THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^{0}. 4 – 2010, ISSN 1453 – 083X

VALUE ANALYSIS BETWEEN ART AND TECHNIQUE

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ABSTRACT

Value Management is a method that provides an operating technique using a creative and organized approach. The Value Management includes Value Analysis managed by a group, each of them selected by their expertise in specific subjects and coordinated by a Value Analysis expert. The paper presents a complete study of Value Analysis applied specifically to one equipment, with one finality: re-design two selected pieces (the Flywheel and the Bearing). The phases and iterative operation of the Value Analysis method are presented. Value Analysis combines both engineering and economics without, however, placing either engineering or economics first. They both are similarly important, as can be concluded by the end of this paper.

KEYWORDS: value management, value analysis, value, optimum variant

1. Value analysis

Value Analysis is a method that provides an operating technique utilizing a creative and organized approach. It is managed by a group, each of them selected by their expertise in specific subjects and coordinated by a Value Analysis expert.

The Value Analysis group activity is managed in seven stages:

1.formation and functional analysis,
2.creativeness,
3.evaluation and selection of the proposals,
4.the creative phase,
5.development of the selected proposals,
6.presentation of the selected proposals, set in order by priority,
7.implementation phase.

An example of Value Analysis is presented, applied to the re-design of a jaw crusher used for primary crushing of a wide variety of materials in the mining, iron and steel and pit and quarry industries.

Next the establishing mode of the optimum constructive solution is presented from the technical and economic viewpoint for *two parts participating in two functions with a high cost:*

1. the Flywheel which contributes to the function F7 (it ensures the uniformity of the movement) and

2. the Bearing which contribute to the function F4 (it supports the assembly).

2. Establishing the list of functions and dimensions

Table 1 presents the list of functions of the jaw crusher.

Table 1. *List of functions (*FS – Service function, ***FE – Estimation function)*

Symbol	Function	Type of function	Technical dimension of function		
			Name	UM	Value
...					
F4	*It supports the assembly*	*FS*	*weight*	*daN*	*20000*
F5	Aesthetics	FE***	colour, form	-	7
F7	*It ensures the uniformity of the movement*	*FS*	*revolution pulsation*	*rpm rad/sec*	
...					

3. Establishing the levels of importance of the functions-step 1

Table 2 presents the value weighting of the functions. The following percentage values of the functions value weighting result: X_{F1}=20%, X_{F4}=17.8%, X_{F3}=15.6%, X_{F7}=13.1%, X_{F5}=11.1%, X_{F6}=8.89%, X_{F2}=6.67%, X_{F10}=4.44% and X_{F9}=2.22%.

The product value is equal to the sum of the functions levels and is equal to 45.

The studied jaw crusher is shown in [8].

Table 2. *Value weighting of the functions (*X coordinate)*

Functions	F1	F4	F3	F7	F5	F6	F2	F10	F9	Total
No. of points	9	8	7	6	5	4	3	2	1	45
Ratio	0.2	0.17	0.15	0.13	0.11	0.08	0.06	0.04	0.02	1
*Percentage %	20	17.8	15.6	13.3	11.1	8.89	6.67	4.44	2.22	100
Functions	F1	F4	F3	F7	F5	F6	F2	F10	F9	Total

4. Economic dimensioning of the functions

Costs were assigned to the various functions by means of the functions-costs matrix shown in Table 3.

The percentage values of the functions participation in the total cost are: Y_{F1} = 16%, Y_{F4} = 14.3%, Y_{F3} = 15.2%, Y_{F7} = 14.4%, Y_{F5} = 11.7%, Y_{F6} = 7.83%, Y_{F2} = 11.2%, Y_{F10} = 4.79% and Y_{F9} =4.6%

Table 3. *Distribution of costs on functions (*Y coordinate, ** monetary units)*

No.	Parts	Functions									Cost part**
		F1	F4	F3	F7	F5	F6	F2	F10	F9	
7	Flywheel	20			15			30	10	25	100
...											
17	Bearing	250	30					70	20	30	400
...	...	550	700	750	720	500	400	410	215	175	4420
Total cost		820	730	775	735	600	400	570	245	235	5110
Ratio		0.16	0.14	0.15	0.14	0.11	0.07	0.11	0.04	0.04	1
Cost of functions %		16	14.3	15.2	14.4	11.7	7.83	11.2	4.79	4.6	100

5. Diagrams

The construction of the diagrams is presented.

