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Production Flow Analysis in Textile Production

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Abstract

This paper analyzes the possibility of using group technology in the textile industry. The used method of grouping is based on the technological processes analysis of products and their pathways through the production process (Production Flow Analysis - PFA). Based on the given methodology, the product paths were recorded and a path diagram was generated. Moreover, product groups with same or similar paths were shaped in order to form the basis for the formation of cells and / or virtual cells. In order to identify and consider a number of possible solution variants, the Implanner Cell software package was used to generate optimal solutions in real time, upon which the proposed variant was discussed in order to derive relevant conclusions.

Key words: *Group technology (GT), PFA method, Textile industry, Cell*

1. INTRODUCTION

The group concept has been developed as an approach in design, organization, system management, material handling, material processing, etc. It is a method of organizing a production system into such organizational units (groups) that are known as cells. A cell is a set of similar products or parts thereof, a set of machines, and a set of people necessary to carry out the production process of a given set, at a certain time and to certain parameters [1-4]. PFA methodology is a set of steps that allows companies to move from process to subject production using Group Technology [5]. The process of grouping is carried out in two main phases:

- Analysis of flows in the production system
- Analysis of groups

Analysis of flows in the production system consists of several steps:

1. Determining the current flows - In order to perform the procedure it is necessary to determine, for all parts of the production program, the flow on the input - output relation. At this stage, identified flows contain departments in which a certain part is processed.
2. Flowchart design - Using a frequency chart, it is necessary to design a flowchart in such a way that in the logical schedule of the department all paths from the chart are entered and their direction indicated. The flowchart should indicate the number of parts passing through a defined path between the two departments.
3. Flowchart simplification - Process data processing indicates a high likelihood that a flowchart, generated upon real-system data is complex, which initiates the need to simplify the flows. Flowchart simplification could be performed by applying the following methods:
    - department combination
    - certain types of processing systems allocation
    - the elimination of a particular type of work that creates specific difficulties to achieve the ultimate form of flow suitable for analysis of groups

As a result of Flowchart simplification, some paths do not fit into a simplified flowchart - such exceptions should be eliminated. There are three ways to perform elimination:

- Changing the work construction
- Changing the procedure

- Procurement instead of work item production

The aim of the second phase in grouping process is to regulate the flows of materials within a part of the production system, that is, the design of cells in such a way to define the function of the criteria in the form of a substrate for each cell that contain: Team - Group of executors, a Group of parts that are fully processed in cell, Group of working systems on which all parts of the group are processed, Surface required for deployment and Size of cell.

2. SOFTWARE PACKAGE - IMPLANNER CELL

Implanner cell is a software package developed to facilitate the application of PFA analysis in order to form cells. There are various software solutions based on techniques such as Operations Research, Genetic Algorithms, Neural Networks and Space Search. However, the Implanner Cell software solution [6] was selected, because it is based on an algorithm for forming cells using PFA method. The software itself is based on CM, CF, Space search algorithm and PFA method. This software tool was built on the Java 2 Foundation classes and the Java Swing API platforms [7]. Space search algorithm [6] is formed to select the best variant in the given conditions. The data entered for the products are: path, quantity, production time, production costs, etc. For machines, this includes data indicating the machine model (SICGE), the frequency of machine use, efficiency, etc. Most of CF algorithms start with the initial product-machine matrix (Table 1).

Table 1. An example of the product path input (Part), subtypes (A) and the machines that are needed in the production process. (1 means the presence of a particular machine in the process)

Part \ Machine		M1	M2	M3	M4	M5
Part 1	A1	1	1	0	1	1
	A2	1	1	1	0	0
	A3	0	1	1	0	1
Part 2	A1	1	0	0	0	1
	A2	1	1	1	0	1
	A3	0	1	0	1	1
Part 3	A1	0	0	0	1	1
	A2	0	1	1	1	0
Part 4	A1	1	0	1	0	1
	A2	0	1	0	1	0
	A3	0	0	0	1	1

The results are displayed as "space state", due to a possibility to obtain more similar solutions. When forming cells, it is necessary to assign information about the maximum size of it during the simulation process, or how much products (n) can be found in one cell.

3. FORMATION OF CELLS

The textile industry is a branch of industry which deals with the processing of fibrous raw materials, manufacturing of fabrics, knitted products and yarns.

