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MODEL OF CAPACITY PLANNING OF BASIC POLYETHYLENE FOILS MANUFACTURING IN THE COMPANY CHEMYZ

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Abstract: *The paper describes the methodology of creation of the capacity planning model and production scheduling, at manufacturing process of basic polyethylene foils in the company Chemyz which deals with the production of packaging materials mainly for the food industry. The complexity of the problem lies mainly in the wide range of assortment connected to possible chemical composition, thickness, widths and purpose of foils use. Model applies the Synchro-MRP method and it is created on the bases of heuristic approach. The aim of the model is to increase flexibility and productivity of the company.*

Key words: *Polyethylene foils, capacity planning, heuristics*

1 INTRODUCTION

The department of manufacturing of basic foils is the first step in the whole manufacturing process. For better illustration of the position of the manufacturing of basic foils follows Fig 1.

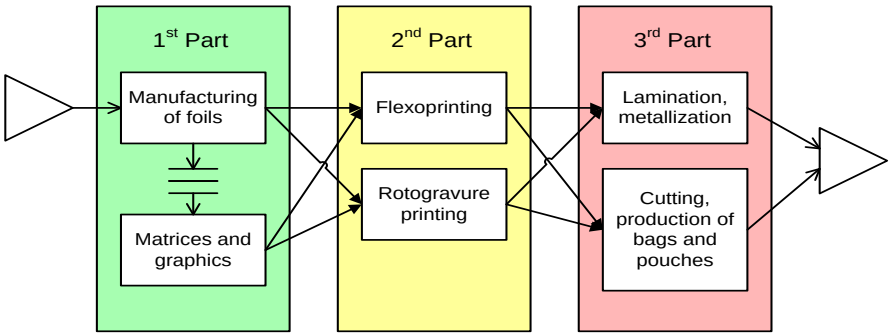


Fig.1 *Three-tact manufacturing process*

The company is divided into three parts at capacity planning. The 1st tact includes basic foils manufacturing and purchasing, in the 2nd there is the printing and in the 3rd tact there are laminating, cutting, slitting and shipping (see the Figure 1). [5], [6]
The assortment of manufactured products in the company Chemyz represents basic polyethylene - PE and polypropylene - PP foils, flexo and rotogravure foil printing, lamination and manufacture of bags and pockets. The company has its own graphic studio and preparation of printing forms for flexo-printing and rotogravure printing.
The assortment of products can be divided into two basic groups:

- Product type of monofoils,
- Product type of laminates (further classified into large range of the assortment). [2], [3], [8].

The basic division of foils:

- Blown (3 layers foils);
- Casted (2 - 5 layers foils).

The basic division of the assortment:

- Barrier foils - polymer (impermeable of certain types of gases): 3 – layers, 5 – layers;
- Polypropylene (so called - the bread foils, suitable for food use): combination of homopolymer and copolymer, pure homopolymer (homo), pure copolymer (copo), twist foil. [4], [8]

Technology of basic foils manufacturing

Manufacturing of basic foils is currently provided on four extruders i.e. blown foils and cast foil technology, i.e. casted foils. The overview of different maximal widths, the number of worms (layers) in the manifold nozzle and manifold nozzle sizes are listed in Tab 1.

Tab. 1 *The overview of width (winding), the number of worms in the nozzle and nozzle dimensions of the technology:*

	Technologies			
	EXT1	**EXT2**	**EXT3**	**EXT4**
Max. width-Wi	W1	W2	W3	W4
Number of worms NWi	NW1	NW2	NW3	NW4
Manifold nozzle size	500	500	500	400

The mixture of granules is prepared by an operator according to the recipe in the technology tab. The granules are melted in the worms (max. number of layers of a foil =

number of worms), homogenized and transported to the extrusion tool (manifold nozzle), where the melt is co-extruded and blown through the nozzle slit to circular cross-section in the form of foil sleeve. Then the process follows this procedure:

1. blowing and stabilization of a bubble – adjustment of the thickness, width by the calibration basket;
2. cooling IBC (internal bubble cooling) and also EBC (external bubble cooling);
3. flattening (by a flattening device);
4. pulling and foil reservation;
5. winding (cutting of a hose to desired foil size);
6. coiling up a roll as a final product, which goes either on sale directly or as an semi-product for further cooperating departments (flexo-printing, lamination, confection, cutting). [7]

2 DEFINITION OF MODEL CREATION PRINCIPLES

Determination of main and alternative technologies

Every product has determined main (most efficient) and alternate technology, where it can be also produced, but with lower efficiency. Example of technology determination is given in the Table 2. (Groups products- GP)

Tab. 2 *The example of technology determination*

The assortment – chemical composition	EXT1	EXT2	EXT3	EXT4
GP1	GP1			
GP2	GP2			
GP3	GP3			
	- main technology		- alternate technology	

The assortment changeover

Changeover is a state, where it is necessary to change one type of material (chemical composition) to another, while it is created a downtime and a waste is produced. A waste is represented by a cleaning of a machine between the manufacturing of two products of different chemical composition. The changeover involves also the exchange of the nozzle. Changeovers respectively changes of assortments are done under the certain rules to these technologies and are explicitly expressed by e.g. the changeover matrix (Tab 3).

