VALUE ANALYSIS IN RE-DESIGN OF INDUSTRIAL EQUIPMENT

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REZUMAT. Analiza Valorii (AV) este o metodă organizată şi creativă ce are ca scop creşterea valorii unui subiect AV (produs, sistem, serviciu, . . .). Demersul este desfăşurat în cadrul unui grup de lucru, fiecare membruu fiind selectat în funcție de experiența specifică şi coordonat de un expert în Analiza Valorii. Lucrarea prezintă un studiu complet de Analiza Valorii aplicat unui echipament. Sunt prezentate fazele şi iterațiile metodei Analizei Valorii. Analiza Valorii combină Ingineria şi Economicul, fără a plasa pe locul întâi nici Ingineria, nici Economicul. Ambele au aceeaşi importanță, aşa cum se va concluziona şi la sfârşitul acestei lucrări.

Cuvinte cheie: analiza valorii, valoare, variantă optimă.

ABSTRACT. Value Analysis (VA) is a method that provides an operating technique using 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 paper presents a complete study of Value Analysis applied concretely to a selected piece of equipment. The phases and Iterative operation of the Value Analysis method are presented. Value Analysis combines both Engineering and Economics without, however, placing neither Engineering or Economics first. They both are similarly important, as can be concluded by the end of this paper.

Keywords: value analysis, value, optimum variant.

1. VALUE ANALYSIS APPLIED TO THE DESIGN OF A JAW CRUSHER

Further on an example of Value Analysis is presented, applied to the redesign 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 a part participating in a function of over-dimensioned cost.

Value Analysis (VA) 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.

2. ESTABLISHING THE LIST OF FUNCTIONS AND DIMENSIONS

"When functions have been identified, clarified, understood and specified, the greatest help would come from the answer to the questions:

– how much, under our conditions of quantities, menufacutre, etc. is the lowest cost that wold provide that function ?

– what approach and method wold secure it for that cost ?

The great danger comes in the form or a proper and practical – sounding question: „*How have we accomplished it in the past and what did that cost ?"*

The three questions are at the beginning at the Third Chapter, "Evaluate the Function", of the *Techniques of Value Analysis and engineering* by L. D. Miles. Table 1 presents the list of functions of the jaw crusher.

Table 1. **List of functions**

Symbol	Function	Type of Function*	Technical dimension of function		
			Name	MU	Value
F_1	Ensure milling	FS	blast degree	-	3 - 12
F_2	Ensure protection of machinery	FC	moment	daN*m	200
F_3	Ensures adjustment	FC	length	mm	10 - 25
F_4	Supports the assembly	FS	weight	daN	20000
F_5	Aesthetics	FE	colour, form,	-	7
F_6	Supplies working energy	FS	moment	daN*m	100
F_7	Ensure uniformity of the movement	FS	revolution pulsation	rot/min rad/sec	
F_8	Capability of work	FC	volume	m^3	2
F_9	Wear resistance	FC	eroded material	g/an	
F_{10}	Part evacuation	FS	debit	m^3/h	1 - 2

*FS – service function; FC – constraint function; FE – estimation function.

Table 2. **Value weighting of the functions**

Functions	F1	F2	F3	F4	F5	F6	F7	F8	Total
F1	1	0	0	0	0	0	0	0	
F2	1	1	0	0	0	0	0	0	
F3	1	1	1	0	0	0	0	0	
F4	1	1	1	1	0	0	0	0	
F5	1	1	1	1	1	0	0	0	
F6	1	1	1	1	1	1	0	0	
F7	1	1	1	1	1	1	1	0	
F8	1	1	1	1	1	1	1	1	
No. of points	8	7	6	5	4	3	2	1	36
Ratio	0,222	0,194	0,167	0,139	0,111	0,083	0,056	0,028	1
*Percentage %	***22,2***	***19,4***	***16,7***	***13,9***	***11,1***	***8,33***	***5,56***	***2,78***	100

* *X* coordinate.

3. ESTABLISHING THE LEVELS OF IMPORTANCE OF THE FUNCTIONS

Table 2 presents the value weighting of the functions.