The type of textile industry observed in this paper, currently operates according to a process-oriented approach to production. Observed enterprise is engaged in the production of women's socks for the European Union market, while the annual production volume amounts about 40 million pairs of socks. Based on the given methodology and program application, the product paths were recorded, the necessary data were integrated and cells were generated.

3.1 **Production program**

Production program consists of seven product groups, as follows:

- short ankle socks (¼ zip socks),
- ¾ socks (women's socks up to the knee),
- halter stockings (stockings up to the middle of the thigh)
- hula-hoop without an insert (long socks with rubber around the stomach, smaller widths, different sizes),
- Hula-hoop with a small insert (the insert is used as an sock enlargement option, which increases the width from the hip to the gum on the stomach),
- Hula-hoop with a large insert, and
- Hula-hoop with saddle inserts.

In addition, the materials (mainly yarns) used to manufacture these types of products in the observed enterprise, are:

- Stretch yarn,
- Textured yarn,
- Multifilament and microfilament yarns
- Pure lycra yarn
- Wrapped lycra yarn
- Metallic yarns-lurex
- Pattern applications

The group of products that is most represented in the production program are ¾-stockings, with a share of about 32.66% in compared to total quantity of products. Moreover, the mostly deployed materials are textured yarns, from which the largest quantities of socks are made. More precisely, 54.35% of overall products were produced from these yarns in 2016. Figure 1 provides clear insight on production volume and the yarn type from which the articles were produced.

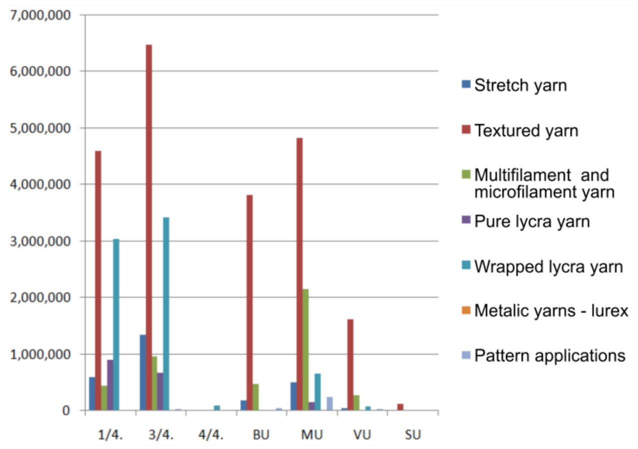

Figure 1. Production program by type of product and material from which they were made

The production program of the observed enterprise includes over 200 types of socks. For the analysis of the process of forming cells, 33 representative products of similar of product groups were selected. Representatives were selected by socks and yarn type (certain types of yarns are used for certain groups of products).

3.2 **Material Flowchart representation**

Production takes place through several phases (Figure 2):

- Knitting (p)
- Sewing (S)
- Preparation for Colouring (J)
- Colouring (f)
- Drying and ironing (n)
- Quality control and packaging (d)
- Transport packing and palletizing (q)

The production process starts from the warehouse, which are: material storage (s) – for necessary materials and yarns in the process of knitting and sewing; packaging storage (b); storage for transport packaging (c); storage for chemicals - necessary in the colouring process (d).

Knitting (knitting department) is a phase in which products are knit on 8 types of machines (L - 301 GE, L - 412, LA10P5, LA04MJ, L04MJ, LA10P6, LA10P7, LA24E7D), which can be divided into 4 groups depending on the product being knit on them. Group 412 (p1), group 301 (p2), group LA (p3), and group LA MJ (p4). After knitting, socks go to fixing (g) (thermal treatment with steam) and then to the sewing phase.

Sewing (sewing department) is a phase in which sockets and inserts are sewn depending on the type of product. Sewing of fingers is done on machines Sp, where sockets without inserts end their process. Subsequently, certain products continue to the Santoni machines, where fingers sewing and insert merging is performed (Hula-hoop socks are formed). Having in mind that some products are made of lace, they are sent to machines configured to work with lace.

Other products, on which the inserts are sewn, are forwarded to cutting machines (socks cutting) and then to sewing the inserts on the Fl and Un machines, which differ in the type of seams they make. The groups of machines that are being formed are Sp (s1), Sa automatic machines (s2), Lace machines (s3), Tailoring machines (s4), Fl machines group (s5) and Un machines group (s6).

Preparation for colouring (prefabrication department) is a phase in which certain quantities of products, which arrive at this intersection, are packed in canvas bags according to a certain weight, depending on the type of machine in which dyeing will be made.