The criteria for the efficient operation of technology are: a minimum number of changeovers, the minimum number of nozzles exchanges.

The colours of the assortment changeover

Similar like in the previous case, here are also rules which are explicitly expressed, e.g. network diagrams at extruder EXT2 (Fig 4).

The cumulation of orders and its rules

The cumulation follows these listed rules:

1. The same quality i.e. the same assortment (chemical composition), type;
2. The same thickness;
3. Different widths, if they can be fit into the coiler.

There are necessary to be kept the following parameters for the required width of an order:

- Blown ratio – equation (1) for standard foils: 1,7 – 3;
- Consideration of a half circle circuit: 1,58 (π/2).

It means that it is possible to produce a min. and max. width from the nozzle 500 mm (taking into account the tolerance):

- Minimal width: 500 x 1,7 x 1,58 = 1343 mm
- Maximal width: 500 x 3 x 1,58 = 2370 mm

Thickness is independently controllable variable and has nothing to do with blowing ratio.

$$Blown\ ratio\ \in \frac{\frac{width\ of\ foil\ for\ an\ order \times number\ of\ coils}{nozzle}}{\frac{\pi}{2}} \quad (1)$$

Blown ratio influences the properties of foils, a foil structure is oriented through that nozzle, i.e. for a given speed and temperature there are oriented polyethylene, chains are oriented and a foil acquires its properties.

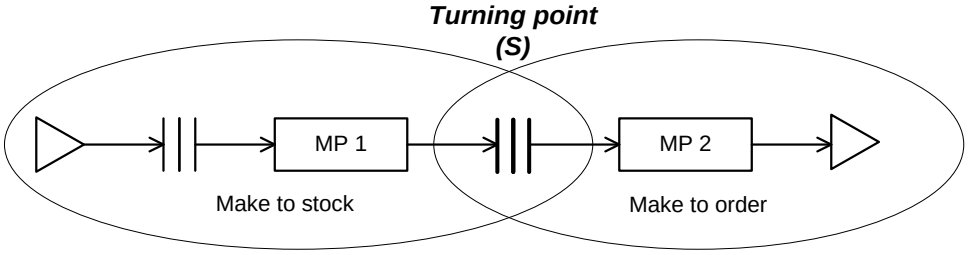
3. PROPOSAL OF THE OPERATIONAL PLANNING MODEL

The conception is based on the analysis, which confirmed the suitability of the present way of capacity planning and production scheduling for particular extruders (technologies). The current way is sophisticated, there were created procedures during a long-term application, which create the appropriate variants of manufacture planning of foils. It is therefore appropriate to apply the heuristic approach that is based on defined and explicit described rules and procedures used at the actual creation of plans by a logistician, to put these rules into the sequence and to draw them into the algorithms (models) for the plans creation. The principle of Synchro-MRP was applied as another strategic principle (Figure 2), and thus it reduces overall manufacturing time of an order execution and increases flexibility. [1], [9]

The levels of foil stocks (in the "turning point" S) were defined based on the analysis of the frequency and volume of contracts over the past two years. "S" means the buffer store of the basic foils at two-week supply of the standard foils.

Then there was applied rule that orders for the manufacturing of foils for the certain planning week N+1 will come out of the consumption in the buffer store "S" in the week N. These may be modified by the prescriptive orders entered by a production manager. The Synchro-MRP is based on the idea that the manufacturing process is divided into 2 parts in terms of planning: [1]

1. MP I - the first part of the manufacturing process, make to stock "S", it is mainly the production of standard foils, which is similar to many products, i.e. planning is provided in the part MP I – by PUSH system, it is planned statistically or with a certain time delay, for example, one time unit (e.g. a week).
2. MP II – it is the manufacturing to order i.e., it is flexible to customers, it is planned by PULL system – make to order – i.e. manufacture of printing.



MP 1 – the first part of manufacturing process – manufacturing of the standard foils
MP 2 – the second part of manufacturing process - rotogravure printing and flexoprinting

***Fig.2** The proposal of production management scheme of basic foils in Chemyz with the principle Synchro – MRP*

Model of capacity planning and scheduling is created by the following activities (Fig 3):

a. The model for calculating of stock levels of standard foils;
b. The calculation of virtual order content (MI, N+1) – the manufacturing volume of products for week N+1 (according to consumption from the stock „S“ in week N);
c. The capacity planning;
d. The cumulating and the sequence planning.

