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CRITERIA FOR MANAGING MATERIAL RESOURCES STOCK AT INDUSTRIAL ENTERPRISES

GONTAREVA IRYNA[1], KROKHMAL SVETLANA[2] AND DOROKHOV OLEKSANDR[3]

ABSTRACT

The purpose of this article is to establish criteria for management of the stock, distributed during the production process.

The article states that at the industrial enterprises with a long production cycle, the material resource is distributed over the various stages of the technological process and ceases to be a resource, only getting the form of products shipped. The authors substantiate the necessity of finding an optimal profile of stock distribution in the course of the multi-phase production process at industrial enterprises.

The synthesis of Green coefficient calculation formula with Wagner-Whitin algorithm was proposed to achieve the optimal profile of levels of different types of stocks.

The article presents the profiles of stock distribution for different types of production with a large multiproduct engineering enterprise "Electrotyazhmash" (Kharkiv, Ukraine) being taken as an example.

Future research will be aimed at improving the accuracy of the calculations and verification of their effectiveness in practice of the other industrial enterprises.

KEYWORDS: *stocks, material resources, management criteria, production process, profile of stocks distribution, Wagner-Whitin algorithm.*

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1. INTRODICTION

The share of material and energy inputs expenditure in the cost of industrial products increases and can reach up to 75%, so the search for the ways of reducing such expenditure has constantly been conducted for a long time.

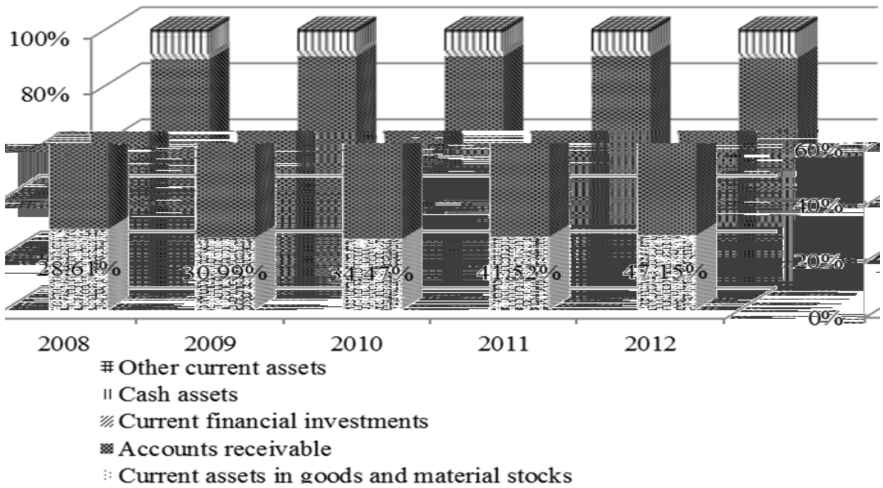
In recent years, the urgency of this problem for the enterprises of Ukraine has increased due to the growth in their volume in the current assets structure Fig. 1.

A way to solve the problem is to increase turnover by reducing stocks of material resources in warehouses. In this case the margin condition for inventory reduction is the possibility of disruptions in the production process.

Many researchers have conducted search for an optimal or rational solution of the problem, though we will only cite those whose work has had the greatest influence on this paper. They are a Nobel laureate in Economics, K. J. Arrow (2000), V. S. Ponomarenko, A. I. Pushkar and O. M. Trydid (2002). The results obtained are undoubtedly important both theoretically and practically.

[1] Simon Kuznets Kharkiv National University of Economics, Department of Economy of Enterprise and Management, e-mail: lider.06@mail.ru
[2] SE Plant "Electrotyazhmash", e-mail: obvorozhitelnaja@ukr.net
[3] Simon Kuznets Kharkiv National University of Economics, Department of Informations Systems, e-mail: aleks.dorokhov@meta.ua

Fig.1. Current Assets Structure in the Industry of Ukraine in 2008-2012.



Source: Ukrstat database, authors' calculation

And yet, some approaches require additional consideration. In particular, it concerns the transition from considering the concentrated material supply management systems to enterprise systems with distributed parameters.

The purpose of this article is to establish criteria for the management of distributed inventory, dispersed in the midstream of the production process.

