MICRO DESIGN AND VALUE ENGINEERING. THE CHOICE OF MATERIAL FOR THE SAND MIXER BLADE

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REZUMAT. Lucrarea de față prezintă o metodă pentru optimizarea selectării materialului necesar pentru obținerea unor produse noi, pentru optimizarea performanțelor și minimizarea costului acestuia, pentru obținerea unei dezvoltări sustenabile, pentru creșterea performanțelor și a timpului de viață a unor componente ale echipamentelor industriale, în funcție de condițiile de funcționare dificile și prin urmare, de scăderea costului de proiectare, fabricare și întreținere a acestor echipamente.

Cuvinte cheie: valoare, modelare, ingineria valorii, strategia de selecție, proiectare, materiale.

ABSTRACT. The present paper presents a method for optimizing the selection of the material needed to obtain a new product, for maximizing its performance and minimizing its cost, to attain the sustainable development objectives, to increase the performance and the lifetime of some components of industrial equipment, subject to the difficult operating conditions, and hence the decrease of the cost of design, manufacturing and maintenance of such equipment.

Key words: value, modelling, value engineering, selection strategies, design, materials.

INTRODUCTION

The preparation of the green sand mold in the foundry workshops is done by means of mixers.

The preparation of the green sand mold consists of coating the refractory sand granules with a binder as homogeneous as possible.

Obtaining binder films on the surface of sand granules is possible both due to complex particle motion in the mixer and due to the adsorption of the binder on the surface of the granules.

ACTUAL STATUS

Obtaining the green sand mold and core blends can be done using several types of mixers.

All these mixers have rollers, pallets, propellers, plows, armor, which make mixing.

The trouble with these machines is the rapid wear of the mixing elements and the tank's armor.

An inventory of solutions to counteract this major disadvantage is made in the morphological box in Table 1.

Table 1 – **Morphological box for function F1- Provides high resistance to abrasive wear**

No.	Solutions for the construction of the sand mixer blade	Operating time
1	Carbon steel	8 hours
2	Alloyed steel	2 days
3	Tool steel	5 days
4	Manganese steel	2 weeks
5	Tungsten-carbide plating in a nickel chromium matrix /1/ and /2/	5 years
6	Rubber plating	3 weeks
7	Ni-Hard and chrome carbide /3/	
8	Protected by a special tool steel shoes /4/	2 – 4 months
9	Reinforced-nylon blade /5/	2 days
10	Low alloy steel plated with tungsten carbide layers /6/	
11	Basalt plating	1 year

THE PROBLEM FORMULATION

The object of the Value Analysis is the activity, product or its components. The product is the only one bearing value and its subassemblies or components contribute to its utility.

Therefore, apparently a part, a component of an alloy could not be approached using the Value Analysis approach. However, if we penetrate within its structure /7/ at micro level we notice that our part is made of several constituents, of several components (Figure 1).

We call these constituents subassemblies and components of our part, which is an assembly at micro level.

In the case of an assembly with several constituents/alloying elements we can apply the Value Analysis approach to this assembly, which is the alloy of the part.

Constituents/alloying elements and heat treatment operations, to a certain extent, contribute each to the increase or decrease of some properties of the part's alloy. The structure and properties of manganese steel are summarized below /7/.

T105Mn120 steel (STAS 3718-76) is a manganese austenitic steel, shock-resistant, containing 0.9-1.2% C, 11.5-13.5% Mn, 0.5-1.0% Si.

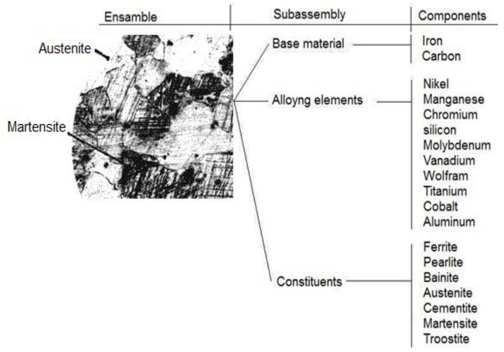

Fig. 1. The assembly of the part alloy, /7/

After forging and slow cooling has a structure consisting of austenite and carbide (Fe, Mn)$_3$C on the grain boundary

By hardening at 1050^{o}C the structure contains homogeneous oversaturated austenite in low carbon hardness 190 HB, R_m = 100 daN / mm^2, high plasticity A = 50%. By plastic deformation, austenite has numerous sliding lines in which small quantities of martensite are found (Figure 1). This structure has a great ecruising capacity, so wear resistance. Hardness increases up to 500 HB. It is difficult to process by cutting, only with hard alloys or by grinding. For this reason these parts are obtained by casting.