Colouring (dyehouse department) is a phase in which raw socks are packed in the jackets of certain weights and painted on the basis of the work order and customer's desire. The machines differ in the mode of operation and the type of yarns that are being dyed. Here it is possible to distinguish the so called T, C and B machine types, where machines C have centrifuging in their working procedure, while the items treated on machines B and T after dyeing continue to centrifuging machines. Groups of machines to which the colouring phase can be divided are T group (f1), C group (f2), B group (f3) and group of machines for centrifugation (f4).

After colouring and sintering (centrifuge) socks are headed to drying and ironing phase. In some cases, drying is done on the RF system (for wrinkled socks without ironing), while in others socks that need ironing are directed to dryers (type M and P), after which they continue to ironing operation (T-SD12 and Co machines). Groups of machines identified in the drying and ironing phase are RF system (n1), group of drying machines Mi (n2), Pa group (n3), T-SD12 group of machines (n4) and Co machine group (n5).

Quality control and packing (finishing department) is a phase in which every pair of socks is being check in order to determine if the quality of the socks is adequate, whether the colour is appropriate, as well as whether the physical or mechanical damages were detected. After quality check, socks are being folded and packed in certain boxes at the customer's request, according to the work orders and type. The process takes place in the quality control departments (d1), stacking (d2) and packing (d3).

Transport packaging and palletizing (sorting department) is a phase in which packed sockets (one or more pairs of sockets) are packed in transit packs according to the customer's work order in the carton boxes. Transportation boxes differ depending on the box type (products and quantities) and transport mode (q1). Thereafter, the transport packages are palletized (q2), strewn and store at the storage for finished products (t).

The initial, material flowchart is given in Figure 2. Based on the initial flowchart, its simplification was carried out in order to reduce the complexity of flows and eliminate reverse movements. Additionally, a number of P2 and P3 machines were added to the knitting machine group P1, and a new group of machines - GP1 was formed (Figure 3), due to the fact that certain products can be knitted on any group of machines.