3.1. The model for calculating of stock levels

The calculation of the proportion of particular foils to the manufacturing volume was quantified by using the Pareto analysis. It points out that the total production of 20% of its products in the company provides 80% of the profits. The idea of the method was used to determine the optimal portfolio of the current products composition, but with a buffer – for a risk in the future.

Based on the Pareto analysis of the current data file of the foils manufacturing and a small but regular repeating products it was designed to produce the standard foils and it resulted that 14,22% of all foils with the different thicknesses are involved in nearly 62,8% of total manufactured output. The remaining foils are considered as the special foils that are about 37,2% of the total manufactured foils during the given period in the company Chemyz. Any other foils that were not produced in a given period or new products shall be considered as the special foils.

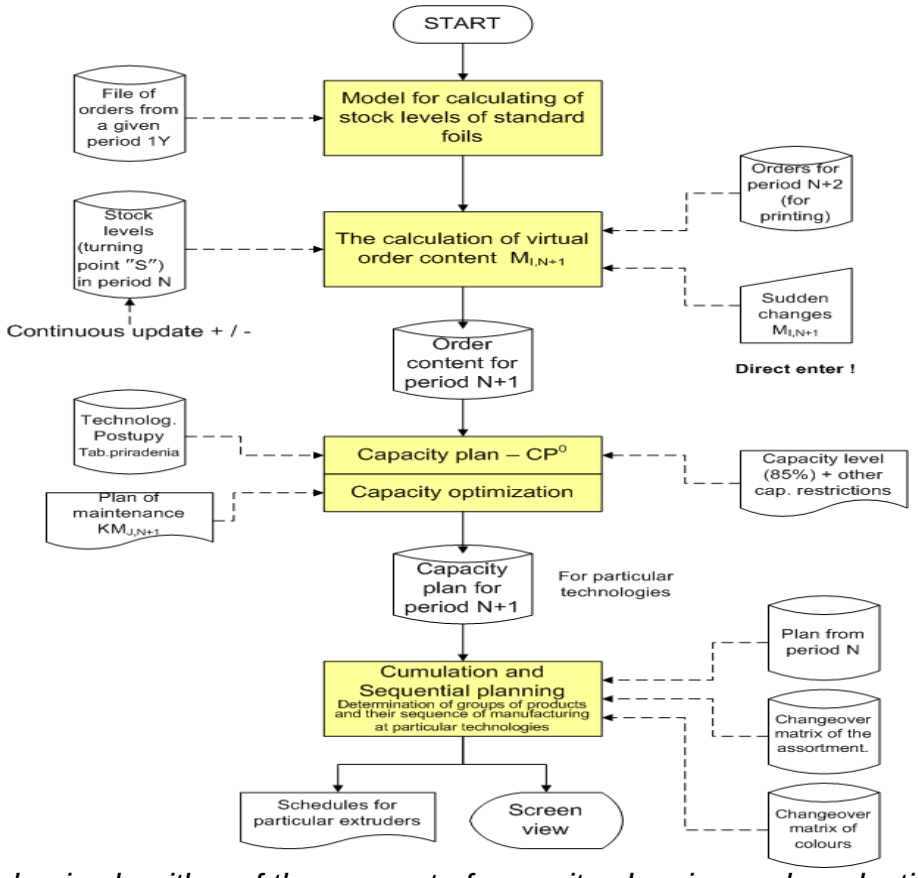


Fig.3 *The basic algorithm of the concept of capacity planning and production scheduling solution*

Two-week stock levels were calculated from the given data file according to equation (2):

$$Two-week\ stock\ level = \frac{Total\ volume\ of\ manufactured\ orders\ during\ given\ period}{number\ of\ weeks\ during\ given\ period}.2 \qquad (2)$$

3.2. The calculation of virtual order content

To add stock levels (and therefore the orders for the manufacturing of foils) for the week N+1 can be defined according to:

1. The basis of the consumption of foils in the week N (if the state is below of the two-week supply), but is produced in whole economically effective batches;
2. The prescriptive enter due to expected consumption e.g. because of a sudden change in the consumption in the downstream manufacturing sections of printing.

Special foils, because they are not produced to the stock, are manufactured on the basis of the material balance of incoming orders for printing. Need foils for week N+2 is manufactured in week N+1.

3.3. The capacity planning model proposal

It is proceed the model of capacity planning after calculation of the order content for the individual extruders. Assignment of the order content for each technology (extruders type EXT1, EXT3, EXT2, EXT4) is done according to the main technology. Thus, it is created the

zero level (unbalanced) capacity plan CP0. After this step, it can be proceed the capacitive balancing – the capacity optimization.

