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REDESIGNING A JAW CRUSHER USING VALUE ANALYSIS
Part II

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ABSTRACT

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 it can be concluded at the end of this paper.

KEYWORDS: value analysis, value, optimum variant

9. 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.

Four constructive variants of flywheel will be studied and eventually the most cost effective and the most competitive one from the technical and economic viewpoints will be selected.

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

Figures 6 and 7 present a flywheel made from welded semi-products.

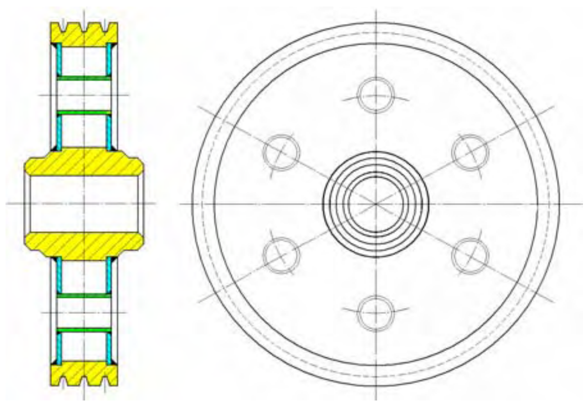

***Fig. 6**. Flywheel made from welded semi-products.*

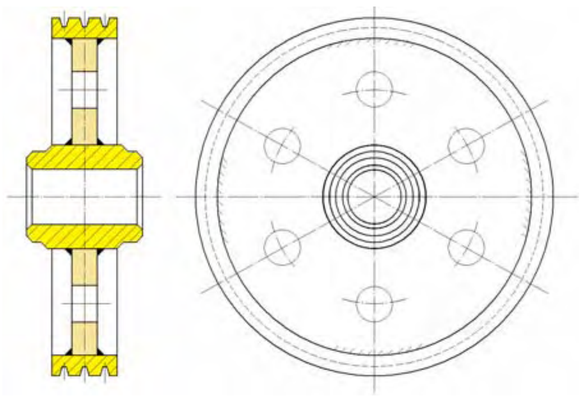

***Fig. 7**. Flywheel made from welded semi-products.*

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

- maximum diameter,
- diameter of egagement,
- geometrical elements of connecting gear,
- internal diameter of wheel hub,
- concentricity between flywheel axis and diameter of egagement,
- wearing resistance,
- reconditioning method.

Figure 8 presents an assembled flywheel screw and figure 9 presents a flywheel made from a cast semi-product.

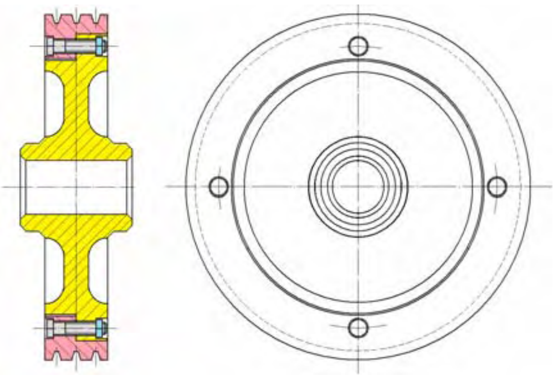

Fig. 8. *Assembled flywheel screw.*

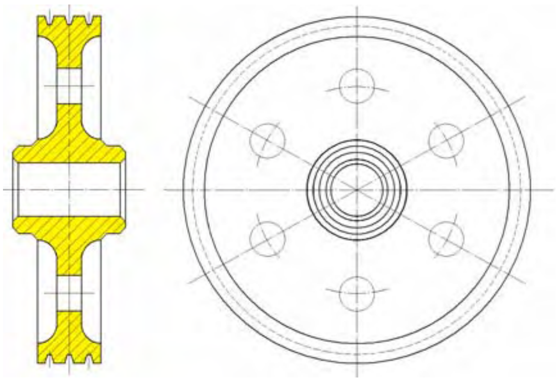

Fig. 9*. Flywheel made from a cast semi-product.*

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

The analysis of the constructive variants for the flywheel of figures 6, 7, 8 and 9 is presented further on.

