

Optimising stock management in foundries to keep the economic size of orders

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Abstract

Skillful stock management is one of the main conditions to raise the production output of an enterprise, foundry shop included. This article outlines modern methods of stock management using the generally available Excel calculation sheet to estimate the economic order quantity and minimum stock level required for selected auxiliary materials used in foundry production.

Keywords: computer-aided foundry production, stock management, logistics, economic order quantity.

1. Introduction

Proper management of foundry stock, including frequent inspections of the content of a store-room - should enable undisturbed run of production and failure-free, current servicing of goods traffic. Proper management of the store-room has an enormous impact on the cost level in a foundry shop. Depending on whether the foundry enterprise is in charge of casting production or casting trade, the trade costs and material costs make from 45% to 90% of the total turnover.

The most important aspect of the stock management is to have (at any time) complete information on the volume of the stock on hand. This information can be obtained from data collected in book-keeping (provided this operation is done in a sufficiently reliable and trustworthy manner) of all the stock-related operations related to a particular type of goods. In effective stock management, a very important role is played by the cost reduction and cost optimising, including determination of the, so called, „critical stock level”, as quite often "optimum" costs do not necessarily mean "minimum" stock on hand. Quite often it happens so that a rough estimate of the general stock level leads to a false conclusion that the level of stock is high and stable, while in reality a more detailed review of some specific goods (raw materials, semi-finished products, and ready-for-use

materials) may indicate some serious irregularities and zero reserve of materials indispensable for the uninterrupted run of production process [1].

2. Methods and results

Even in the case when a foundry store-room contains a large variety of different goods, it is possible - using a calculation sheet - to control the stock in quite an efficient manner. The main task to be done is to prepare and keep in the database sheet an inventory (or list) and add at the end of each reporting day the values of income and expenditure. In this, quite simple, way it is possible to get at any moment exact information on the stock level available in store-room along with other, sometimes very valuable, pieces of information.

The principle of running a store-room is apparently quite simple - the first step is to establish the current stock on hand, examining each item separately, the second step is to record any changes. The value of the income is added to the initial stock, the value of the expenditure is subtracted:

$$\text{Final stock} = \text{initial stock} + \text{income} - \text{expenditure} \quad (1)$$

Every change in the stock assortment should be marked with a date, and final stock at the end of a reporting period (e.g. one day) will make the initial stock on the day to follow:

$$\text{Initial stock on day } x = \text{Final stock on previous day} \quad (2)$$

The analysis of stock management presented in this paper will be based on a specific example of a chosen assortment of goods (designated with index 000.011.A), necessary for production in a selected foundry shop. For calculation an Excel sheet will be used.

The first head line of the sheet holds five fields with the following items: *Index, Date, Stock, Income, Expenditure*, and *Reminder* (Fig. 1).

1	A	B	C	D	E	F	G
1	Indeks	Data	Stan	Przychód	Rozchód	Przypomnienie	

Fig.1. Fragment of calculation sheet with head items

In the block of cells I2:K6 of this sheet, the following data have been entered for a selected item: *Price/piece - Cena/szt*, *Date of Supply- Termin dostawy*, *Availability of Supply - Gotowość dostawy* (calculated probability of supplies consistent with orders placed during previous periods of cooperation with the supplier), *Storage cost - Koszty składowania* (including, among others, the rent fees, preparing the storage site and other storage means, etc.), *Cost of Order - Koszty zamówienia* (results from the ordering procedure, also includes the cost of telephone calls to a supplier, the cost of preparing documentation, and the cost of delivery) (Fig. 2). Cells J8 and J9 give preliminary determination of *Minimum Stock On Hand - Stan minimalny* and *Size of Order - Wielkość zamówienia*.