2. ANALYSIS OF THE LAST RESEARCHES AND PUBLICATIONS

The global criterion of the quality of material procurement is ensuring a stable and smooth process of production. Stability and reliability of the supply system is evaluated by the accomplishment of the tasks facing the company, i.e. the full completion of all planned activities in accordance with the requirements to the deadlines, quality of results and processes for their achievement. Refusal implies disruption in the operation of the production system leading to the failure to accomplish scheduled tasks qualitatively and on time (Gontareva 2012, p. 64).

There are three main groups of stock management methods (Repina 2012, pp. 166-173):

a) direct optimization methods – different models of economically sound stock size and a "just in time" approach based on them;

b) methods based on the queuing theory. They present stock like a stream of elements that are in the queue for being serviced (used);

c) simulation, the most famous model of system dynamics of J. W. Forrester.

Each of these groups has its own advantages and disadvantages, as well as preconditions and limits of applicability. The common thing among them is the fact that groups represent the stock of material resources concentrated in one place: a raw materials warehouse, in-process storage, and finished goods warehouse. Actually, a material resource in different processing power is distributed throughout the manufacturing process and, according to the global criterion of the supply function quality, only ceases to be a resource, getting the shape of a shipped product.

This approach is similar to the model of multiphase queuing system with storage after each stage. However, firstly, these models are not ready for practical use. Only single-phase queuing models are widely described and used (Volkova and Kozlov 2004, p. 508; Kozlovskiy, Markina and Makarov 2006, pp. 93-94). This is due to the great complexity of analytical calculation of efficiency indicators, which requires solution of higher order differential equations (Patrushev and Rembeza 1988, pp. 217-238).

Secondly, it is assumed that the number of phases of the multiphase model is larger than the number of storage space points (Patrushev and Rembeza 1988, p. 137). At the same time, the number of storage space points at an enterprise may exceed the number of phases. Anyway, they are available before the first phase, a raw materials warehouse, and after the final one, a warehouse of finished products. This is because the external resources inflow is not considered in the queuing models, the orders availability is sufficient. In production systems customer needs for products are a necessary but not sufficient condition to start the process. It is the availability of material, technical and human resources which is, in fact, a sufficient condition.

Thirdly, performance indicators of a multiphase queuing system do not take into account the possibility of forming a system-wide stock made up of separate interphase ones, which is the main feature of a distributed system.

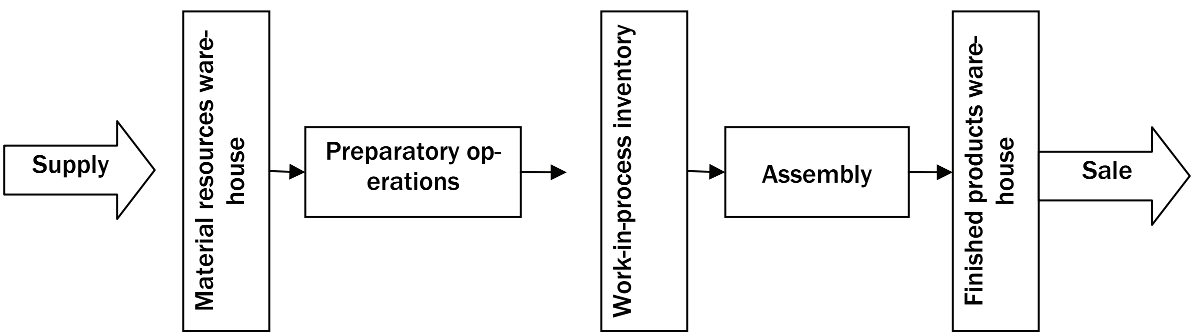
The description of the system with distributed parameters involves changing the values of one or more parameters of the spatial and/or temporal coordinates. The difference in the profiles of distribution of variables in the coordinates can significantly change the indicators of the system performance. In economics, the range problems of distributed systems include, in particular, the problem of finding the optimal relative position of objects for production and sales purposes. In the MRP (Material Requirements Planning) methodology, this approach is applied in product positioning and production technology. The concept of product positioning determines the degree of processing of the objects of labor, of which the enterprise forms the main stocks: raw materials, assembly units and finished products.

The choice of the positioning strategy is based on the desired reaction rate on the order for the supply of products. If you intend to immediately supply rather standardized products, the majority of stocks of the enterprise will contain finished products; if you intend to supply a limited range of assembly units, it is necessary to collect a large number of standard size products, with basic supplies being stored in the form of production reserve; in the single-unit and experimental production the stocks are formed as raw materials (Gavrilov 2002, pp. 46- 49).