The example above represents an analysis on the influence of the semi-product on the constructive form and functional characteristics of the part.

By analyzing the welded variants based on the criterion UNDER WHAT CONDITIONS IS IT ACHIEVED? valid conclusions follow also for other parts made from such semi-products:

The welded semi-products are usually obtained by welding simple parts made from rolled semi-products. In order to ensure a good weldability, steels with reduced contents of carbon are used for welded constructions, like OL 37 (C = 0.15 – 0.22%); even if the additive material has an identical composition to the one of the base material, these semi-products cannot be hardened or hardened-annealed in order to achieve the imposed wear resistance, only subsequent to cementing the surfaces that require a higher hardness.

The welding seams need to be protected during cementing in order to avoid the occurrence of cracks during and after heat treatment. The solution of heat treating constructions welded from low carbon steels is not applicable due to the required large number of technological conditions.

On the other hand, any welded construction is subjected to a relaxation heat treatment in order to eliminate the welding stress and to ensure stability of form. Using for the simple welded parts rolled semi-products of hardening-annealing high carbon steels like OLC 45, 25MoC11 does not ensure a good weldability.

These steels allow for superficial hardening-annealing or hardening by high frequency currents or oxy-acetylene flame. This is not a correct solution as the mechanical strength of the part is not ensured by classical welding procedures.

Using a rolled semi-product of OLC 45 for disks and of OL 37 for the ribs does not ensure a strong joining as the steels have different carbon contents (OLC 45 has 0,45% C, and OL 37 has 0.15-0.22% C). Such solutions need to be completely avoided as cracks occur in the welding seam due to welding stress. The imposed characteristics are not ensured for the studied part. In order to avoid obtaining a fragile welding seam by rapid cooling particularly when rolled semi-products with large differences of cross-sections and different carbon contents are used, a pre-heating of the part to 200-300^{o}C is required, while the cooling needs to take place slowly, in the furnace or by wrapping the part in asbestos. The pre-heating is successfully applied in all described cases. Finally it can be argued that the „welded construction” variant is not one to ensure all imposed characteristics. Dimensional precision is obtained in any welded construction by machining the functional surfaces, but never prior to welding, as at times it is wrongly done. Prior to welding only the contour of the simple parts is machined if they have been cut with oxy-acetylene flame, as well as their joining surfaces. A series of mechanical machining operations are eliminated by mechanical cutting. From the viewpoint of achieving the assembly of the flywheel, the welded variant is technological, as the welding ribs are not positioned with a hidden welding. Further analyzing the variants by the FROM WHAT IS THE PART MADE? criterion, the following can be established:

Flywheel can be achieved only from a semi-product cast of OT 45 or OT 55. In this semi-product casting defects appear observable after machining, and can be eliminated by welding followed again by machining.

The constructive variant of figure 9 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.

10. Comparison of the variants

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

The cost of the final variant of figure 9 presented in table 6 (step 2 of the Value Analysis – VA – study) is of 1120 monetary units and has a weighting of 15.79% of the final cost as compared to the initial situation of 1320 monetary units with a weighting of 17.72%, for function F7 presented in table 3 (step 1 of the VA study).

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

No.	Analysis criteria	Figures			
		6	**7**	**8**	**9**
		welded 5 modules	**welded 3 modules**	**screw assembled**	**cast**
	variant	initial			final
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**

***Table 6.** Cost distribution on functions (partial) (*Y coordinate, ** monetary units).*

No.	Parts	F u n c t i o n s							Cost/ part**
		F_1	F_2	F_3	F_4	F_5	F_6	F_7	
7	Flywheel	*300*				*20*	*250*	*550*	*1120*
...									
n		800	600	200	800	300	1600	600	4900
Total cost			1950	825	460	1600	350	2010	1350
Ratio		0.2282	0.0965	0.0538	0.1872	0.041	0.2352	0.158	1
Cost of functions %		**22.82**	**9.65**	**5.38**	**18.72**	**4.09**	**23.523**	**15.79**	**100**

The final situation – step 2 of the VA study

By introducing the new data into table 7 the four diagrams of figures 10, 11, 12 and 13 are plotted.