Based on the values for coordinates x_i and y_i presented in Table 4 the diagrams of Figures 1, 2 and 3 are plotted.

The parameters have the following computed values: a = 0.93, α = 42.9^o, S = 4.57, S' = 0.

Table 4 provides the necessary values for constructing the following types of diagrams:
1. in Figure 1, the diagram of the functions value weighting,
2. in Figure 2, the diagram of the functions cost weighting,
3. in the Figure 3, the diagram of the functions value and cost weighting.

Table 4. *Computational elements for plotting the diagrams*

No	**Computational elements**	**Functions**									**Total value**
		F1	F4	F3	F7	F5	F6	F2	F10	F9	
1	X_i	20	17.8	15.6	13.3	11.1	8.89	6.67	4.44	2.22	100
2	Y_i	16	14.3	15.2	14.4	11.7	7.83	11.2	4.79	4.6	100
3	$(X_i)^2$	400	316	242	177	123	79.0	44.4	19.7	4.93	1407
4	$X_i * Y_i$	320.9	254	235	191	130	69.5	74.3	21.3	10.2	1309
5	$(Y_i - a*X_i)^2$	6.493	5.03	0.49	3.94	1.99	0.19	24.5	0.43	6.41	49.57
6	S' *	101.9	79.7	-21	-52	-31	7.76	-66	-5.8	-11	2E-13

$^*S' = 2 * a * (X_i)^2 - 2 * X_i * Y_i$

Figure 1 shows the ranking of the functions by their value.

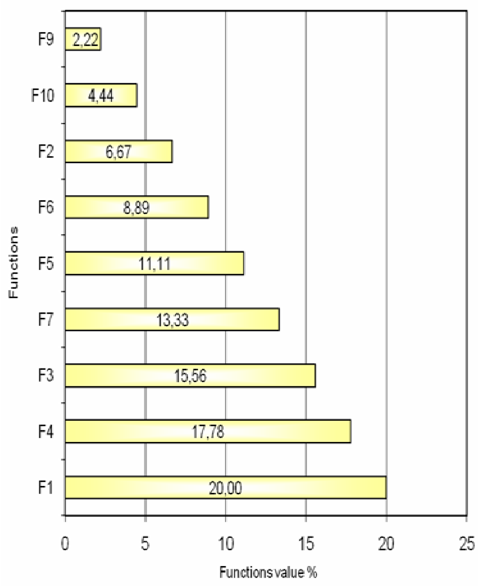


Fig.1. *Diagram of the functions value weighting.*

Figure 2 shows the ranking of the functions by their functional cost.

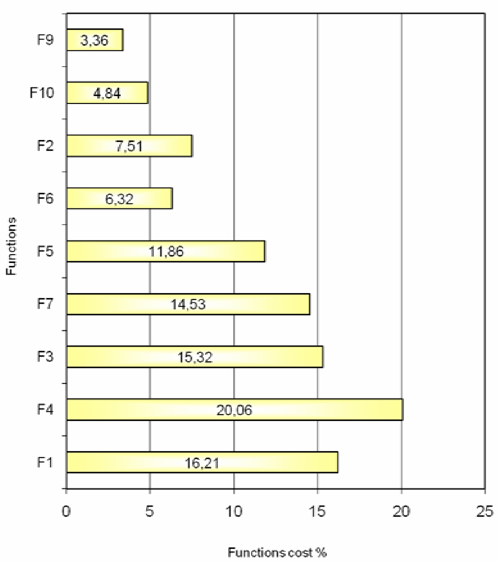


Fig.2. *Diagram of the functions cost weighting*

The diagram reveals a Pareto type distribution, meaning that 20 - 30% of the total number of functions include 70 - 80% of the total costs of the functions. These functions are F1, F4, F3 and F7.