	I	J	K
2	Cena/szt	15,00	Zł
3	Termin dostawy	3	Dni
4	Gotowość dostawy	98,00%	
5	Koszty składowania	20%	
6	Koszty zamówienia	10,00	Zł
8	Stan minimalny	1850	Sztuk
9	Wielkość zamówienia	4000	Sztuk

Fig.2. Fragment of the data sheet used in optimising the stock on hand

The creation of a database starts with introducing the index of an article (cell A2). Having formatted column B in the category *Date - Data* of the type *yyyy-mm-dd*, enter to cell B2 the first date (the first operation done on an article in the store-room), e.g. 2002-05-01 (Fig.3). Enter next to cell C2 (showing the stock on hand) the expression allowing for formula (1): *Initial stock + income - expenditure*. So, when the initial stock is e.g. 3000

pieces, the formula will assume the following form: $=3000+D2-E2$. Enter to cell E2 the size of the first expenditure e.g. 50 (pieces).

	A	B	C	D	E	F	G	H	I	J
1	Indeks	Data	Stan	Przychód	Rozchód	Przypomnienie				
2	000.011.A	2002-05-01	2950	=3000+D2-E2	50				Cena/szt	15,00
3	000.011.A	2002-05-01	2850		100				Termin dostawy	3
4	000.011.A	2002-05-02	2690	=C2+D3-E3	160				Gotowość dostawy	98,00%
5	000.011.A	2002-05-03	2490		200				Koszty składowania	20%
6	000.011.A	2002-05-03	2360	=JEŻELI(C2<=\$J\$8;"Zamówić !";")	130				Koszty zamówienia	10,00
7	000.011.A	2002-05-04	2260		100					
8	000.011.A	2002-05-04	2010		250				Stan minimalny	1850
9	000.011.A	2002-05-05	1840		170	Zamówić !			Wielkość zamówienia	4000

Fig.3. Creating the database of the stock

Enter to cell F2 formula $=""$, since in creation of all further records in the stock database, we shall use one of the tools called *Form - Formularz*, available in Excel menu *Data - Dane*. Enter to cell G2 formula *IF... -then ORDER =JEŻELI(C2<\$J\$8;"Zamówić !";""),* to get under the head title *Reminder - Przypomnienie* displayed the message *Order - Zamówić*. This refers to the case when the current stock level (the value in cell C2) is lower than the one defined in cell J8, which is the minimum level. Copy next to cells A3, B3, F3 and G3 the contents of cells A2, B2, F2 and G2. In cell C3 write down a formula computing the current stock level in the store-room (from formula 1): *Initial stock + income - expenditure* ($=C2+D3-E3$), and enter to cell E3 the current value of *expenditure*, e.g. 100 (Fig. 3).

To use a tool very handy in creation of the database, that is the tool called *Form - Formularz*, mark the block of cells A1:G3 and choose the command *Form - Formularz* in menu *Data - Dane* (Fig. 3).

Fig.4. The window *Form - Formularz* with information on the read in records is a dialogue window for data loading

Having loaded all the stock-related data to the sheet *Stock On Hand - STAN_MAGAZYNU* (the data cover the selected period of time, e.g. 3 months), create now the sheet called *Expenditure - ROZCHÓD*, in which the size of the annual expenditure will be

determined (Fig. 5). For this purpose define in cells B1 and B2 the starting („First day”) and the ending („Last day”) value of the date, using data comprised in the sheet *Stock On Hand - STAN_MAGAZYNU*, assuming that in this sheet maximum 2000 records can be loaded. Next, in cell B3, through straight subtraction, compute the difference in days between the date of the first and the last record. To this difference (amounting to 91 days) add figure one (one day) because the true number of the book-keeping days is 92.

	A	B	C	D	E	F
1	Pierwszy dzień	2002-05-01		=STAN_MAGAZYNU!B2		
2	Ostatni dzień	2002-07-31		=MAX(STAN_MAGAZYNU!B2:B2000)		
3	Liczba dni księgowania	92	Dni	=B2-B1+1		
5	Rozchód sumaryczny	13 200	Sztuk	=SUMA(STAN_MAGAZYNU!E2:E2000)		
7	Przewidywany rozchód roczny	52 369	Sztuk			
				=ZAOKR.DO.CAŁK((365/B3)*B5)		

Fig.5. Fragment of the sheet *Expenditure - ROZCHÓD*

The total (summed up) expenditure in the reporting period (cell B5 – Fig. 5) is calculated by adding all values of the expenditure comprised in the sheet *Stock On Hand - STAN_MAGAZYNU* (in column E). Next, the anticipated annual expenditure is determined dividing the number of the days in a year (365) by the number of the days in the accepted reporting period and multiplying the result by total expenditure within the reporting period (cell B7). This value should be rounded off to the whole number.