The principle is as follows:

1. Machines are sorted to sequence EXT1, EXT3, EXT2, EXT4, this order is a priority for capacity optimization (ranking from the highest quality technology to less quality);
2. It begins with the first machine J, where the capacity is exhausted;
3. Then it is found an available technology (machine) K with the highest priority;
4. It is found an order with the main technology in machine J and alternate in the machine K;
5. This order is moved from the technology J to K and then there are re-calculated the capacity requirements at the technology J and K;
6. If such an order is not found, it is continued with next available technology K+1 and the procedure is repeated from the point 4;
7. Finally it is found another machine J, where the capacity is exhausted.

The process is repeated until all machines are balanced. If this is not possible, the orders, which cannot be produced for capacity reasons, remain as unmanufacturable in a week N+1 and they are entered in the file of unmanufacturable contracts.

3.4. The production scheduling model

The production scheduling aims to arrange orders to the optimal sequence. Sequential planning is divided into two activities:

- Cumulation orders to groups;
- Sequential planning.

Cumulation

Developing algorithms for cumulation was based on the conditions that production is made to stock. It includes the following procedure:

1. Entering of so called side-runs (side-run is a part of unused width of a foil) into the system (by a logistician of production section).
2. Grouping of orders according to the quality (chemical compos.), then to the thickness.
3. The calculation of the minimum and maximum width of side-runs to each planned order based on the blown circumference.
4. Assigning of side-runs to manufactured orders:
   a. Assigning of manually entered side-run into the calculated tolerance of side-run to each manufactured order;
   b. Assigning of side-run as an order, if the calculated tolerance range of side-run meets some dimensions of orders from the technology and the creation of so called double-order.
   c. Assigning of side-run to defined storing assortment.

Orders with unassigned side-runs will be manufactured in the way that the blown ratio will be closed to 3.

Sequential planning

Criteria for sequential planning:

1. Minimizing of changeovers of chemical composition of the s consecutive orders;
2. Exact date (time) within a week is not set, the production must be executed within one week (manufacturing is made to stock with weekly advance).

Each extruder can be considered as separate element at sequential planning because the rules are different for each extruder. Thus, each technology has different criteria. As an example there is the sequential planning for extruder EXT2:

The situation on the technology EXT2 is the most difficult because it produces a large range of products. It can produce almost complete range of assortment produced at all machines.

Production at this technology already includes coloured assortment of white, black and white and white-black-white. These colours are in particular layers e.g. white-black-white is made up of layers of white - black - white. Possible changeovers are shown in the Figure 4.

The changeover from one type of a white assortment to a clear of another type would cause a high production of waste, because there is a different polymer composition.

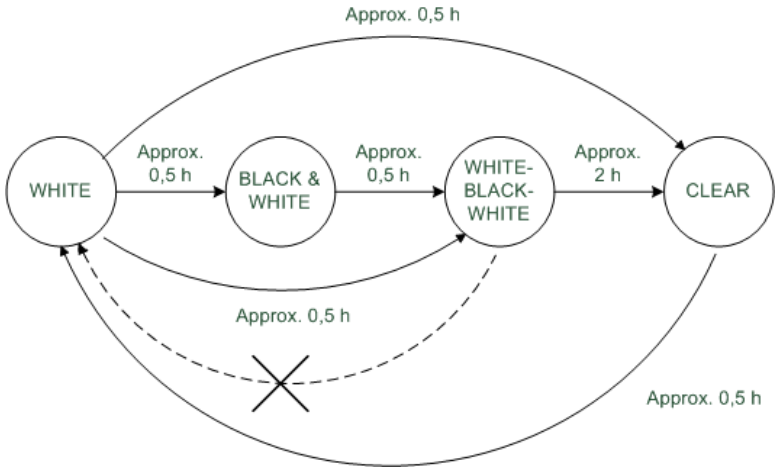


Fig.4 *Network diagrams of colour changeovers*

4 CONCLUSIONS

The proposed system is built as an autonomous information system, which will itself monitor inventory levels, set the level in stocks with directive inputs of extreme or urgent orders. Its autonomy is more advantageous as a link with the capacity planning of printing because of the effectiveness of the work.

The benefits of this planning model are:

a. Increasing of objectivity at inclusion of orders to the plan;
b. Increasing of variability because a person normally created only one option of the plan but this model can serve as a simulator and in a moment it can prepare several variations of the capacity plan and production schedules.
c. Efficiency performance of orders fulfilment was improved, because in the case of obtaining orders with higher priority, the system can be restarted from any time, i.e. changes are not made at random, but they respect all the rules.
d. The model allows establishing an advantageous variant of plan in order of optimizing because optimization criteria are directly incorporated in the model of its work.

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