In the case of such a distribution, the first functions in the order of costs, representing 20 - 30% of the total number of functions (in the above example functions F1, F4, F3 and F7) are considered to be very expensive functions.

The real situation is represented by the shape of the straight line in Figure 3, plotted by means of the smallest squares method, and showing disproportions in the distribution of costs and in the contribution of the various functions to the value of the product.

An analysis of the diagram in Figure 3 shows that functions F9, F5, F7 and F4 are located above the regression line, indicating high costs, not justifiable in relation to the value.

These aspects allow the assumption that these functions are deficient, hence the solutions to be identified are to focus on those assemblies, parts, materials and technological operations that contribute, within the general structure of the product, to the achievement of these functions.

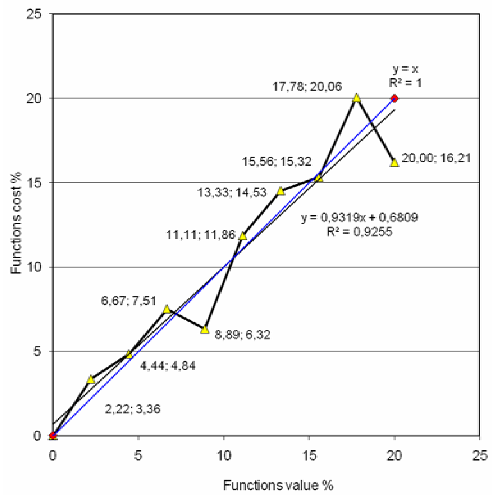


Fig. 3. *Value and cost weightings of the functions.*

A basic criterion of Value Analysis is obtaining a minimum value for S’.

In order to diminish estimator S’, the points need to be aligned as perfectly as possible along the straight line y = a * x, with a tilt of 45^o.

Firstly, in order to diminish the costs, those functions will be re-designed that are located above the straight line.

For the points below the line the problems is more complicated.

By diminishing the cost of the functions above the straight line, it may change its tilt and the points initially located below the line may appear above it. It is also evident that by diminishing the cost of certain functions the total costs of the product decreases, the weighting of the functions that were not modified increasing implicitly.

This is another cause for some points relocating from below the straight line to above it, without, however, any modification occurring in the absolute value of the costs of these functions.

Secondly, the minimization of S’ needs to be understood in the sense of growth of the value/cost ratio as much as possible, and not in the sense of imposing S’ = 0.

Thirdly, Value Analysis also admits the increase of the costs of some functions, provided their value increases at a faster rate than the costs.

Practically, the criterion of minimization of S’ leads most often to cascading Value analysis studies, the optimization of the constructive solution being thus an iterative process. At first, the functions above the regression straight line are analyzed and their costs reduced, then the regression line is re-plotted and the functions relocated above it are noted; these functions too are analyzed in view of reducing their costs, followed by the re-plotting of the regression line, etc.

Hence the constructive solution is improved from one iteration to the other.

6. Establishing the functional-technological form of the parts in view of cost reduction for the flywheel

An analysis from the technical and economic viewpoint will be carried out in order to select a technically optimum variant for *two selected pieces of equipment: the flywheel and the bearing.*