Production system response speed increases if stocks are stored in the form of finished products, which results in a decrease of

- efficiency since the cost of storage includes production costs; and
- flexibility of supply under the variations in consumer demand for various standard size products. In other words, it is necessary to build an optimal profile of stocks distribution in the course of the multi-phase production process (Fig. 2).

Fig. 2. Structure of the multiphase production process



Source: authors' own research

The best-known solution to this problem was proposed by J. Green (1997). He introduced the coefficient (K):

$$K = \frac{PT}{DT}, \quad (1)$$

where

PT– the time required for production, the time from placing an order for raw materials until delivery of products to customers (total time of manufacture);

DT – the time of processing the order acceptable by customers (delivery time).

Here we consider three options:

a) the delivery time is longer than the total manufacturing time, while the main stocks should be in the form of raw materials;

b) the delivery time is longer than the time of the final assembly, but shorter than the total manufacturing time, while the main stocks should be in the form of work- in-process inventory; and

c) if the delivery time is shorter than the time of the final assembly, then the main stocks must be formed as finished products. Here it is necessary to make two stipulations: the client's allowable waiting time is a difficult to be defined random variable with a large spread of values; and the coefficient does not give an optimal distribution of stocks throughout the manufacturing cycle stages.

3. THE RESEARCH BASIC MATERIAL

3.1. THEORETICAL RESULTS

To achieve an optimal level profile of different types of stocks it is suggested to modify the coefficient by combining the k coefficient calculation formula with a Wagner-Whitin algorithm.

The Wagner-Whitin algorithm is used to plan the optimum size of lot-sizing run in production and able to meet the a priori known demand in successive time periods. This algorithm is based on the principles of dynamic programming. It uses a system of two equations as the rules allowing the optimal solution (Sadjadi, Aryanezhad and Sadeghi 2009, p. 120.):

$$C_i^{(j)} = S_i + C\left(P_i + P_{i+1} + \ldots + P_j\right) + h(\ J_{i+1} + 2J_{i+2} + \ldots + (j-1)J_j) \qquad (2)$$

$$c_i = \min\left[C_i^{(j)} + C_{j+1}\right], \qquad (3)$$

where

S_i – the cost of resetting or order is accepted as permanent for the period i, UAH;

C – unit price, UAH;

P_i –production in period *i*, units;

h – inventory unit holding cost, UAH;

$C_i^{(j)}$ – total period cost, UAH;

c_i – minimum cost for the two consecutive periods, UAH.

J_i – stocks by the end of period *i*, units

$$J_i = J_{i\ 1} + P_i - d_i\,, \qquad (4)$$

where d_i – demand in period *i*, units.

Despite its complexity, the Wagner-Whitin algorithm is used widely enough in planning lots run in production or determining the optimal materials order size. This is explained by the fact that it captures almost all the limitations of the various modifications of the Wilson immediate optimization formulas (Gonzalez and Tullous 2004).

To solve the posed in the article problem of determining the optimal profile of stocks during the production process the article proposes to present equation (2) in the following way:

$$C_i^{(j)} = S_i P_i + C(P_i + \ldots + P_j) + (h_i P_i + \ldots + h_j P_j), \quad (5)$$

where in this case:

P_i – stocks in phase *i* of the production cycle, units
h_i – inventory holding cost in phase *i* of the production cycle, UAH /units.
In turn:

$$S_i = S(k_{i+1} + \ldots + k_j) \quad (6)$$

$$h_i = Hk_i \quad (7)$$

$$k_i = \frac{Pt_i}{PT}, \quad (8)$$

where

S_i – total order and resetting cost for the whole production cycle, UAH /units;
k_i – coefficient of relative duration of phase *i* of the production cycle;
H – total inventory holding cost for the whole production cycle, UAH /units;
Pt_i – length of the production phase *i* from the start of the production cycle to the end of phase *i*.

The equation (6) shows that the farther from the final phase are basic stocks the higher are costs of supply (distribution) of the product to the customer. Conversely, the equation (7) shows that the closer to the final phase are basic supplies the greater is the cost of storage.

