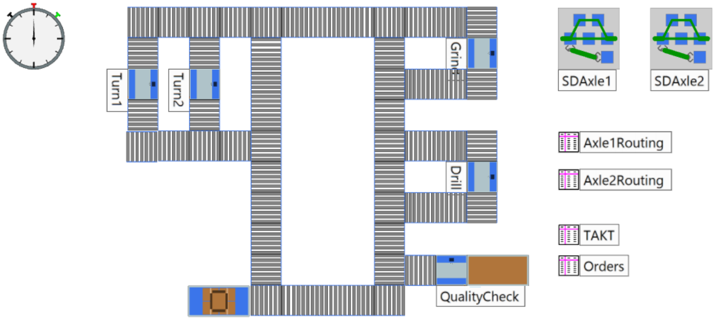

Figure 3 – Simple flexible manufacturing cell layout in simulation environment

The arrangement shown in the diagram produces two products. The technological parameters of the two products are different, the production times are different on each machine and the routing of the two products is also different.

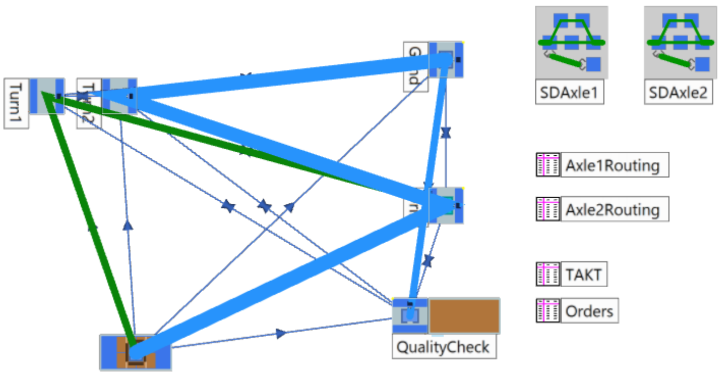

Figure 4 – Material flow by product between the activity points

In the first step, the machining machines are included in the simulation and the parameters that determine the material flow between them. After examining the material flow, it is clear which machine has the strongest material flow, so it is worth placing them as close as possible to each other (Figure 4).

In the next step, different layout variations can be created that can increasingly approach the solution that may work best in terms of space utilization and technological feasibility. Once the location of the machines has been determined, we must also ensure that the material flows between them, so that the equipment needed for the material flow can operate. A minimum distance must also be defined between the production stations of the various machines and stations.

There are various possibilities for realizing the flow of material between the machines, such as the conveyor track but also the AGVs (Figure 5) [7], [8].

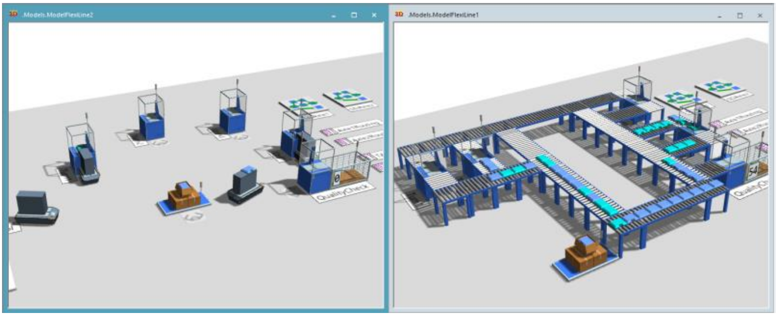

Figure 5 – The first three steps of the Simplified Systematic Layout Planning

Not only do the technological parameters play an important role in the final selection but also, for example, the size of the investment costs, so in the end we decided on the conveyor solution. The final layout ensures that the production system is flexible and complies with the Systematic Layout Planning methodology.

4. SUMMARY

In this article, we examined how a layout design methodology can be used to design increasingly flexible manufacturing systems today. Scaling down the methodologies used to design larger layouts provides a useful solution. Also, during layout design, the steps were well defined and can be mapped well in a discrete simulation environment. The model, which was created in the simulation environment, made it very easy to understand and interpret the layout design parameters and results.

The combination of the systematic layout planning methodology with discrete event-driven simulation, enabled efficient and highly productive layout design. Further steps in the research are aimed at automating the design methodology to the highest possible level.

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ВИКОРИСТАННЯ МЕТОДУ СИСТЕМНОГО ПЛАНУВАННЯ РОЗМІЩЕННЯ ОБ'ЄКТІВ ПРИ ПРОЕКТУВАННІ ГНУЧКИХ ВИРОБНИЧИХ ОСЕРЕДКІВ

Анотація. *Гнучкі виробничі системи стають все більш важливими, оскільки клієнти все частіше бажають індивідуалізованих продуктів. Крім того, тенденція до скорочення життєвих циклів продуктів викликає поширення гнучких виробничих систем. Правильне компонування - ключ до справді гнучкої виробничої системи. Нові дослідження та ця стаття показують, як метод планування системного компонування може бути застосований до проектування гнучких виробничих систем та, надалі, як процес проектування може підтримуватись моделюванням виробничого процесу. Системне планування макета переважно використовується для великих проектів. Він ділить проектування компонування на чотири основні частини та визначає точки діяльності, що визначають рух матеріалів у виробничій зоні при виробництві. Для планування компонування невеликих проектів, таких як компонування конкретного відділу або навіть групи машин, у Systematic Layout Planning є спрощена версія, яка називається «Спрощене системне планування компонування». Ця методологія може добре працювати для невеликих проектів, де матеріальний потік менш домінуючий, але розміщення окремих пристроїв та обладнання важливіше. У разі гнучких виробничих систем важливо наголосити, що з п'яти основних параметрів, продукт, кількість та маршрут можуть змінюватися досить часто. Також важливо бачити, що життєвий цикл гнучких виробничих систем може бути продовжений, у більшості випадків із запровадженням нового продукту, що означає, що система має бути підготовлена до впровадження нових елементів та нових машин протягом її життєвого циклу. У цій статті ми розглянули, як сьогодні можна використовувати методологію макетування для проектування більш гнучких виробничих систем. Поєднання методології системного планування компонування з дискретним моделюванням, керованим подіями, забезпечило ефективне та високопродуктивне проектування компонування. Подальші кроки у дослідженні будуть спрямовані на автоматизацію методології проектування максимально можливого рівня.*

Ключові слова: *системне планування компонування; моделювання; гнучкі виробничі системи.*