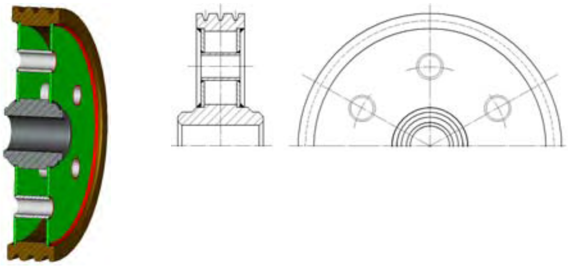


Fig. 4. *Flywheel made of the welded semi-products.*

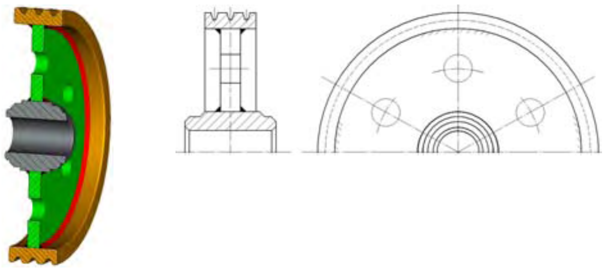


Fig. 5. *Flywheel made from the welded semi-products.*

Four constructive variants of flywheel will be studied and eventually the most cost effective and the most competitive one from the technical and economic viewpoint will be selected. Figures 4 and 5 present a flywheel made of the welded semi-products.

The functional characteristics for this type of part are the following:

1. maximum diameter, diameter of engagement, geometrical elements of connecting gear,
2. internal diameter of wheel hub, concentricity between flywheel axis and diameter of engagement,
3. wearing resistance, reconditioning method.

Figure 6 presents a flywheel screw assembled and Figure 7 presents a flywheel made of a cast semi-product.

All variants are technological and the selection of one of them depends on the level of endowment of the company.

The constructive variant in Figure 7 obtained from a cast semi-product ensures the best functional characteristics, if the technical conditions for heat treatment are provided. It has, however, the disadvantage that it allows only one solution for reconditioning: build-up welding and re-machining to the initial functional dimensions.

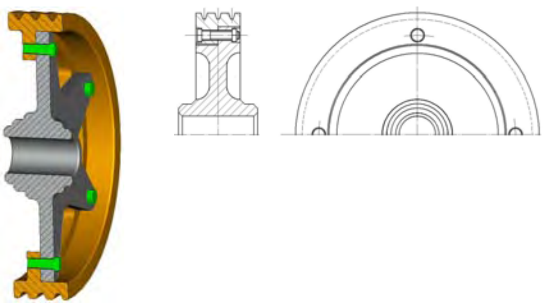


Fig. 6. *Flywheel screw assembled*

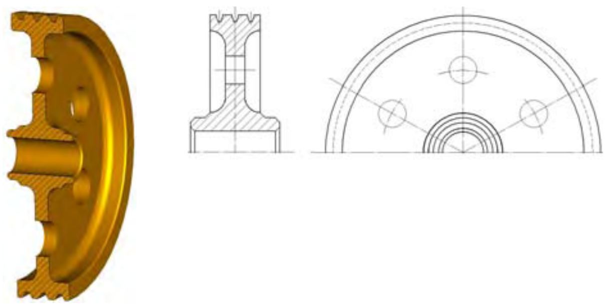
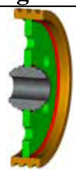


Fig. 7. *Flywheel made of a cast semi-product*

7. Comparison of the variants for flywheel

Table 5 presents the denotings by 9 assessment criteria of the analyzed constructive variants of a flywheel. The variant in Figure 7 has obtained the highest score, and will thus be selected as the constructive solution within the assembly of the jaw crusher.

Table 5. *Synthetic table with the analyzed constructive variants for flywheel*

No.	Analysis criteria	Figure 4	Figure 5	Figure 6	Figure 7
					
1	Functional characteristics	4	4	4	4
2	Semi-product	1	2	3	4
3	Mechanical machining	1	2	3	1
4	Mounting	4	4	4	4
5	Repair	4	4	4	4
6	Rigidity	3	3	2	4
7	Ergonomics	2	2	2	4
8	Aesthetics	3	3	3	4
9	Cost	1	2	3	4
	TOTAL	23	26	28	33

8. Establishing the functional-technological form of the parts in view of cost reduction for the bearing

An analysis from the technical and economic viewpoint will be carried out in order to select a technically optimum variant for the bearing. Six constructive variants of bearings will be studied and eventually the most cost effective and the most competitive one from the technical and economic viewpoint will be selected.