The following percentage values of the functions value weighting result:

X_{F1} = 22,2 %, X_{F2} = 19,4 %, X_{F3} = 16,7 %,
X_{F4} = 13,9 %, X_{F5} = 11,1, X_{F6} = 8,33 %,
X_{F7} = 5,56 %, X_{F8} = 2,78 %.

The product value is equal to the sum of the functions levels and is equal to 36.

Figure 1 shows the studied jaw crusher.

4. ECONOMIC DIMENSIONING OF THE FUNCTIONS

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

The percentage values of the functions participation in the total cost are:

Y_{F1} = 16,8 %, Y_{F2} = 16,5 %, Y_{F3} = 14,8 %,
Y_{F4} = 14,4 %, Y_{F5} =13,0 %, Y_{F6} = 9,4 %,
Y_{F7} = 10,0 %, Y_{F8} = 4,9 %.

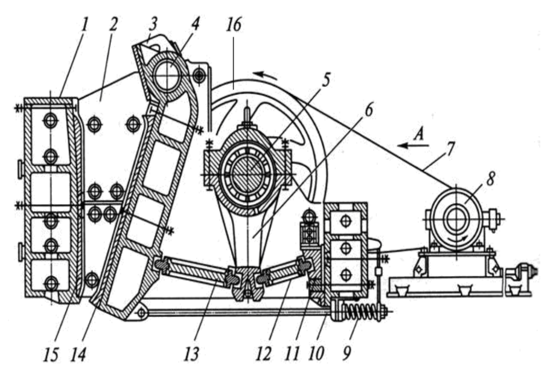

Fig. 1. Jaw crusher:
1 – fixed crushing jaw; *2* – walls of the crushing zone are made of replaceable wearing sheets; *3* – moveable crushing jaw (moving jaw); *4* – axle; *5* – eccentric shaft; *6* – pitman; *7* – belting; *8* – electric motor; *9* – cylindrical spring; *10* – the bar; *11* – the adjustable wedge; *12*, *13* – toggle; *14*, *15* – wearing parts; *16* – flywheel.

Table 3. **Distribution of costs on functions**

No.	Parts	Functions								Cost part**
		F1	F2	F3	F4	F5	F6	F7	F8	
1	Motor			30		90		50		170
2	Reducing gear		40			90	90		25	245
...	...									
5	Flywheel	280	35					75	15	405
...	...	600	800	730	750	510	410	350	203	4353
Total cost		890	875	785	760	690	500	530	263	5293
Ratio		0,168	0,165	0,148	0,144	0,13	0,094	0,1	0,05	1
*Cost of functions %		**16,8**	**16,5**	**14,8**	**14,4**	**13**	**9,45**	**10**	**4,97**	100

*Y coordinate, ** monetary units.

Table 4. **Computational elements for plotting the diagrams**

No.	Computational elements	Functions								Total value
		F1	F2	F3	F4	F5	F6	F7	F8	
1	X_i	**22,2**	**19,4**	**16,7**	**13,9**	**11,1**	**8,33**	**5,56**	**2,78**	100
2	Y_i	**16,8**	**16,5**	**14,8**	**14,4**	**13**	**9,45**	**10**	**4,97**	100
3	$(X_i)^2$	493,8	378,1	277,8	192,9	123,5	69,444	30,864	7,716	1574
4	$X_i * Y_i$	373,7	321,4	247,2	199,4	144,8	78,72	55,629	13,8	1435
5	$(Y_i - a*X_i)^2$	11,83	1,42	0,13	2,888	8,461	3,426	24,498	5,939	58,6
6	S' *	152,9	46,34	12	–47,21	–64,64	–30,84	–54,99	–13,54	–2E–13

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

5. COMPARISON OF THE FUNCTIONS VALUE AND COST WEIGHTINGS

The value-costs relationship needs to identify:

– the functions that are very expensive in relation to the others;

– the functions that are too expensive in relation to their contribution to the value of the product;

– the functions that are too expensive in relation to the existing technical possibilities of achievement.

6. DIAGRAMS

Further on 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 2, 3, 4 and 5 are plotted.