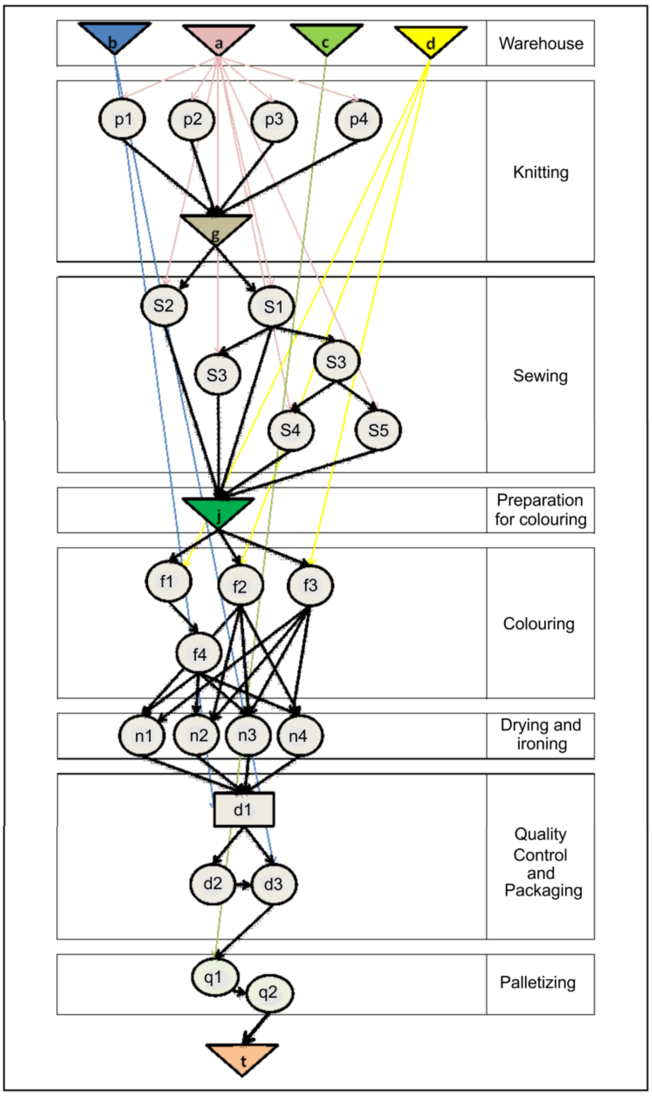

Figure 2. The initial material flowchart

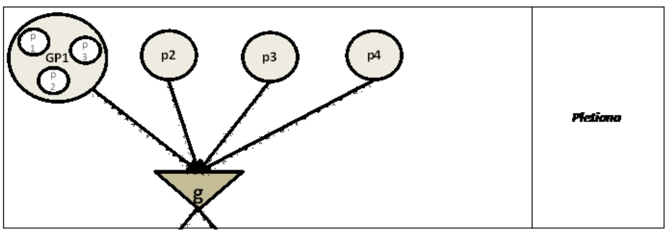

Figure 3. Grouping in the knitting department

Depending on the product material, the products can be dyed on several types of machines. T machines (f1) are used exclusively for stretching yarns in addition to all materials, while other yarns can be dyed on other types of machines. Likewise, some products can be dyed on all types of machines (B (f3), C (f2) and T (f1)). Bearing this in mind, a common group of machines GF1 is formed (Figure 4).

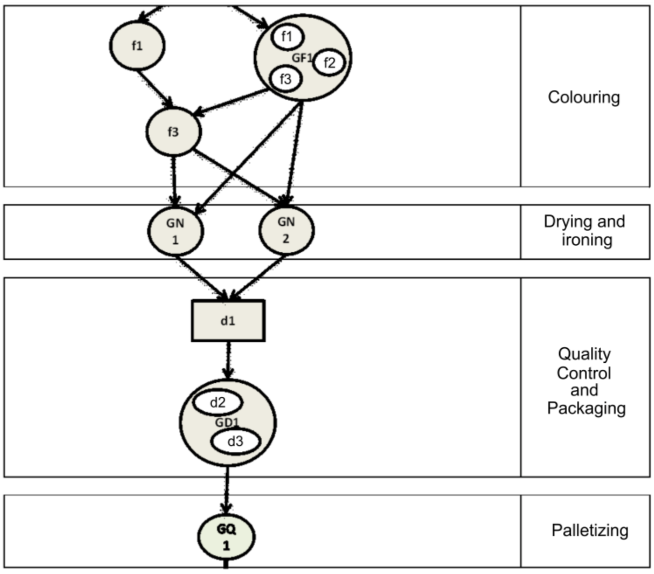

Figure 3. Initial grouping in departments of colouring, drying, finishing and sorting

However, all products are directed to the drying department, to the RF system and driers Mi (n2) and Pa (n3), which form a common group of machines GN1, or ironing where the common group GN2 consists of T-SD12 (n4) and Co (n5) machines.

3.3 **Cell forming through Implanner Cell**

The Implanner Cell software solution enables a group of products to form the same or similar path in the production process through simulation. 33 product representatives have been subjected to simulation, while all relevant alternatives were taken into account (Figure 5). Alternatives are the paths in production in case a particular product can be produced on several different machines of the same group [8].

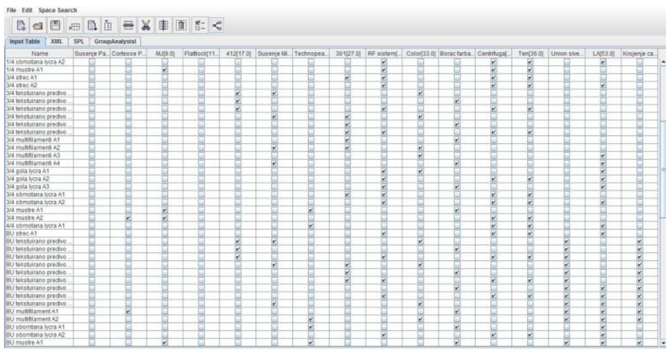

Figure 5. Products Representatives and alternatives (33 products, 104 paths/alternatives)

The entered parameters, which were analyzed by this program, are: cell size 7, which means that the size of cell is up to a maximum of 7 machines inside it respectively; Elimination percentage of 60%; and The number of iterations (10). Due to the limited resources for research, it was not possible to implement ALL steps mode, which allows obtaining a vast number of variants in the solution generation process.

Another input parameter was elimination of certain machines such as Fixir, Sp, Lace Machine and Sa Automats from the path. The reason for elimination is that these machines are present in 99% -100% of the paths like Fixir and Sp, or in only 2% -3% in cases of lace machines and SA Automats. These machines generate exceptions for each of the following groups in a large percentage of the path. However, because they have been classified in the previous group, they couldn't be integrated in the other one.

