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RESEARCH ON DEFORMATIONS WHICH APPEAR IN WITHIN THE METAL STRUCTURES OF MINING EQUIPMENT

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Metal structures of the mining equipment are made of a steel with good weldability and mechanical characteristics corresponding and namely St 52.3 steel that allows the use of these metal structures in heavy duty. Metal structures of the mining equipment are very large structures and strong requested mechanical, and in these conditions during exploitation can occur large deformations at these that may cause a decrease in the exploitation safety of mining equipment. Research has followed in principal the analyze of deformations appear in metallic structures, and for realizing the researches has been used both a dimensional analysis and one that is based on the finite element method.

Key words: metal structures, deformations, dimensional analysis, finite element method

INTRODUCTION

Evaluation and knowledge of deformations which appear in the metallic structures of the mining equipment is particularly important to assess their lifetime. Metallic construction used at mining equipment are welded metallic construction which must provide a service life as big as possible. [1].

A big problem of equipment is the welded metallic construction which over time has not been modernized but suffered only some repairs. The life of welded metallic construction of the mining equipment is very much influenced by the evolution of deformation suffered by them. Deformations suffered by metallic construction are caused by very high mechanical requests, but also because phenomena of corrosion and dimensional change which appear by redistributing material, and they all appear after a certain period of exploitation.

Welded metal constructions have become increasingly popular in recent years, within the mining equipment, because of the advantages they have in comparison with other structures obtained by other technological processes. Through its specificity, the process of achieving products in welded constructions presents a number of disadvantages arising primarily from working with liquid materials [3].

Welded metal constructions used in mining exploitation are very strong mechanically requested, but at the same time they are subject to the action of specific agents of working environment [4]. The life of these welded metallic construction is very much influenced by the evolution of size and deformation suffered by them. Thus an important analysis which must be realized relates to the evolution of the deformations that occur within the welded metallic construction, and determining principal causes that cause these deformations [5].

Construction steels for general use, type St 52.3, compared with carbon steels, have become widely used in construction machineries in the mining exploitation, due to the characteristics they have and allow a proper behavior of complex requests combined with action of corrosive working environment [6].

Welded metal constructions used in the mining of coal are cyclic requested at fatigue, but also works in a chemically aggressive environment. The aggressiveness of the environment in which the construction work can be explained by the presence in the atmosphere of large quantities of chemicals that can act as an aggressive environment [7].

Aggressive working environment is characterized mainly by the presence in the atmosphere of large quantities of sulfur from emissions from the local power plants. The apparition of corrosion within metallic structures cause a change in the size of the metal building, and this influence the occurrence of phenomena by the type of deformations [8].

Also it should be considered the fact that in the metal construction of mining equipment is a random distribution of efforts and thus should be considered all the possibilities of requests that may arise.

MATERIALS

Research has primarily aimed to determine the deformations that occur in metallic structures made of steel St 52.3, and to do research it must be used a dimensional analysis, and an analysis using the finite ele-

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ment method. The research was focused on those welded steel constructions that have been used a long time and through this analysis it was aimed to establish possibilities which are for the safe use of such metallic constructions. The use of this steel is indicated at the fabrication of resistance elements (beams, columns, sections, rails, brackets, etc.).

Defects which appeared during operation are determined by the incognizance of technological aspects , but also the use of materials with inadequate for purpose. Among the factors that have influence on the life of welded metal constructions are mentioned: the choice of materials and welding processes, chemical composition, thermal influence zone, etc. To achieve desired results in the research, it was initially determined the chemical composition for steel St 52.3 which is presented in Table 1.

Table 1 **The chemical composition of the steel St 52.3 / %**

C	Mn	Si	S	P	Al	Ni	Cr
0,136	1,22	0,365	0,017	0,017	0,011	0,022	0,027

For St 52.3 steel is recommended that up to a thickness of 10 / mm of pieces,they must not preheat, because welding linear energy realize a sufficient preheating for welding operation.

Analyzed metallic construction “excavator arm ERc 1300” is obtained from the highlights of rolled St 52.3 steel with thickness of 10 / mm, positioned and assembled by manual welding with basic electrodes.