The parameters have the following computed values: $a = 0{,}91$; $\alpha = 42{,}3\ ^{o}$; $S = 58{,}6$; $S' = 0$.

Table 4 provides the necessary values for constructing the following types of diagrams:

– in figure 2, the diagram of the functions value weighting;

– in figure 3, the diagram of the functions cost weighting;

– in the figure 4, the diagram of the functions value and cost weighting;

– in figure 5, the diagram of the comparing the functional values and costs weighting.

Figure 2 shows the ranking of the functions by their value. Figure 3 shows the ranking of the functions by their functional cost.

The diagram allows significant comparisons of the functions total costs, and, within the total costs, of the work and material costs, highlighting:

– the very expensive functions with the highest weighting in the total cost of the product;

– the secondary functions that are very expensive in relation to the objective functions, or even more expensive than these;

– the functions the achievement of which requires disproportionate material or work costs.

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, F2 and F3.

The real situation is represented by the shape of the straight line in figure 4, 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 of figure 4 shows that functions F8, F7, F6 and F5 are located above the regression line, indicating high costs, not justifiable in relation to the value.

The disproportions are highlighted also in the diagram of figure 5, where it can be noticed that functions F5, F6, F7 and F8 have disproportionate costs (13,04%, 9,45 %, 10,01%, 4,97%) in relation to their respective contributions to value (11,11%, 8,33 %, 5,56%, 2,78%).

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.

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°.

Firstly, in order to diminish costs those functions will be redesigned 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 the value/cost ratio as much as possible, and not in the sense of imposing *S'* = 0.

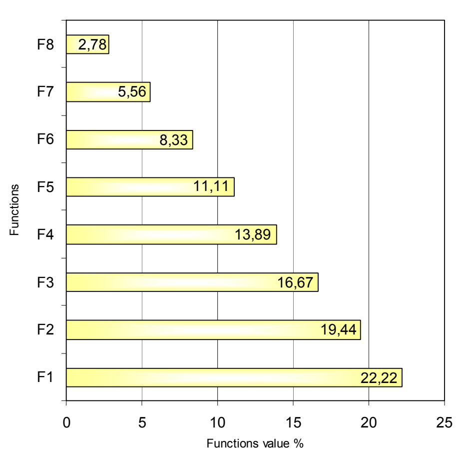

Fig. 2. Diagram of the functions value weighting.

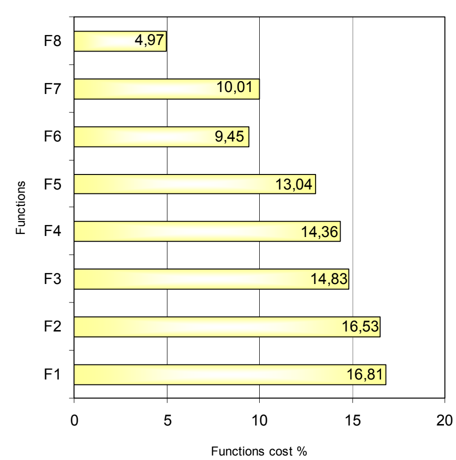

Fig. 3. Diagram of the functions cost weighting.

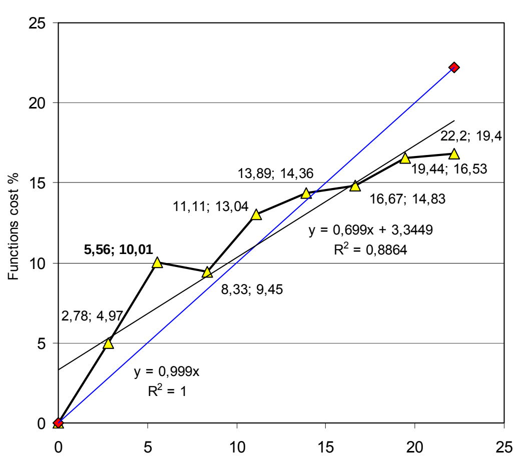

Fig. 4. Value and cost weightings of the functions.