Due to the high abrasion resistance is used for the highly loaded parts: jaw crusher and excavators, crawlers, railroad crossing, etc.

The characteristics imposed to steels used to manufacture the sand mixer blade are:

1 – mechanical characteristic:

– hardness,

2 – technological characteristics:

– high hardenability due to the presence of chromium, silica and nickel,

– low fusion weldability,

– susceptibility to deformation,

– cracking tendency,

3 – operating characteristics generated by the chemical composition and the structure:

– high resistance to wear, provided by the presence of chromium, vanadium, molybdenum and wolfram carbides,

– resistance to bending, tenacity, resistance to deformations,

– resistance to shocks (tenacity), provided by the suitable content of alloying elements, especially silica, nickel, manganese, chromium and molybdenum,

– high hardness, provided by large quantities of carbon (0.7 – 1.2%C), wolfram, vanadium, chromium, manganese and cobalt,

– resistance to crushing provided by the elements dissolved in austenite and martensite, especially by cobalt,

– dimensional stability, given by manganese, vanadium, chromium and wolfram.

The chemical composition and the costs of the steel is given in Table c.

Table 2 – **The chemical composition of the steel and cast iron**

Steel	T105Mn120 (STAS 3718-76) - Iteration 1 /8/ C.Ştefănescu						
T105Mn120	Fe	C	Mn	Si	P	Ni	Total
Maximum (%)	83,39	1,2	13,5	1	0,11	0,8	100
Cost ($)/kg.	1,8	6,62	3,2	2,75	4,1	5,5	23,97
Total cost ($)	150,1	7,944	43,2	2,75	0,451	4,4	208,85
Cast iron	Fc250 - Iteration 2						
Fc250	Fe	C	Si	Mn	S	P	Total
Maximum (%)	93,5	3,2	2	1	0,1	0,2	100
Cost ($)/kg.	1,8	6,62	2,75	3,2	2,2	4,1	20,67
Total cost ($)	168,3	21,184	5,5	3,2	0,22	0,82	199,22

APPLYING THE VALUE ANALYSIS

Table 3 presents the classification of the functions starting from the functional analysis of the product – respectively – the alloy of the sand mixer blade. Applying the Value Analysis comprises of 2, 3, 4, ..., iterations and in each iteration is determined:

– value weighting of the functions,

– cost weighting of the functions,

– valueand cost weighting of the functions, and drawing:

– value weighting of the functions diagram,

– cost weighting of the functions diagram,

– valueand cost weighting of the functions diagram.

For selecting a material, the author has created one programs / softwares to automate calculations.

The programs include many subroutines, in which are calculated for up to 24 functions:

1 – value weighting of the functions,

2 – cost weighting of the functions,

3 – parameter calculation using the method of the least squares and plot the following diagrams:

4 – value weighting of the functions,

5 – cost weighting of the functions,

6 – weighting of the functions in value and cost.

These programs are general (can be run for more input data) and are easy to use.

Throughout the two iterations of the Value Analysis there shall be kept the 12 functions outlined in Table 3.

Table 3 – **Classification of the functions**

Symbol	Functions	*Type of function
F1	Provides high resistance to abrasive wear	FC
F2	Provides hardness	FC
F3	Provides resistance to deformations	FC
F4	Provides tenacity	FS
F5	Provides tensile strength	FC
F6	Provides resistance to crushing	FC
F7	Provides resistance to bending	FC
F8	Provides resistance to shocks	FC
F9	Provides elongation	FC
F10	Provides elasticity limit	FC
F11	Supports the assembly	FS
F12	Provides dimensional stability	FC

* FS – Service Function, FC – Constraint Function

In the first iteration, actions were taken for the following cost elements:

– using a manganese steel, T105Mn120, the cost and the composition being shown in Table 1:

– semimanufactured obtained by casting,

– alloying elements in the maximum percentage,

– there are applied a secondary heat treatment (improvement),

– forging,

The result of product modeling using Value Analysis can be seen in the diagram in Figure 2 with the weight of functions in value and cost.

In diagram from Figure 2 the following lines can be seen:

– the regression line drawn using the method of the least squares, the comparison of functions in terms of value and costs, the equation line $y_1 = x$ (the first bisector) the line that averages the weighting of functions in value and cost, expresses the ideal situation of the disparity between the two weightings, the weighting of functions in value and cost,

– the regression line of equation $y_2 = 0.981 * x + 0.144$, which approximates the arrangement of the points, expresses the real situation of the disparity between the two weightings, the weighting of functions in value and costs,

– functions F1 – Provides high resistance to abrasive wear, F2 – Provides hardness, F6 – Provides resistance to crushing, F7 – Provides resistance to bending and F8 – Provides resistance to shocks are situated above the lines aforementioned. The weighting of the cost is larger than the weighting of the value of these functions.