In the next sheet called *Daily Expenditure - ROZCHÓD_DZIENNY* copy to columns A and B the dates and expenditures from the relevant column of the sheet *Stock On Hand - STAN_MAGAZYNU* (Fig. 6).

	A	B	C	D
1	Data	Rozchód	Kumulowanie rozchodu dziennego	Dzienny rozchód skumulowany
2	2002-05-01	50	=B2	=JEŻELI(A2=A3;"",C2)
3	2002-05-01	100	150	150
4	2002-05-02	160	=STAN_MAGAZYNU!E2	160
5	2002-05-03	200	200	=JEŻELI(A3=A2;C2+B3;B3)
6	2002-05-03	130	330	330

Fig.6. Fragment of the sheet *Daily Expenditure - ROZCHÓD_DZIENNY*

To compute the total expenditure during one day of the store-room operation, otherwise called. *Cumulative Daily Expenditure - Rozchód dzienny skumulowany*, enter to cell C2 the formula =B2, which copies the value of the first expenditure on the first day of the store-room operation, while to cell C3 enter the formula IF =JEŻELI(A3=A2;C2+B3;B3), which - depending on the change of the date - will compute the sum of all the values of the expenditure or will copy the relevant value of the expenditure. To obtain in column D the cumulative expenditure falling to each day of the store-room operation, enter to cell D2 formula IF

=JEŻELI(A2=A3;"",C2) which, according to change in the date of the next book-keeping (a comparison of the content of cells A2 and A3), will either return an empty string of characters (if the date has not changed – that is A2=A3), or will return the content of cell C2 (cumulative expenditure), if the date has changed. This formula is copied to cell D3. Next, the block of cells C3:D3 is copied to the remaining cells in columns C and D.

To obtain information on structure of the daily expenditure, a division into classes should be made, determining next the frequencies of occurrence (absolute, relative and cumulative) of the individual classes, that is, computing the number of cases when the daily expenditure is corresponding to an identified class. The division of daily expenditure into classes is a good illustration of the method, very useful in statistics, which consists in replacing the detailed enumeration series (which the values of the daily expenditure obviously are) with a distributive interval series.

To create a series composed of e.g. 40 classes, it is necessary to form in column G a series of values from 2,5% to 100% at a step of every 2,5% (Fig.7).

	G	H	I	J	K	L
1	Odsetek	Klasy wielkości rozchodu		Częstość występowania rozchodu		
2	maks. rozchodu	Dolna granica	Górna granica	bezwzględna	względna	skumulowana
3	2,5%	0	11	1	1%	1%
4	5%	11	21	0	0%	1%
5	7,5%	=I3	32	2	2%	3%
6	10	=ZAOKR(G3*MAX(\$D\$2:\$D\$165);0)		7	8%	11%
7	12,5%	42	=CZĘSTOŚĆ(D2:D165;I3:I4)	9	=J3/SUMA(\$J\$3:\$J\$42)	21%

Fig. 7. Fragment of the sheet with computed frequencies of occurrence of the expenditure in identified classes