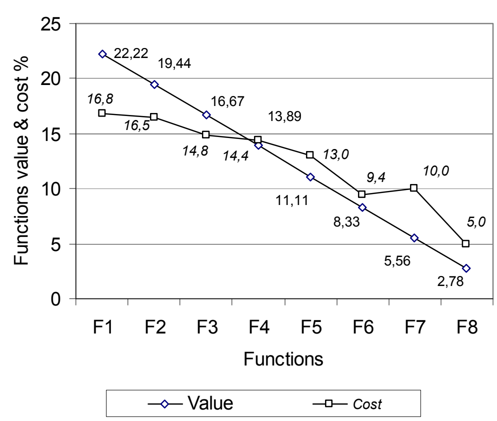

Fig. 5. Comparison of values weighting (*x*---) and functional costs (*y*- - -).

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 optimisation 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. etc.

7. ESTABLISHING THE FUNCTIONAL - TECHNOLOGICAL FORM OF THE PARTS IN VIEW OF COST REDUCTION

Further on an analysis from the technical and economic viewpoint will be carried out in order to select a technically optimum variant for one of the parts: the flywheel.

Five 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 selected.

Prior to the actual study a number of basic ideas of creative engineering will be presented in short.

Figures 6, 7 and 8 presents a flywheel made from the welded semi-products.

Figure 9 presents a flywheel screw assembled and figure 10 presents a flywheel made from a cast semi-product.

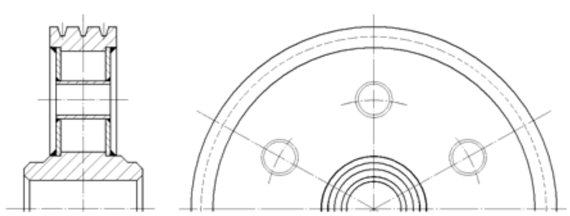

Fig. 6. Flywheel made from the welded semi-products.

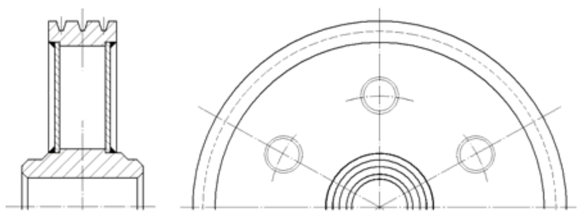

Fig. 7. Flywheel made from the welded semi-products.

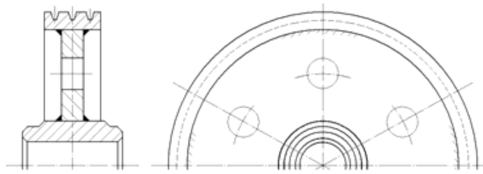

Fig. 8. Flywheel made from the welded semi-products.

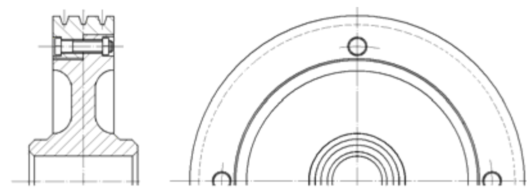

Fig. 9. Flywheel screw assembled.

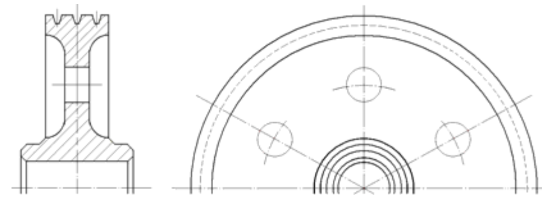

Fig. 10. Flywheel made from a cast semi-product.

All variants are technological and the selection of one of them depends on the level of endowment of the company. Thus the variants presents the aspects enumerated below.

8. COMPARISON OF THE VARIANTS

Table 5 presents the denoting by 9 assessment criteria of the analyzed constructive variants of a flywheel. The cost variant of figure 10 has obtained the highest score, and will thus be selected as the constructive solution within the assembly of the jaw crusher.