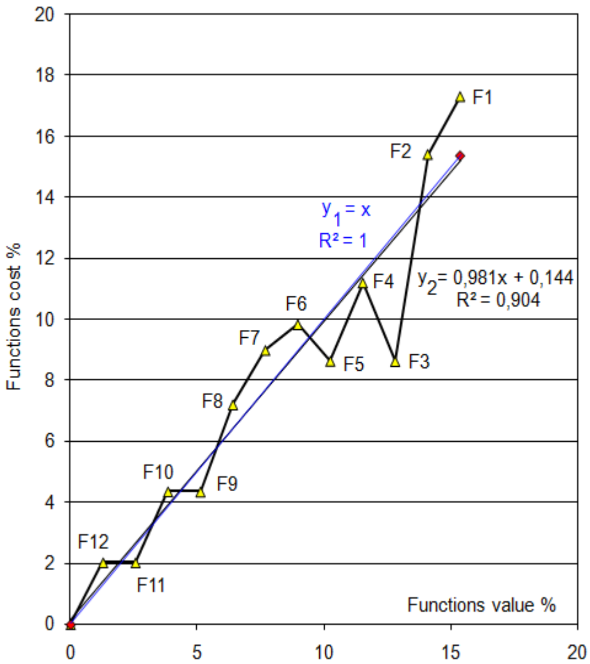

Fig. 2. The weighting of functions in value and cost.

These functions are deficient and attention should be focused on them. The cost of these functions should be reduced.

In the second iteration of the Value Analysis approach there shall be considered the functions situated above the ideal regression line (1): F1 – Provides high resistance to abrasive wear, F2 – Provides hardness, F6 – Provides resistance to crushing, F7 – Provides resistance to bending and F8 – Provides resistance to shocks.

In the second iteration, actions were taken for the following cost elements:

– cast iron (FC250) is used, the cost and the composition being shown in Table 1 /9/.

– alloying elements to the minimum percentage,

– obtaining semi manufactured (cast),

– primary heat treatment,

– roughing (milling 3D),

– secondary heat treatment (improvement),

– finishing (grinding, ...),

– plating with cast basalt. Basalt finds wide application in industry as abrasion, wear and chemical resistant materials.

The cost of these functions can be reduced by answering the following questions:

– can there be used less expensive semi-products?

– can the thermal regimes of the heat treatments be reduced?

– can there be eliminated a heat treatment operation?

– can there be used another thermal, thermo-chemical operation?

These questions must be answered in such manner so that the properties, characteristics and performance of the alloy are not affected, but improved if possible!

The result of product modeling using Value Analysis can be seen in the chart in Figure 3 with the weight of functions in value and cost.

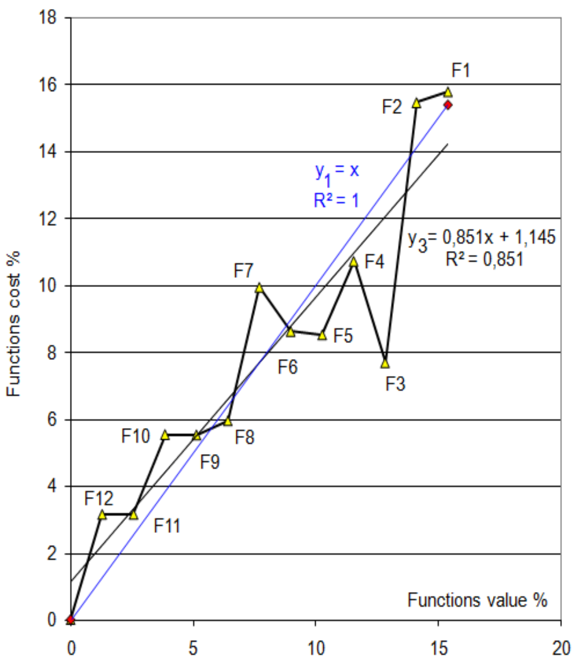

Fig. 3. The weighting of functions in value and cost.

The diagram in figure 3 represents the regression line drawn using the least squares method and presents the comparison of functions in terms of value and cost.