Enter to cell H3 (Fig. 7) the value 0 (this is the lower limit of the first interval), while in cell I3, to determine an upper limit of this interval, use formula *Rounded off - ZAOKR(G3*MAX(\$D\$2:\$D\$165);0)*, since the above is a rounded off 2,5% value of the maximum daily expenditure. Copy first the formula to cell I4, and next copy to cell H4 the value of an upper limit of the first interval, which will make the lower limit of the second interval. Copy next the content of cell block H4:I4 to the remaining cells of the block in which the limits of the remaining intervals are comprised. On the other hand, to determine absolute frequencies of occurrence in a given class of expenditure, enter to cell J3 (Fig. 7) a rather complicated table function *FREQUENCY=CZĘSTOŚĆ(D2:D165;I3:I42)*, which states the distribution of frequencies in the form of a vertical table. As a first argument of this function (*Table data - dane*) give the address of the block which comprises the data for which the frequency has been computed; as a second argument (*Table intervals-przedziały*) give the address of the intervals which comprise the values from the first table (*Table data - dane*). Since this is the table function, and the function should be entered into the remaining cells of the block, after copying the content of cell J3 to the memory, mark the whole block of the resultant cells and, placing cursor in the field of the formula, press simultaneously three keys [SHIFT], [CTRL] and [ENTER].

A relative (percent) frequency of the expenditure in the first class can be determined dividing the absolute frequency by the number of all daily expenditures. To the first cell in block (L3), in which the percent cumulative frequencies had been computed, the content of cell K3 was copied, and then to cell L4 a formula =L3+K4 was entered, copied next to the remaining cells of the block in which the percent cumulative frequencies of the expenditure had been computed.

Finally, using *Excel Tool - Narzędzie Excela* from *Menu Data analysis - Analiza danych: the Descriptive Statistics - Statystyka Opisowa*, the main characteristics of the descriptive statistics regarding the size of the daily expenditure (loss) were estimated for a given reporting period (Fig. 8). As follows from the obtained results, the mean value of the daily loss within the reporting period amounted to about 143 pieces, while the median (the middle value in the ordered series) assumed a slightly lower value of about 120 pieces. The (relatively) high value of standard deviation (about 97,5) and of the variability index equal to about 68% (i.e. the deviation-to-mean ratio) indicate a high degree of the variability (dispersion, scatter) of the daily expenditure (loss).

	N	O
2	Statystyki opisowe	
3	średniego ubytku dziennego	
4	Średnia	143
5	Błąd standardowy	10,2
6	Mediana	120
7	Dominanta (Tryb)	50
8	Odchylenie standardowe	97,49
9	Przedział zmienności (Zakres)	410
10	Minimum	10
11	Maksimum	420
12	Suma	13200
13	N	92
14	Wskaźnik zmienności	67,95%

Fig. 8. Selected characteristics of descriptive statistics as referring to the size of expenditure within the reporting period

The obtained results of computations are illustrated with graphs plotted in Figs. 9 and 10.

From plotted diagrams it follows, among others, that in 80% of cases the daily expenditure has not exceeded 200 pieces of the examined item. The average daily loss (expenditure) amounted to about 140 pieces. If this value was accepted as an output value in computation of the safe stock reserve, only smaller part of the expenditure faced until now would be covered. For this reason, in determination of an optimum stock on hand and orders to be placed, it is required to allow not only for an average value of the expenditure faced within the reporting period, but also for its distribution and structure. So, in the discussion to follow, an assumption will be made (though perhaps not always correct) that the values from the reporting period should be valid also in future. In the new sheet, called *Minimum Stock Level - STAN_MINIMALNY*, orders have been computed for the

number of the days which will have elapsed until the supply is ready and for the required availability of the supply.

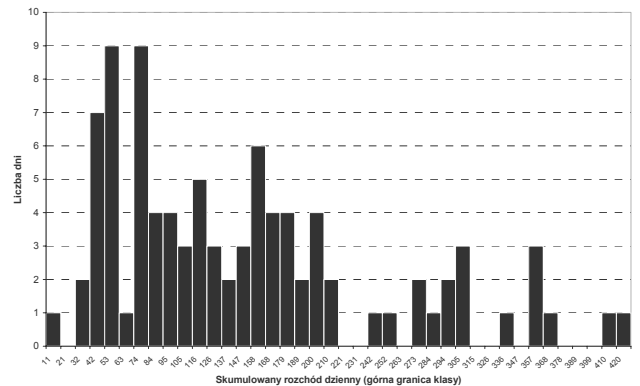


Fig. 9. Absolute frequencies of occurrence of the expenditure in identified classes