The constructive variant of figure 10 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 functional cost of the final variant of figure 10 presented in table 6 (step 2) is of 480 monetary units and has a weighting of 9,16 % of the total cost as compared to the initial situation of 530 monetary units with a weighting of 10,01 %, for function F7 presented in table 3 (step 1). The flywheel cost 405 monetary units in the initial variant and 355 monetary units in the final variant.

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

No.	Analysis criteria	Figures				
		6	**7**	**8**	**9**	**10**
		welded 5 modules	**welded 4 modules**	**welded 5 modules**	**screw assembled**	**cast**
1	Functional characteristics	5	5	5	5	5
2	Semi-product	1	2	3	4	5
3	Mechanical machining	1	2	3	4	5
4	Mounting	4	4	4	4	4
5	Repair	1	2	3	4	5
6	Rigidity	3	3	3	4	5
7	Ergonomics	2	2	2	4	5
8	Aesthetics	3	3	3	4	5
9	Cost	1	2	3	4	5
	TOTAL	21	25	29	37	**44**

Table 6. **Cost distribution on functions (partial)**

No.	Parts	Functions								Cost part**
		F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	
5	Flywheel	*280*	*35*					*25*	*15*	355
...	...	*600*	*800*	*730*	*750*	*510*	*410*	*350*	*203*	4353
Total Cost		890	875	785	760	690	500	480	263	5243
Ratio		0,17	0,167	0,15	0,145	0,132	0,095	0,092	0,05	1
*Cost of functions %		***17***	***16,7***	***15***	***14,5***	***13,2***	***9,54***	***9,16***	***5,02***	100

*Y coordinate; ** monetary units.

Table 7. **Computational elements for plotting the diagrams**

No.	Computational elements	Functions								Total value
		F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	
1	X_i	***22,2***	***19,4***	***16,7***	***13,9***	***11,1***	***8,33***	***5,56***	***2,78***	100
2	Y_i	***17***	***16,7***	***15***	***14,5***	***13,2***	***9,54***	***9,16***	***5,02***	100
3	$(X_i)^2$	493,8	378,1	277,8	192,9	123,5	69,444	30,864	7,716	1574,1
4	$X_i * Y_i$	377,2	324,5	249,5	201,3	146,2	79,471	50,861	13,93	1443,1
5	$(Y_i - a*X_i)^2$	11,55	1,294	0,095	3,106	8,844	3,5973	16,498	6,099	51,079
6	S' *	151	44,23	10,25	-48,96	-66,09	-31,61	-45,13	-13,72	8E-13

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

By introducing the new data into table 7 the four diagrams of figures 11, 12, 13 and 14 are plotted.

These diagrams will be compared to those of figures 2, 3, 4 and 5.

The parameters have the following computed values:

$$a = 0{,}92,\ \alpha = 42{,}5\ ^{o},\ S = 51{,}08,\ S' = 0.$$

It can be noticed that S and S' have smaller values than in the initial variant.

Table 7 provides the necessary values for the plotting of the following types of diagrams:

– the diagram of the value weighting of the functions (figure 11); this diagram has not changes, as the value of the system and of the functions has remained the same;

– the diagram of the functions cost weighting (figure 12). The diagram of figure 12 presents the functional costs of the new variant, step 2;

– the diagram of the cost weightings of the functions, step 1 and step 2 (figure 13); figure 13 presents comparatively the old variant, step 1 and the new one, step 2;

– the diagram of the comparison of values weighting (x---) and functional costs (y---) (figure 14).

Only the costs are represented in order to not overload the diagram and to observe the decrease of the value of cost of function F7, from 10,01 %, in the first step of VA study to 9,16 % in the second step of VA study.

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

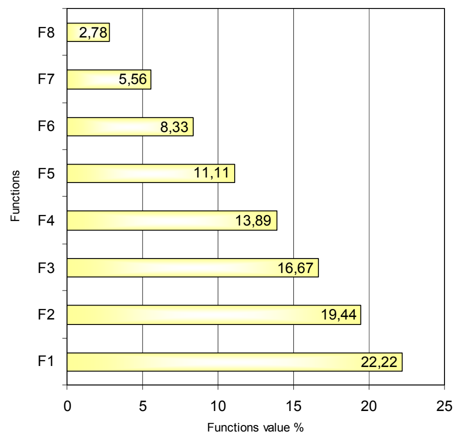

Fig. 11. Diagram of the value weighting of the functions.

