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Management of Tool Inventory at Mechanical Engineering Plants on the Basis of Statistic Simulation

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Abstract
The issues of tool inventory management at mechanical engineering plants are important in terms of theory and practice.
The main difficulties of management of tool inventory are related with inability to account precisely for all variations in tooling of main process line.
Our study confirms the hypothesis that dynamics of key indices in the field of tooling can be of random nature, which is attributed to simultaneous influence of various factors [1].
This article discusses in details the method of statistic simulation permitting to take into account the influence of numerous factors and to develop the most accurate model describing planning, production and consuming of tools at industrial enterprise.
Key words: process tooling, in-house produced tools, reserves of tools and auxiliaries, tooling stock, tool inventory management, statistic simulation.

1 Introduction

Technological advances in industry are characterized by increased implementation rates of new products, which is accompanied by increased scope of activities devoted to preproduction engineering.

High-quality and appropriate tooling of main process lines make it possible to increase significantly labor efficiency, to decrease expenses and labor consumption for production, to improve the use of fixed assets and, finally, to reduce the lead time [1, 2].

Up-to-date system of tool inventory management at industrial enterprise should support solution of the following functional tasks [3]:

1. Setting of standards: development of material and labor standards, timing of process cycles for production of tools and auxiliaries, determination of limits for each process stage;
2. Planning: selection of short-term and project promotion methods;
3. Accounting: accounting of labor and material consumptions, equipment load, accounting of delivery and consumption of tools and auxiliaries, rejects;
4. Monitoring: monitoring of individual and total plan performances, monitoring of reserves of tools and equipment;
5. Control of delivery of engineering equipment to main process lines.

The main task is planning of reserves and production of engineering equipment and auxiliaries for continuous operation of main process lines.

2 Planning of reserves

A model of consumption and renewal of tool reserves is based on regularities and variables of distribution characterizing this random process. These variables are comprised of distribution of lot sizes delivered to storehouse from tool shops, distribution of time intervals between ordering of tool production and delivery [4]. Rational value of guaranteed reserve should provide steady delivery of tools to working areas according to demands of main process lines.

Statistic simulation is comprised of three main steps [5, 6]:

1. Generation and acquisition of random data in order to predefine their distribution pattern.
2. Simulation of random events.
3. Analysis of the acquired results.

Distribution laws of lot sizes and time intervals before ordering and tool production are determined by processing of statistic material based on analysis of their actual values in random selection. The analysis is initiated by plotting of distribution histograms [7]. Then the statistical data are smoothed using preselected analytical function for evaluation of probability density. The selected function should be coordinated as much as possible with experimental data. Various fitting criteria are applied for estimation of accuracy of the verified hypothesis including Pearson's chi-squared test [5].

Tools' delivery and consumption are simulated as follows:

Let us introduce the following designations:

R_m is the current reserve, measured in natural units, pieces;

R_{op} is the reserve corresponding to order point;

R_g is the guaranteed reserve in natural units;

R_{end} is the reserve at the end of delivery cycle;

n is the tool lot size;

q_{op} is the time interval required for production of tool lot, the level of order point in time units;

j_i is the time of delivery of the i-th tool lot to storehouse;

j_{op} is the time when the next tool lot is ordered;

q_{suff} is the time interval with sufficient tool reserve due to current reserve;

j_{suff} is the time when current tool reserve reaches zero;

Δq is the tool reserve at delivery of a next lot expressed in tie units.

At the start of the first delivery cycle, the tool reserve is zero. At this time the first tool lot is delivered to storehouse. The lot size corresponds to the first random number obtained with the consideration for normal distribution law of lot sizes [5]

The current tool reserve at this time is comprised of the reserve existing at the cycle start plus the size of delivered lot.

Then the time interval is calculated with sufficient tool reserve due to current reserve and the time when the current reserve reaches zero according to the equations:

$$qsuff = \frac{R_T}{P_M};$$

$$j_{suff} = j_{i-1} + q_{suff}, \quad (1,2)$$

where j_{i-1} is the time of delivery of previous tool lot to storehouse; for the first delivery cycle it is zero.

At the next calculation stage, the time is determined when tool delivery is ordered. The variable q_{op} is standard, it is calculated as follows:

$$q_{op} = \frac{R_{op}}{P_M}, \quad (3)$$

$j_{op} = j_{suff} - q_{op}$, if $j_{op} > j_{i-1}$, otherwise, $j_{op} = j_{i-1}$

The delivery time of the next i-th tool lot is calculated as follows:

$$j_i = j_{op} + t_i, \quad (4)$$

where t_i is the random number calculated by exponential law of distribution with variable λ=1.47.

The i-th delivery cycle is finished at the time j_i. At this time the remaining tools at storehouse are determined in natural units as follows:

$$\Delta q_i = j_{suff} - j_i; \; R_{end} = \Delta q_i * P_M \quad (12)$$

If these values are negative, then tool shortage takes place.

Table 1 summarizes the calculations according to the given algorithm.