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

***Table 7**. Computational elements for plotting the diagrams.* $* \; S' = 2 * a * (X_i)^{2} - 2 * X_i * Y_i$

No.	Computational elements	F u n c t i o n s							Total value
		$\mathbf{F_1}$	$\mathbf{F_2}$	$\mathbf{F_3}$	$\mathbf{F_4}$	$\mathbf{F_5}$	$\mathbf{F_6}$	$\mathbf{F_7}$	
1	X_i	**25**	**10.71**	**7.149**	**17.85**	**3.57**	**21.42**	**14.28**	100
2	Y_i	**22.82**	**9.65**	**5.38**	**18.72**	**4.09**	**23.52**	**15.79**	99.97
3	$(X_i)^2$	625	114.8	51.02	318.88	12.755	459.18	204.08	1785.7
4	$X_i * Y_i$	570.5	103.39	38.429	334.29	14.607	504	225.57	1790.8
5	$(Y_i - a*X_i)^2$	5.067	1.1984	3.1796	0.6596	0.2585	4.1232	2.1425	16.629
6	S' *	112.55	23.458	25.473	-29.01	-3.632	-87.02	-41.82	7E-13

The parameters have the following computed values: a = 1.028, α = 45.081 °, S = 16.62, 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:

1) The diagram of the value weighting of the functions (figure 10). This diagram has not changed, as the value of the system and of the functions has remained the same.

2) The Diagram of the cost weighting functions (figure 11). The diagram of figure 11 presents the functional costs of the new variant, step 2.

3) The diagram of the cost weightings of the functions, in step 1 and step 2 (figure 12). Figure 12 presents comparatively the old variant, step 1 and the new one, step 2.

4) The diagram of the comparison of value weighting (x---) and functional costs (y- - -) (figure 13).

Only the costs are represented in order not to overload the diagram and to observe the decrease of the value of cost of function F7, from 17.72 %, in the first step of VA study to 15.79 % in the second step of VA study, decrease by 10.89 %.

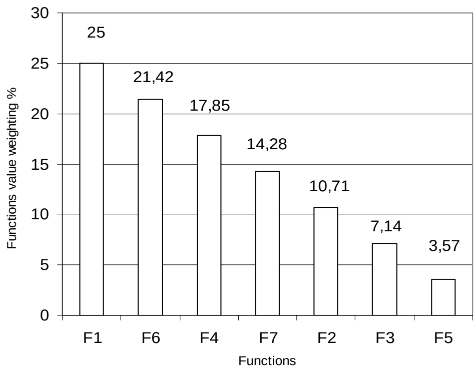

Fig. 10. Diagram of the value weighting of the functions.

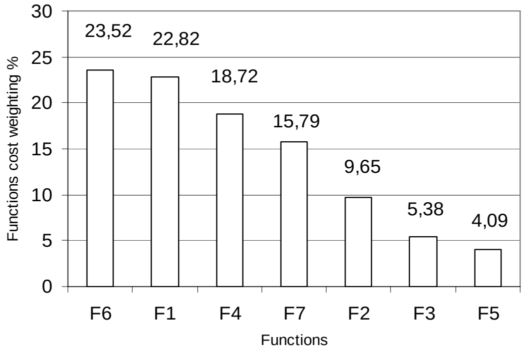

Fig. 11. Diagram of the cost weighting functions.

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 whose achievement affects 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.

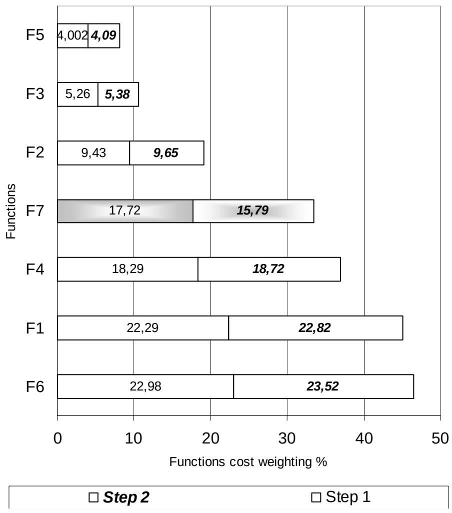

Fig. 12. The diagram of the cost weightings of the functions, in step 1 and step 2.