The analysis of the constructive variants for the support (bearing) in Figures 8, 9, 10, 11, 12 and 13 is presented further on.

The Figures 8, 9 and 11 show three constructive – technological variants of the support (bearing): welded semi-product made of three, six and five modules, the Figures 10 and 12 shows two constructive cast semi-product and Figure 13 presents a complex bearing.

The constructive variant of Figure 12 obtained from a cast semi-product ensures the best functional characteristics, if the technical conditions for heat treatment are provided. It has, however, the disadvantage that it allows only one solution for reconditioning: build-up welding and re-machining to the initial functional dimensions. The difficulty in this case is applying a heat treatment subsequent to reconditioning.

Fig. 8. *Support made of welded semi-products.*

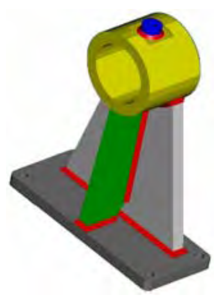


Fig. 9. *Support made of welded semi-products.*

Fig. 10. *Support made of cast semi-product.*

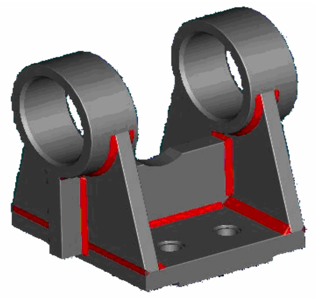


Fig. 11. *Support made of two welded semi-products*

Fig. 12. *Support made of cast semi-product*

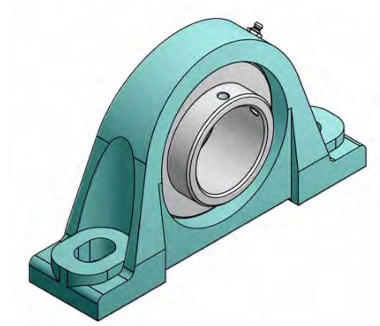
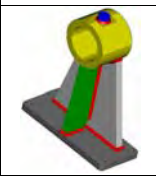
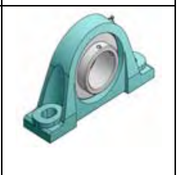


Fig. 13. *Complex bearing*

9. Comparison of the variants for bearing

Table 6 presents the denoting by 9 assessment criteria of the analyzed constructive variants of a bearing. But in many cases the bearing must be made of two parts, to facilitate quick installation and removal of all assembly (Figure 14 and Figure 15). The bottom can body with the cradle, can be incorporated into the cradle.

Table 6. *Synthetic table with the analyzed constructive variants for bearing.*

No.	**Analysis criteria**	**Figure 8**	**Figure 9**	**Figure 10**	**Figure 11**	**Figure 12**	**Figure 13**
							
...	...						
9	Cost	5	4	4	3	6	2
	TOTAL	45	40	42	39	*51*	41

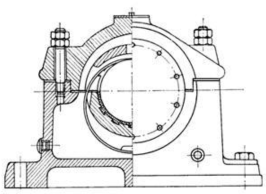


Fig. 14. *Complex bearing*

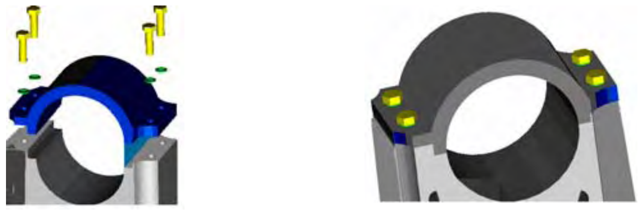
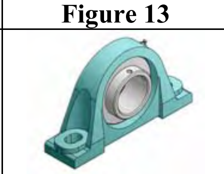
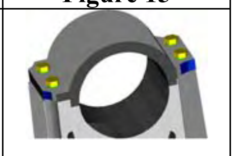


Fig. 15. *Bearing incorporated in to the cradle*

Given the option of Figure 14 and 15, the Value Analysis study may be repeated, for comparing the share value and cost functions and this is the next step of the study and Table 7 presents the new denoting by 9 assessment criteria of the analyzed constructive variants of a bearing.