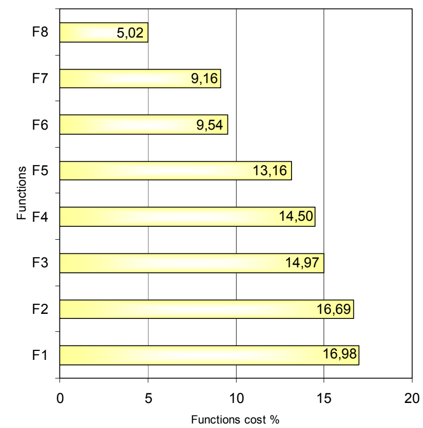

Fig. 12. Diagram of the functions cost weighting.

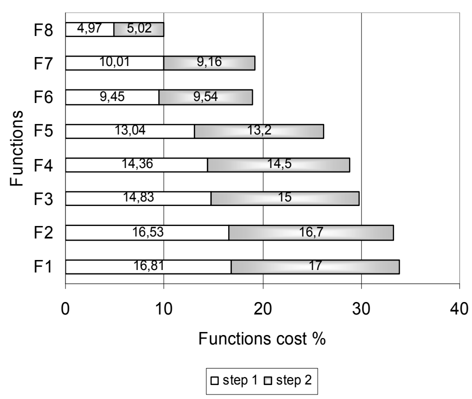

Fig. 13. The diagram of the cost weightings of the functions, in step 1 and step 2.

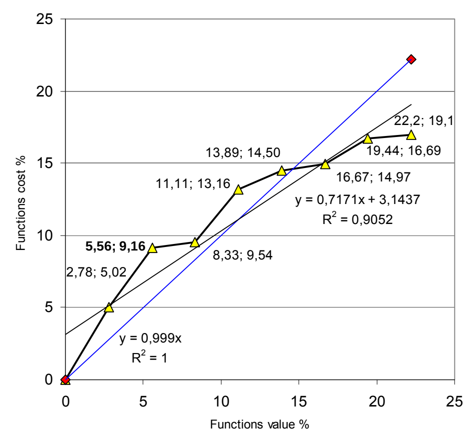

Fig. 14. Comparison of values weighting (x---) and functional costs (y- - -).

These evaluations aim at identifying those functions, the too costly technical solutions of achievement of 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;

– too expensive functions in relation to the existing technical possibilities of achievement.

Evaluation by the criterion of economic dimension can be achieved in several ways, presented below:

1) comparison of costs per function, by means of the diagram presented in figure 13, in step 1 and step 2; this diagram allows comparisons of: the costs of the functions and comparisons of the total cost and the cost of each function,

2) comparison to the functions of other products; other products refer to:

– products of the same typo-dimensional range or family, manufactured by that company;

– products similar to the analyzed one, manufactured by other companies;

– products with other destinations, but having some functions similar to those of the analyzed product.

3) theoretical evaluation of the costs of the function.

11. CONCLUSION

In two steps of Value Analysis study one component of jaw crusher, the flywheel who contribute at the function F7 (ensure uniformity of the movement) was redesign and optimized:

– from engineering viewpoint, from variant of flywheel of figure 6 consists of five welded modules, one complicated part (many components, mechanical machining, turning of metal parts complicated, long and very expensive, etc.) to the variant of figure 10 consists of cast semi-product (one component, mechanical machining, turning of metal parts simple, short and less expensive than the flywheel of figure 6, etc.).

– from the economic viewpoint: the cost of function F7 (figure 14) decrease from 10,01 %, in the first step of Value Analysis study to 9,16 % in the second step of Value Analysis study (decrease with 9,37 %).

– in the third step of Value Analysis study are analyzed other functions above the regression straight line (for exemple F4) 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. etc.

– in the fourth step of Value Analysis study are analyzed functions F1 above the regression straight line 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. 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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