Delivery cycle No.	Initial reserve	Lot size	Current reserve	Guaranteed reserves of tools	Order point	Lot arrival time	Final reserves
	Pieces	Pieces	Pieces	Months	Months	Months	Months
	$P_M * \Delta q$	N	$з_т$	j_{suff}	j_{op}	j	Δq
1	0	44	44	2	0.77	1.92	0.08
2	1.00	22	23	2.968182	1.922727	2.71	0.26
3	5.00	56	61	5.485455	4.258182	5.19	0.30
4	6.00	79	85	9.051818	7.824545	8.65	0.40
5	8.00	77	85	12.51818	11.29091	11.74	0.78
6	17.00	89	106	16.55909	15.33182	15.93	0.63
7	13.00	2	15	16.61364	15.93182	17.72	-1.11
8	-25.00	45	20	18.63091	17.72182	18.73	-0.10
9	-3.00	75	72	22.00455	20.77727	22.28	-0.27
10	-7.00	27	20	23.18636	22.27727	22.94	0.25
11	5.00	35	40	24.75545	23.52818	24.01	0.75
12	16.00	13	29	25.32636	24.09909	26.47	-1.14
13	-26.00	10	-16	25.74182	26.46909	27.65	-1.91
14	-42.00	29	-13	27.05818	27.64909	28.41	-1.35
15	-30.00	33	3	28.54545	28.40909	29.62	-1.07
16	-24.00	4	-20	28.71	29.61909	30.07	-1.36
17	-30.00	38	8	30.43273	30.06909	32.25	-1.82
18	-40.00	42	2	32.34	32.24909	32.67	-0.33
19	-8.00	53	45	34.71455	33.48727	34.17	0.55
	Shortage	-235.00	Average	-23.5			

Table 1: Calculations for Experiment No. 1

In order to increase validity of reserve stock, it is required to carry out several experiments. Average shortage for all experiments expressed in natural units determines minimum required reserve stock for all tool types.

Calculations for two other experiments are summarized in Table 2 and 3 below.

Delivery cycle No.	Initial reserve	Lot size	Current reserve	Guaranteed reserves of tools	Order point	Lot arrival time	Final reserves
1	0.00	66	66	3	1.772727	3.19	-0.19
2	-5.00	78	73	6.510909	5.283636	6.70	-0.19
3	-5.00	57	52	9.067273	7.84	8.46	0.61
4	13.00	28	41	10.32364	9.096364	9.66	0.67
5	14.00	49	63	12.52	11.29273	11.85	0.67
6	14.00	31	45	13.89818	12.67091	13.12	0.78
7	17.00	43	60	15.84818	14.62091	15.66	0.19
8	4.00	48	52	18.02455	16.79727	17.27	0.76
9	16.00	85	101	21.85818	20.63091	21.29	0.57
10	12.00	64	76	24.74545	23.51818	24.09	0.66
11	14.00	51	65	27.04273	25.81545	26.82	0.23
12	4.00	60	64	29.72455	28.49727	29.39	0.34
13	7.00	42	49	31.61455	30.38727	31.06	0.56
14	12.00	48	60	33.78455	32.55727	33.23	0.56
15	12.00	45	57	35.81818	34.59091	35.94	-0.12
16	-3.00	85	82	39.66818	38.44091	39.48	0.19
17	4.00	37	41	41.34455	40.11727	42.72	-1.37
18	-31.00	75	44	44.71727	43.49	44.29	0.43
19	9.00	45	54	46.74455	45.51727	47.77	-1.02
20	-23.00	20	-3	47.63091	47.76727	48.66	-1.03
	Shortage	-67.00	Average	-13.4			

Table 2: Calculations for Experiment No. 2

Delivery cycle No.	Initial reserve	Lot size	Current reserve	Guaranteed reserves of tools	Order point	Lot arrival time	Final reserves
1	0.00	88	88	4	2.772727	3.75	0.25
2	5.00	68	73	7.070909	5.843636	7.26	-0.19
3	-5.00	62	57	9.854545	8.627273	9.20	0.66
4	14.00	83	97	13.60636	12.37909	13.17	0.44
5	9.00	32	41	15.03273	13.80545	14.65	0.39
6	8.00	49	57	17.23636	16.00909	17.93	-0.69
7	-16.00	37	21	18.88364	17.92909	19.77	-0.89
8	-20.00	25	5	19.99636	19.76909	20.27	-0.27
9	-7.00	29	22	21.26909	20.26909	20.93	0.34
10	7.00	59	66	23.92909	22.70182	23.87	0.06
11	1.00	56	57	26.46273	25.23545	25.78	0.69
12	15.00	34	49	28.00273	26.77545	27.62	0.39
13	8.00	24	32	29.07	27.84273	29.76	-0.69
14	-16.00	1	-15	29.08091	29.76273	30.23	-1.15
15	-26.00	62	36	31.86909	30.64182	31.94	-0.07
16	-2.00	68	66	34.94182	33.71455	34.86	0.08
17	1.00	49	50	37.13727	35.91	36.36	0.78
18	17.00	60	77	39.86	38.63273	39.48	0.38
19	8.00	54	62	42.30091	41.07364	41.64	0.66
20	14.00	38	52	44.00727	42.78	43.20	0.81
	Shortage	-92.00	Average	-13.1429			

Table 3: Calculations for Experiment No. 3

On the basis of the acquired data, the amount of reserve stock for the considered tool size can be accepted at about 17 pieces. Hence, the stock corresponding to order point will increase and amount to 44 pieces.

3 Conclusion

The described planning method makes it possible to consider for numerous random factors and to develop the most precise model describing the planning, production and consuming of tools at industrial enterprise. This model, adjusted for individual managerial, economical and engineering features of certain industrial company, should be used as the main basic component of complex management system of tool inventory at enterprise.

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