3.2. EMPIRICAL RESULTS

A large engineering multiproduct enterprise can manifest different profiles of stock distribution. Kharkiv "Electrotyazhmash", (Ukraine) produces a wide range of electrical equipment for various industries. The structure of the types of the enterprise products is shown in Table 1.

The largest share in the total commodity output of the enterprise in 2010-2013 is occupied by the traction electric motors, turbogenerator, hydrogenerator and generator production. Each of them has different cycles of production.

Turbogenerator and hydrogenerator production have the longest cycle of production - more than one year, traction electric motors and generator production is characterized by 1.5-3 month long production cycle.

Control facilities production is usually associated with the cycles of turbogenerator production or manufacture of large electrical machines. Control facilities production has a production cycle of about 3-4 months.

Since the products are characterized by different production cycles, as well as various forms of production organization, the production of each type must have an appropriate approach to reproduction of material resources.

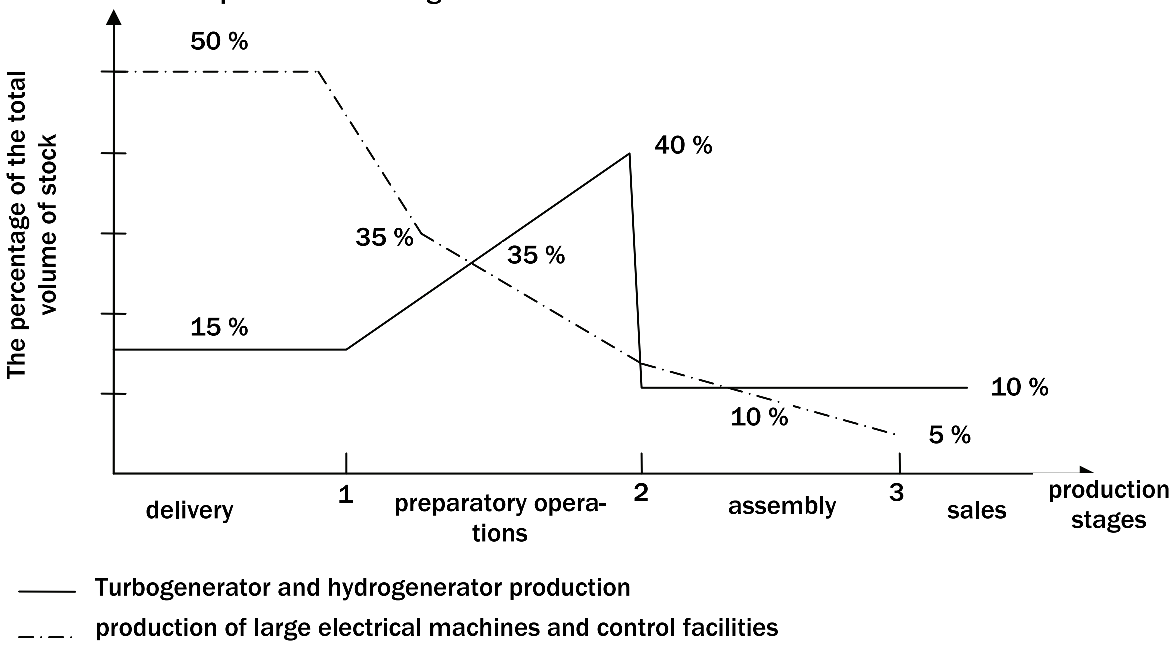
The preliminary analysis shows that determination of the optimal profile of stock distribution using the Wagner-Whitin algorithm is only necessary for the motor and generator production. In turbogenerator and hydrogenerator production, having a long production cycle, single unit output, and no assembly operation (it is carried out either by the client or on the test bench of a related enterprise), the profile of stock distribution is determined experimentally (Fig. 3, solid line).