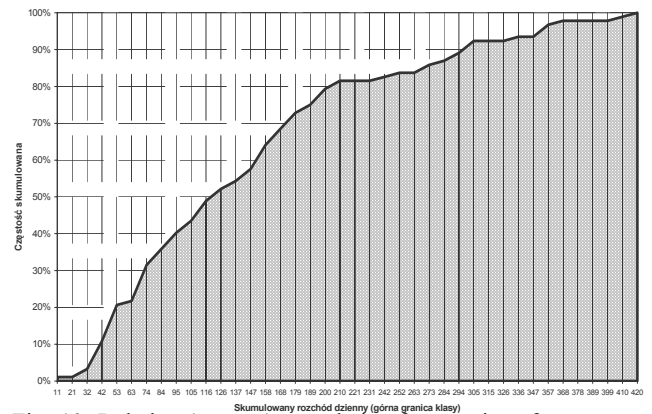


Fig. 10. Relative (percent) cumulative frequencies of occurrence of the expenditure in identified classes

After copying the necessary values from the sheets *Daily Expenditure - ROZCHÓD_DZIENNY* and *Stock on Hand - STAN_MAGAZYNU*, in cell B3 (Fig. 11) the relative cumulative frequency was computed for the established date of supply according to formula: =1-(1-A3)^\$B\$2, determined from the following expression:

$$100\% - (100\% - \text{Skumulowana_częstość_danej klasy}\%)^{\text{Termin_dostawy}} \quad (3)$$

$$100\% - (100\% - \text{Cumulative_frequency in_given class}\%)^{\text{Date_supply}}$$

	A	B	C	D	E	F	G
1	Częstość	Termin dostawy [dni]	Klasy wielkości rozchodu		Gotowość dostawy:	98,00%	
2	skumulowana rozchodu	3	Dolna granica	Górna granica	Stan minimalny:	278	
3	1%	3,23%	0	11	=STAN_MAGAZYNUIJ4		
4	1%	3,23%	11	21	=ROZCHOD_DZIENNYI3		
5	3%	9,47%	21	32	=ROZCHOD_DZIENNYI3		
6	11%	29,19%	32	42	=ROZCHOD_DZIENNYI3		
7	21%	50,04%	=1-(1-A3)^\$B\$2	53	=STAN_MAGAZYNUIH3		
8	22%	52,07%	53	63			
9	32%	=ROZCHOD_DZIENNYI3	63	74			

Fig. 11. Fragment of the sheet *Minimum Stock Level - STAN_MINIMALNY*

The *Minimum Stock Level* - STAN MINIMALNY was computed in cell G2 (Fig.11). For this purpose, the formula *Search Vertically... Daily Expenditure* - =WYSZUKAJ.PIONOWO ((1-G1)+B3;B3:D42;3)*B2+(B2/2)*ROZCHÓD_DZIENNY!O4 was used. The computed minimum stock level, amounting to about 278 pieces, was next transferred to cell J8 of the first sheet *Stock On Hand* - STAN_MAGAZYNU in the folder.

As a last step, an optimum batch of goods that should be kept in the store-room, and that is called economic order quantity (Q), is computed [2,3]. For this purpose, to a newly created sheet *Size of Order* - WIELKOŚĆ_ZAMÓWIENIA the necessary data were copied from other sheets (block of cells B1:B4) (Fig. 12).

The economic size of product batch Q (The Economic Order Quantity) was computed in cell F1 (Fig.12) using the following equation:

$$Q = \sqrt{\frac{2 \cdot \text{Zapotrzebowanie}_{\text{roczne}} \cdot \text{Koszt}_{\text{zamówienia}}}{\text{Cena}_{\text{sztuki}} \cdot \text{Koszt}_{\text{składowania}}\%}} \quad (4)$$

$$Q = \sqrt{\frac{2 \cdot \text{Demand}_{\text{annual}} \cdot \text{Cost}_{\text{order}}}{\text{Price}_{\text{piece}} \cdot \text{Cost}_{\text{storage}}\%}}$$

In cell F2 the estimated economic order quantity was rounded off to a decimal place. As follows from the obtained data, an optimum size of order (in respect of cost minimising) is 600 pieces, so to optimise the cost of running a store-room, it is recommended not to order the batch of 4000 pieces established formerly, but only 600 pieces of the examined item. The obtained economic order quantity was copied to cell J9 in first of the sheets *Stock On Hand* - STAN_MAGAZYNU in the folder.