Tabele 7. *Synthetic table with the analyzed constructive variants for Bearing.*

No.	**Analysis criteria**	**Figure 10**	**Figure 12**	**Figure 13**	**Figure 15**
					
...	...				
9	Cost	4	6	2	3
	TOTAL	42	*51*	41	***49***

The variant in Figure 12 obtained a score better than the version in Figure 15, but in many cases the bearing must be made of two parts, to facilitate quick installation and removal of the assembly.

The score obtained by the variant in Figure 15 is less than the cast version in Figure 12, but choise of the variant in Figure 15 is made because the weight of the advantages is greater than the weight of disadvantages for variant in Figure 12.

The version in Figure 15 has the following advantages over the version in Figure 12:

1. installation and removal are all much easier,
2. maintenance runs also easier.

The disadvantages of the variant in Figure 15 and of the variant in Figure 12 are:

1. the process of obtaining semi – product: this can be seen in the choise of the piece compared of 2 modules,
2. the machining by cutting: machining process is longer, more complicated and costly,
3. the functional cost of this variant is greater, but the difference is non significant.

10. Establishing the levels of importance of the functions – step 2

Table 8 presents the value weighting of the functions, in the second step of the Value Analysis study, the final situation.

Table 8. *Cost distribution on functions (*Y coordinate, ** monetary units)*

No	**Parts**	**Functions**									**Cost part****
		F1	*F4*	F3	*F7*	F5	F6	F2	F10	F9	
1	Fix crushing jaw		60	24		90		50		4	228
...											0
7	Flywheel	10			15			25	5	22	77
...											0
17	Bearing	250	20					68	15	28	381
...	...	550	800	750	670	500	400	300	215	175	4360
Total cost		810	880	774	685	590	400	443	235	229	5046
Ratio		0.16	0.17	0.15	0.13	0.11	0.07	0.08	0.04	0.04	1
Cost of functions %		16.1	17.4	15.3	13.6	11.7	7.93	8.78	4.66	4.54	100

By introducing the new data into Table 9 the three diagrams in Figures 16, 17 and 18 are plotted. These diagrams will be compared to those in Figures 1, 2 and 3. The parameters have the following computed values: $a = 0.95$, $\alpha = 43.6^o$, $S = 23.83$, $S' = 0$. It can be noticed that S and S' have smaller values than in the initial variant.

Table 9 provides the necessary values for the plotting of the following types of diagrams:

1. the diagram of the value weighting of the functions (Figure 16).
2. this diagram has not changed, as the value of the system and of the functions has remained the same and is similar to Figure 1,
3. the diagram of the functions cost weighting (Figure 17). The diagram in Figure 18 presents the functional costs of the new variant, step 2.
4. the diagram of the cost weightings of the functions, step 1 and step 2 (Figure 18).

Figure 18 presents the diagram of the cost weightings of the functions in step 2 of the Value Analysis.

Table 9. *Computational elements for plotting the diagrams.** $S' = 2 * a * (X_i)^2 - 2 * X_i * Y_i$

No	**Computational elements**	**Functions**									**Total value**
		F1	F4	F3	F7	F5	F6	F7	F10	F9	
1	X_i	20	17.8	15.6	13.3	11.1	8.89	6.67	4.44	2.22	100
2	Y_i	16.1	17.4	15.3	13.6	11.7	7.93	8.78	4.66	4.54	100
3	$(X_i)^2$	400	316	242	177	123	79.0	44.4	19.7	4.93	1407
4	$X_i * Y_i$	321	310	238	181	129	70.4	58.5	20.6	10.0	1340
5	$(Y_i - a*X_i)^2$	8.97	0.25	0.27	0.76	1.23	0.29	5.90	0.18	5.86	23.74
6	S' *	119	-18	-16	-23	-24	9.57	-32	-3.7	-10	0

Only the costs are represented in order not to overload the diagram and to observe the decrease of the value of cost:

1. of function F4, from 20.06 %, in the first step of the Value Analysis study to 17.44 % in the second step of the Value Analysis study, with a decrease of 15 %.