From Figure 6 it is possible to notice the presence of certain solutions on the Search Space tab under the state 1 folder. Here, the generated Chillds can be divided as input groups that further branch out. Conclusively, the state Child1 0 was selected as the most suitable solution (Figure 7).

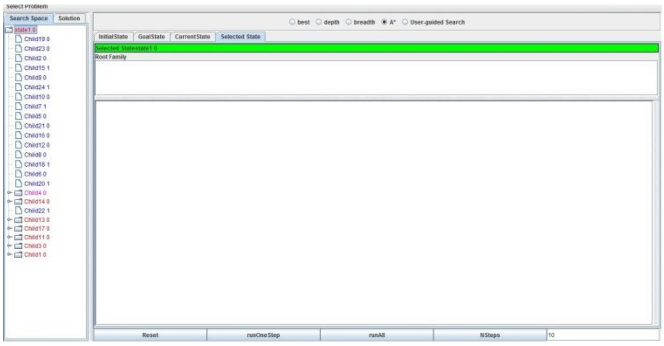

Figure 6. Space searcher interface

Based on the simulation results, a solution that includes three cells was proposed:

- Cell 1 (Figure 7) - consists of machines and workplaces in the departments of: knitting (MJ), sewing (S3 and S1), colouring (f1 and f4), drying and ironing (n5), finishing and sorting. Furthermore, in Cell 1 the majority of products are made of pre-fabricated yarn.

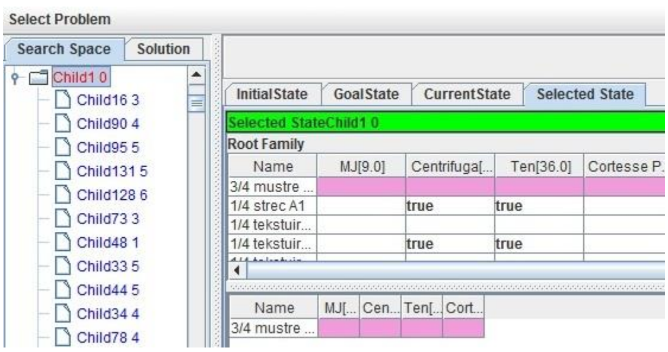

Figure 7. The formation of Cell 1

- Cell 2 (Fig. 8) - consists of machines and workplaces in the departments of: Knitting, LA (P3); Sewing, Fl (S5) and lace machine (S3); Colouring, C (f2), B (f3) and centrifuges (f4); Drying and Ironing, the RF (n1, n2) and T-SD12 (n4); finishing and sorting. In Cell 2, majority of products without inserts, lycra and multifilament are mainly made of textured yarn.

Figure 8. The formation of Cell 2

- Cell 3 (Fig. 9) - consists of machines and workplaces in the departments of: knitting, 412 (P1), tailoring (S4, S2 and S6), Colouring (f2), Drying and Ironing (n1), finishing and sorting. In Cell 3, products from textured yarns with inserts are predominantly made.

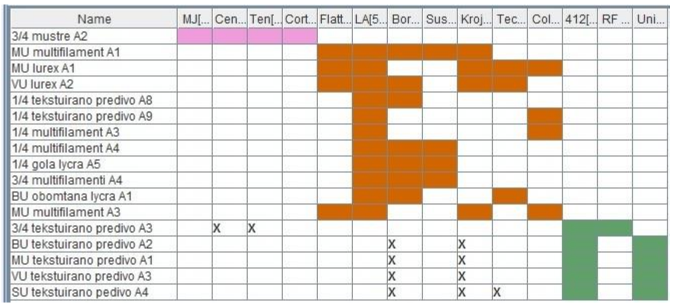

Figure 8. The formation of Cell 3

4. CONCLUSION

The research indicated the possibility of grouping concept application in the production of textile products. Analysis of product flows (PFA), based on existing technological procedures represents a good tool for grouping products with the same paths and desig of cells as basic elements of effective production systems.

Although, applied software allows consideration of a large number of design options in real time, certain shortcomings were detected regarding the width of production program and the number of iterations in the simulation.

The proposed solution of three cells represent a good basis for further activities in the reengineering process of a given production system.

Further research is focused on software improvements such as Saving option, machine number entry, limiting solutions for display, eliminating the possibility of one product participates multiple alternatives.

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