	A	B	C	D	E	F	G
1	Cena szt.	15,00	=STAN_MAGAZYNUJ2		Ekonomiczna wielkość zamówienia:	590	Sztuk
2	Koszty składowania	20%	=STAN_MAGAZYNUJ5		Zaokrąglona wielkość zamówienia:	600	Sztuk
3	Koszty zamówienia	10,00	=STAN_MAGAZYNUJ6	=ZAOKR.DO.CALK(PIERWIASTEK((2*B4*B3)/(B1*B2)))			
4	Rozchód roczny	52369	=ROZCHODI\$B\$7		=ZAOKR(\$F\$1;ZAOKR.DO.CALK(LOG(\$F\$1)))		
5							
6		=A9*\$F\$2	=ZAOKR.DO.CALK(\$B)	=C9*\$B\$	=B9/2	=E9*\$B\$1*\$B\$	=D9+F
7							
8	Współczynnik	Wielkość zamów.	Liczba dostaw	Koszty zamówienia (zł)	Stan magazynu (szt.)	Koszty składowania (zł)	Koszty ogólne (zł)
9	0,2	120	436	4 360	60	180	4 540
10	0,3	180	290	2 900	90	270	3 170
11	0,4	240	218	2 180	120	360	2 540
12	0,5	300	174	1 740	150	450	2 190
13	0,6	360	145	1 450	180	540	1 990
14	0,7	420	124	1 240	210	630	1 870
15	0,8	480	109	1 090	240	720	1 810
16	0,9	540	96	960	270	810	1 770
17	1	600	87	870	300	900	1 770
18	1,1	660	79	790	330	990	1 780
19	1,2	720	72	720	360	1 080	1 800
20	1,3	780	67	670	390	1 170	1 840
21	1,4	840	62	620	420	1 260	1 880
22	1,5	900	58	580	450	1 350	1 930
23	1,6	960	54	540	480	1 440	1 980
24	1,7	1020	51	510	510	1 530	2 040
25	1,8	1080	48	480	540	1 620	2 100
26	1,9	1140	45	450	570	1 710	2 160
27	2	1200	43	430	600	1 800	2 230
28	2,1	1260	41	410	630	1 890	2 300
29	2,2	1320	39	390	660	1 980	2 370

Fig.12. Computation of the economic order quantity in the sheet *Size of Order* - WIELKOŚĆ_ZAMÓWIENIA with data necessary for plotting of the cost diagram

To create data for the graphic representation of cost structure, to the block of cells A8:G8 in the sheet *Size of Order* - WIELKOŚĆ_ZAMÓWIENIA (Fig.12) were entered proper head titles, and in the first column of the block of data (in cells A9:A29) were defined examples of the values of the coefficients (e.g. from 0,2 at a step of 0,1 up to 2,2), for which the cost components and the overall cost should be computed (Fig. 12).

To compute the cost components and the overall cost for the selected coefficients, the following operations should be done:

- to compute the *Size of Order* - *Wielkość zamówienia* (in cell B9) for a given multiplier (equal to 0,2), multiply it by the, rounded off to the second place, *Rounded Off Size of Order* - *Zaokrągloną wielkość zamówienia*, that is =A9*\$F\$2.
- the *Quantity of the Necessary Supplies*- *Liczba koniecznych dostaw* was computed in cell C9, rounding off to the whole number the quotient of the *Annual Expenditure* - *Rozchód roczny* divided by the *Size of Order* - *Wielkość zamówienia*, that is - *Rounded off to the whole number* =ZAOKR.DO.CALK(\$B\$4/B9).
- the item *Cost of Order* - *Koszty zamówienia* was computed in cell D9 multiplying the formerly computed *Quantity of Orders* - *Liczbę zamówień* by the *Cost of Each Order* *Koszt* każdego zamówienia, that is =C9*\$B\$3.
- the average *Stock On Hand* - *Stan magazynu* was computed in cell E9 dividing the *Size of Batch* - *Wielkość partii* by two, that is =B9/2.
- the overall *Cost of Storage* - *Koszty składowania* was computed in cell F9 multiplying the average *Stock On Hand* - *Stan magazynu* by *Price/piece* - *Cena/szt.* and, expressed in percent, *Cost of Storage* - *Koszty składowania*, that is =E9*\$B\$1*\$B\$2.
- the *Overall Costs* - *Koszty Ogólne* were computed in cell G9 adding *Cost of Order* - *Koszty zamówienia* to *Cost of Storage* - *Koszty składowania*, that is =D9+F9.

The formula from the block of cells B9:G9 was copied to the block of cells B10:G29 obtaining data for the diagram of cost structure, wherefrom one can, without any difficulties, read an optimum value of the batch of ordered goods.

Finally, a diagram of the cost structure can be plotted allowing for the series: *Overall Costs* - *Koszty ogólne* (G9:G29), *Cost of Storage* - *Koszty składowania* (F9:F29) and *Cost of Order* *Koszty zamówienia* (D9:D29) (Fig.12).

The diagram showing in a very clear way the cost structure was plotted in a new sheet called *Graph of Cost Structure* - WYKRES_STRUKTURY_KOSZTÓW (Fig. 13). On this diagram, the point of intersection of the line *Cost of Order* - *Koszty zamówienia* determines on the axis of abscissae (which is the *Size of Ordered Batch of Goods* - *Wielkość zamawianej partii artykułu*) an optimum (economic) size of order. For this point, the line of *overall costs* - *koszty ogólne* approaches most the axis of abscissae. From the diagram it follows that this point (the saddle point) is equal to about 590-600 pieces.

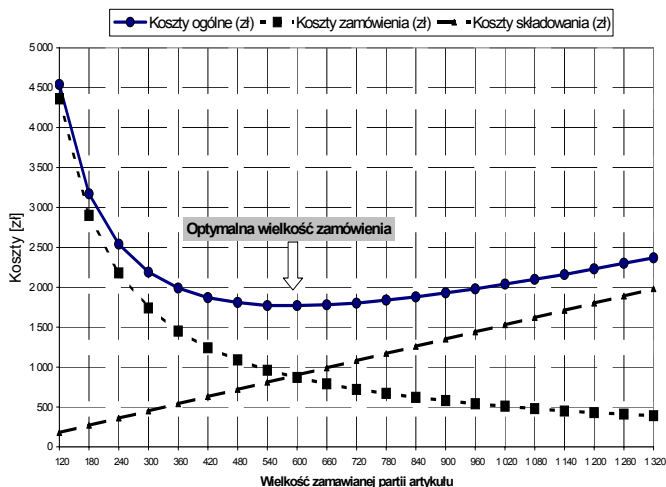


Fig.13. Cost structure diagram in the store-room of a foundry shop plotted for a selected item

3. Summary and conclusions

Basing on the description of an optimum stock management in foundry, it can be concluded that an excellent tool for analysis of this type is a very popular calculation sheet operating in the Excel program.

Optimising the stock management requires knowledge of the basic economic relationships.

Basing on the results of a three-month analysis of the store-room operation carried out in order to optimise its management for a selected assortment of goods ordered by the foundry, it was concluded that the minimum stock level providing the lowest cost of the store-room operation amounting to 1770 PLN (with other parameters, i.e. Price/Piece - *Cena/szt*; Date of Supply - *Termin dostawy*; Availability of Supply - *Gotowość dostawy*, Cost of Storage - *Koszty składowania*, Cost of Order - *Koszty zamówienia*, kept at the same level as adopted previously) would be ensured with the goods level of about 280 pieces, while the minimum size of the supply of the examined item to the store-room should be kept at a level of about 600 pieces.

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