2. of function F7, from 14.53 %, in the first step of Value Analysis study to 13.58 % in the second step of Value Analysis study, with a decrease of 7 %.

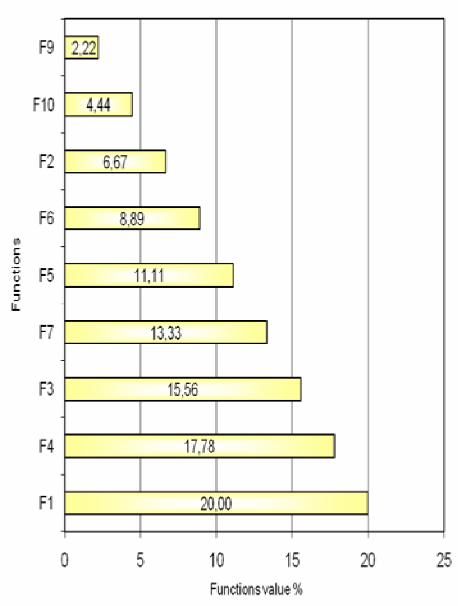


Fig. 16. *Diagram of the value weighting of the functions.*

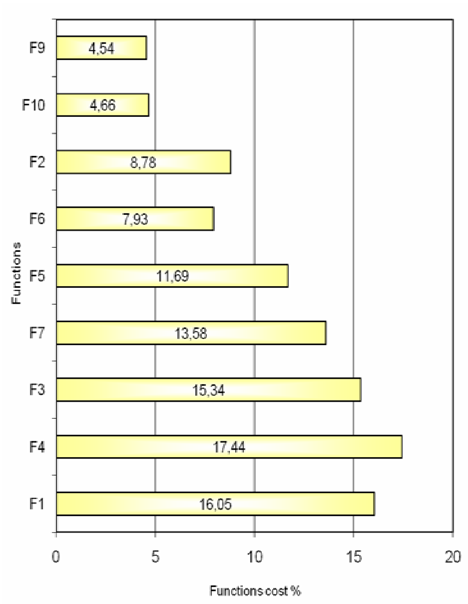


Fig. 17. *Diagram of the functions cost weighting.*

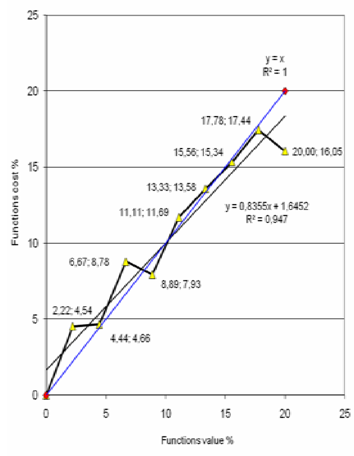


Fig. 18. *The diagram of the cost weightings of the functions in step 2.*

The economic dimension or the cost of the function represents the main criterion for the critical evaluation of functions.

These evaluations aim at identifying those functions, the too costly technical solutions of achievement which affect the total manufacturing cost of the analyzed product.

A correctly completed critical evaluation will directly lead to the identification of what can be called the deficient functions of the analyzed product that is of those functions that include useless costs.

The deficient functions from the economic viewpoint appear as: very expensive functions in relation to the others.