In the diagram from figure 3 there can be seen the following lines:

– the equation line $y_1 = x$ (the first bisector), the line that averages the weighting of functions in value and cost, expresses the ideal situation of the disparity of the two weightings, the weighting of functions in value and cost,

– the regression line, of equation $y_3 = 0.851 * x + 1.145$, which approximates the arrangement of the points, expresses the actual situation of the disparity of the two weightings, the weighting of functions in value and cost,

– functions F2 – Provides hardness, F7 – Provides resistance to bending, F10 – Provides elasticity limit and F12 – Provides dimensional stability are situated above the lines aforementioned. The weighting of the cost is larger than the weighting of the value of these functions.

These functions are deficient and attention should be focused on them. The cost of these functions should be reduced.

RESULTS

Following the second iteration there can be seen in Figure 3 that the deficient functions (which are expensive – situated above the ideal regression line – F6 – Provides resistance to crushing, F9 – Provides elongation, F7 – Provides resistance to bending and F3 – Provides resistance to deformations) have a decreased cost.

The functions F2 - Provides hardness, F7 – Provides resistance to bending, F10 – Provides elasticity limit and F12 – Provides dimensional stability are situated above the regression line. There can be seen comparatively to Figure 2 (Iiteration 1) in Figure 3 (Iteration 2) that the functions are grouped closer to the ideal regression lines.

Below are presented comparatively the equations of the regression lines (the real situation) and the correlation coefficients R^2 for the two iterations:

Iteration 1: $y = 0.981 * x + 0.144$, $R^2 = 0.904$,

Iteration 2: $y = 0{,}851 * x + 1.145$, $R^2 = 0.851$,

There can be seen an increase in the value of the correlation coefficient R^2 in the second iteration as compared to the first iteration, thus resulting that the dispersion of the points decreased in relation with the regression line.

The iterations continue until the correlation coefficient R^2 tends to value 1 and the regression line (the actual situation) tends to $y = x$ (the ideal situation).

In the two iterations of the Value Analysis study our product was redesigned and optimized in terms of:

1 – engineering:

– was replaced steel T105Mn120 first iteration, an expensive material with iron Fc 250 in the second iteration, a cheaper material,

– basalt was used for plating cast iron parts,
– the lifetime of the parts covered with basalt is greater than the parts of manganese steel.

2 – economics:

– the cost of function F1 – Provides high resistance to abrasive wear, decreased from 17.31% in the first iteration to 15.78 % in the second iteration, a decrease of 9.7%,

– the cost of function F3 – Provides resistance to deformations, decreased from 8.63% in the first iteration to 7.68% in the second iteration, a decrease of 22.3%,

– the cost of function F4 – Provides tenacity, decreased from 11.2% in the first iteration to 10.71 % in the second iteration, a decrease of 4.56%,

– the cost of function F5 – Provides tensile strength decreased from 8.64% in the first iteration to 8.52% in the second iteration, a decrease of 1.43%,

– the cost of function F6 – Provides resistance to crushing decreased from 9.84% in the first iteration to 8.62% in the second iteration, a decrease of 14.2%.

– the cost of function F8 – Provides resistance to shocks decreased from 7.21% in the first iteration to 5.95% in the second iteration, a decrease of 21.3%.

– the cost of the other functions has increased, but

– the cost of the product decreased from 513.2$ in the first iteration to 458.18$ in the second iteration, a decrease of 10.72%.

In the third iteration of the Value Analysis study there shall be analysed the functions situated above the regression line y = x, (F2 – Provides hardness, F7 – Provides resistance to bending, F10 – Provides elasticity limit and F12 – Provides dimensional stability), there shall be analysed the ”components” participating to achieving these functions and solutions shall be proposed for reducing the costs.

APPLICATIONS AND CONCLUSIONS

This guide can be used for optimizing the value/cost ratio for a very wide range of materials (cast iron, steel, aluminium alloys, copper alloys, composite materials, basalt, etc.), which is used for various applications, from industrial machinery to aerospace and space industry.

Engineering design using the Value Analysis method is difficult because it starts from immaterial notions, that are the functions.

These functions must then be quantified in terms of value and cost.

It follows the materialization of the functions with technical solutions and then optimization of the design taking into account the costs.

In this article the author highlight and present:

1 – the particular role of applying the Value Analysis approach to a materiall,

2 – the working mode for optimizing the value/cost ratio,

3 – a valid and useful guide for the specialists to optimize the value/cost ratio of the alloys for parts.

With this study, the Value Analysis makes an important step in the world of ”micro assemblies”, it opens new horizons of applications and keeps up with the directions of science to penetrate the micro, nano, . . . limits.

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