Table 1: The structure of the types of Electrotyazhmash products

No.	Types of production	2010		2011		2012		2013	
		Thousand UAH	Share, %	Thousand UAH	Share, %	Thousand UAH	Share, %	Thousand UAH	Share, %
1	Turbogenerators and Hydrogenerators	299627,7	34,7	201876,1	18,6	419943,0	28,9	370088,9	29,4
2	Traction electric motors	417385,4	48,3	679728,1	62,8	765359,6	52,7	670284,7	53,3
3	Generators	74183,0	8,6	108165,4	10,0	127806,5	8,8	115333,9	9,2
4	Control facilities	39249,1	4,5	60717,0	5,6	76109,7	5,2	71983,8	5,7
5	Large electrical machines	0	0	5548,8	0,5	28513,3	2,0	2501,6	0,2
6	Other Products	13036,4	1,5	27109,0	2,5	27288,1	1,9	16111,0	1,3
7	Maintenance service	222,2	0	0	0	6181,8	0,4	10940,4	0,9
Total:		864721,3	100,0	1083144,4	100,0	1451202,0	100,0	1257244,3	100,0

Source: . "Electrotyazhmash" database, authors' own research and calculations

Fig. 3. Profiles of stock distribution for turbogenerator and hydrogenerator production, production of large electrical machines and control facilities



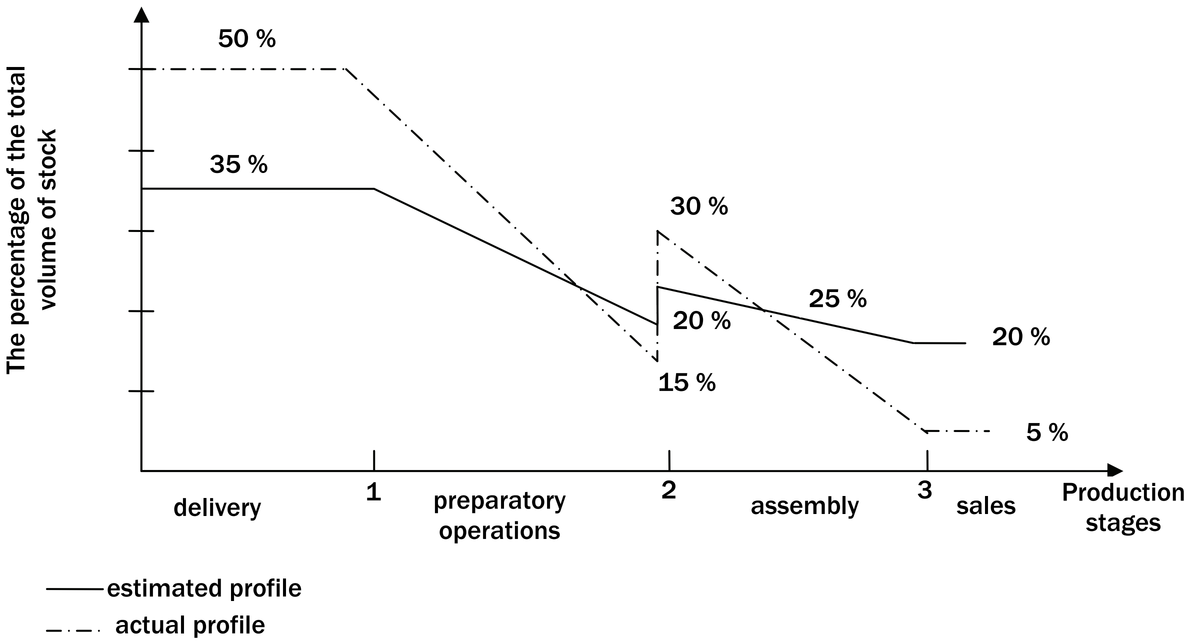
Legend: 1 – material resources storage; 2 - WIP inventory 3 - finished products storage

Source: authors' own research

In the production of large electrical machines with its single item nonscheduled output and related control facilities production the profile is shifted to the material resources storage (Fig. 3, dashed line).

For traction electric motor and generator production the calculations were made using the Wagner-Whitin algorithm and criterion (5) developed in this article. Fig. 4 shows the calculated (solid line) and actual profiles of stock distribution during the manufacturing process.

Fig. 4. Estimated and actual profiles of stock distribution for motor and generator production



Legend: 1 – material resources storage; 2 - WIP inventory 3 - finished products storage

Source: authors' own research

To simplify the calculations the electric motor type EDP-810 was accepted as a single base standard size product by the price and duration of the production cycle, and storage and delivery costs according to the main component of this product. In future it is planned to check the stability of the profile both for different sizes, and average data.

4. CONCLUSION

Thus, the criteria for determining the optimum profile of stock distribution for industrial enterprises during manufacturing process have been modernized. Results showed that the calculated profile differs from that obtained empirically.

Future research will be aimed at improving the accuracy of the calculations and verification of their effectiveness in practice.

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