11. Conclusion

In two steps of the Value Analysis study two components of the jaw crusher, the flywheel which contributes to the function F7 (*it ensures uniformity to the movement*) and the bearing which contributes at the function F4 (*it supports the assembly*) were redesignted and optimized:

1. From the engineering viewpoint (Figure 19 and Figure 20),

a. from variant of flywheel in Figure 4 consisting of five welded modules, one complicated part (many components, machining mechanical, turning of metal parts complicated, long and very expensive, etc.) to the variant in Figure 7 consisting of cast semi-product (one component, mechanical machining, simple turning of metal parts, short and less expensive than the flywheel in Figure 4, etc.).

b. from the variant of bearing in Figure 8 consisting of three welded modules, one complicated part (many components, machining mechanical, complicated turning of metal parts, long and very expensive, etc.) to the variant in Figure 15 consisting of cast semi-product (two components, mechanical machining, simple turning of metal parts, short and less expensive than the bearing of Figure 8, etc.).

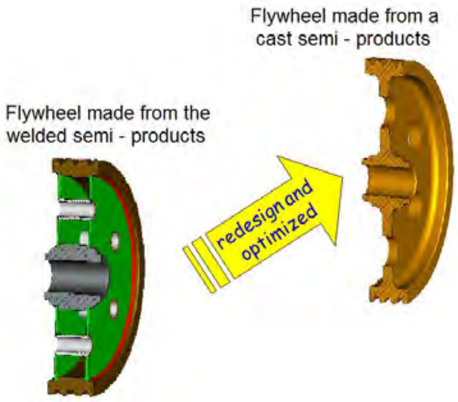


Fig. 19.

2. From the economic viewpoint (Figure 21):

a. the cost of function F7 (Figure 18) decrease sfrom 14.53 %, in the first step of the Value Analysis study to 13.58 % in the second step of the Value Analysis study (decrease by 7 %).

b. the cost of function F4 (Figure 21) decreases from 20.06 %, in the first step of the Value Analysis study to 17.44 % in the second step of the Value Analysis study (decrease by 15 %).

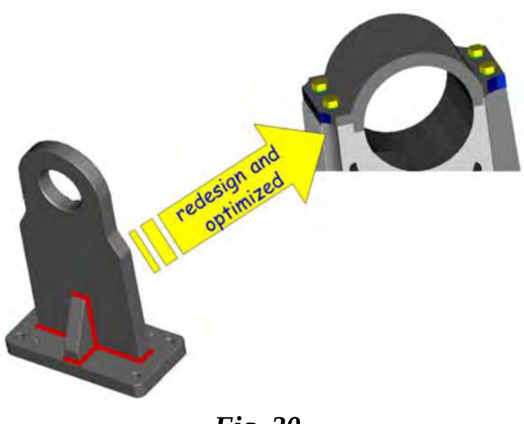


Fig. 20.

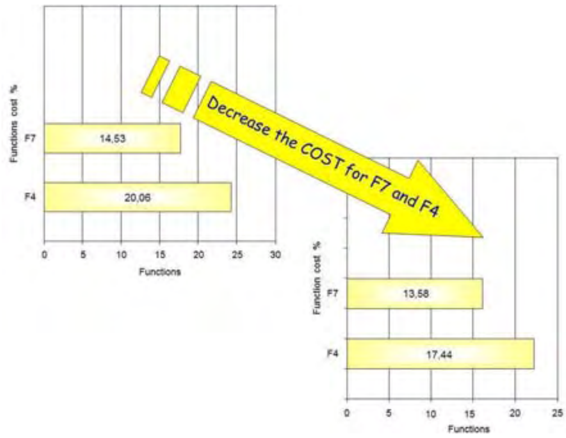


Fig. 21.

3. ***In the third step of the Value Analysis study are analyzed other functions above the regression straight line*** (for example F1) and their costs reduced, then the regression line is re-plotted and the functions relocated above it are noted; these functions too are analyzed in view of reducing their costs, followed by the re-plotting of the regression line, etc.

At the end of the Value Analysis study, the points are aligned as perfectly as possible along the straight line $y = a * x$, with a tilt of 45^o, this is the optimal situation, the values weighting of functions and the functions cost weighting are equal.

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