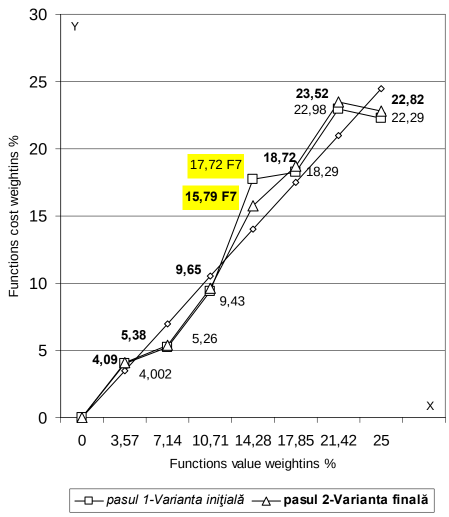

Fig. 13. Value and cost weightings of the functions, in step 1 and step 2.

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 based on 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 12,
   This diagram allows for the comparisons of:
   - the costs of the functions and comparisons of the total cost and the cost of each function,
   - work and material costs, highlighting the very expensive costs, with the highest weighting in the total cost of the product,
   - functions whose achievement requires disproportionate costs, of either work or material,
2) comparison between 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 the two steps of the Value Analysis study, one component of jaw crusher, the flywheel which contributes to the function F7 (ensures uniformity of the movement) was redesigned and optimized:

1 – from the engineering viewpoint, the variant of flywheel of figure 6 which consists of five welded modules, one complicated part (many components, mechanical machining, turning of metal parts complicated, long and very expensive, etc.) and the variant of figure 9 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.)

2 – from the economic viewpoint: the cost of function F7 (figure 13) decreases from 17.72 %, in the first step of the Value Analysis study to 15.79 % in the second step of the Value Analysis study (decrease by 10.89 %).

3 – in the third step of the Value Analysis study are analyzed the functions F6 above the regression straight line and their costs reduced (figure 14); the cost of function F6 (figure 14) decreases from 22.98%, in the second step of the Value Analysis study to 21.69 % in the third step of the Value Analysis study (decrease with 5.61 %).

Then the regression line is re-plotted and the functions relocated above it are noted; these functions too are analyzed with the view of reducing their costs, followed by the re-plotting of the regression line, etc.

The cost of function F7 (figure 14) increases from 15.79 %, in the second step of the Value Analysis study to 16.17 % in the third step of the Value Analysis study (increase with 2.89 %), but with the decrease in the second step results a final increase with 8%.

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.

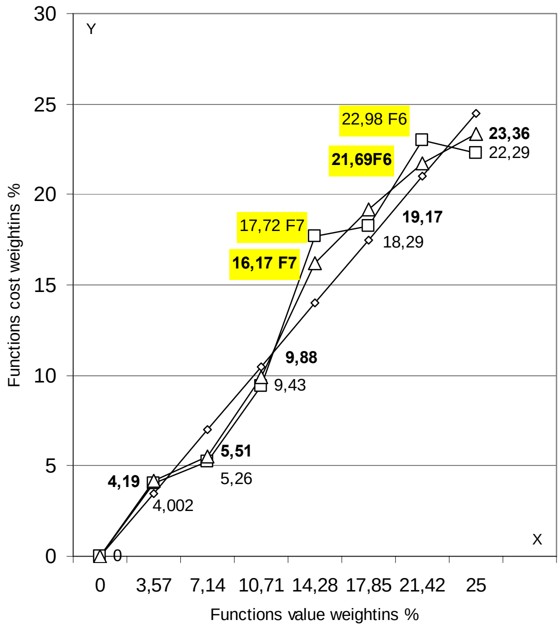

Fig. 14*. Value and cost weightings of the functions, in step 1, step 2 and step 3.*

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