RESULTS AND DISCUSSIONS

To realize the research was ralized initial a drawing of the excavator arm which is partially shown in Figure 1, and in this drawing were established primarily the dimensions component pieces and the arrangement and combination of them.

Experimental research made at different time have shown that in the KL constructive element (Figure 1) of the excavator arm were occurred deformities increasingly larger, and this may cause deformation or breakage of the entire metal construction of excavator . These deformations can be determined by changing the material properties of the metal structure or appearance of intergranular corrosion phenomena and high mechanical requests. Thus in the first phase of experimental research it was visually analyzed the deformations area and were not found superficial corrosion areas where is currently a continuously coating layer Figure 2. Also, the method of deforming the excavator arm element is shown in Figure 3.

Due to the lack of a visible surface corrosion in the next step we aimed to determine possible corrosion phenomena that may occur under the paint and can affect the metal structure. To identify these corrosion phenomena it was used in the experiments LAPTOSCOP

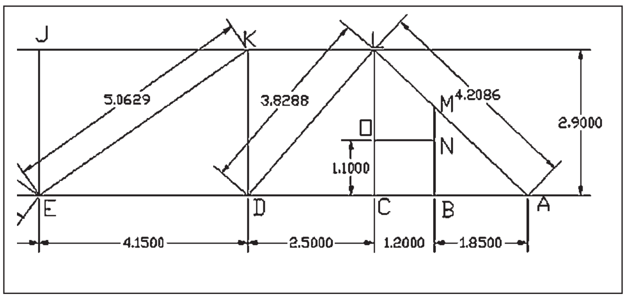

Figure 1 Partial description of shape and dimensions of the excavator arm

Figure 2 The deformed element of the excavator arm

Figure 3 The mode of deformation of the excavator arm element

type apparatus that allows non-destructive determination of thickness of paint and oxides and thus can establish the thickness of metal that is in that structure.

The experiments were performed by making several measurements (18 measuring points) points along the metal piece KL, and the obatined results are presented in Table 2.

Table 2 **Thicknesses determined after measurements performed on the deformed element / mm**

No.	Thickness of the deformed element	The thickness of the paint and oxides	Metallic material thickness
1	10,96	0,967	9,993
2	10,95	0,969	9,981
3	10,92	0,967	9,953
4	10,91	0,965	9,945
5	10,90	1,001	9,899
6	10,91	1,108	9,802
7	10,89	1,147	9,743
8	10,92	1,167	9,753
9	10,91	1,283	9,627
10	10,93	1,288	9,642
11	10,89	1,295	9,595
12	10,96	1,152	9,808
13	10,94	1,038	9,902
14	10,93	0,984	9,946
15	10,96	0,967	9,993
16	10,96	0,961	9,999
17	10,95	0,959	9,991
18	10,94	0,952	9,988

From the results shown in Table 2 it can be observed the fact that the thickness of the KL element is approximately 10,9 / mm, and this size is formed from a layer of paint and oxide plus the thickness of the metal part. After the measurements was found that in the area of points 9 ÷ 11 is the thickest layers of paint and oxides, and in this area there is the smallest thickness of the metal layer , namely the thickness is reduced by 5-6 / % in relation to the new state. In these conditions it was observed that int his area the maximum deformation which extend and has an increasing length.

To determine the causes of deformation of the KL structural element that have been considered and some of it blows received during the operation and that could produce a strain accidentally . It was also taken into account this hypothesis given the shape deformation which occurred. Research has shown that the appearance of the deformation due to a hit is highly unlikely and in these conditions was switched to another method to confirm the results obtained in experimental research, namely the finite element method.

Determining the deformation parameters by conventional analytical methods is not possible for massive spatial structures. Excavator arm ERc 1300, is a massive spatial structure which can be studied using finite element method using a process of discretization, namely h-element method. Discretization was done with second order tetrahedral elements. These elements are used for good discretization with small errors on curved surfaces. The third-order elements used at discretization of spline curves and surfaces generated in this way.

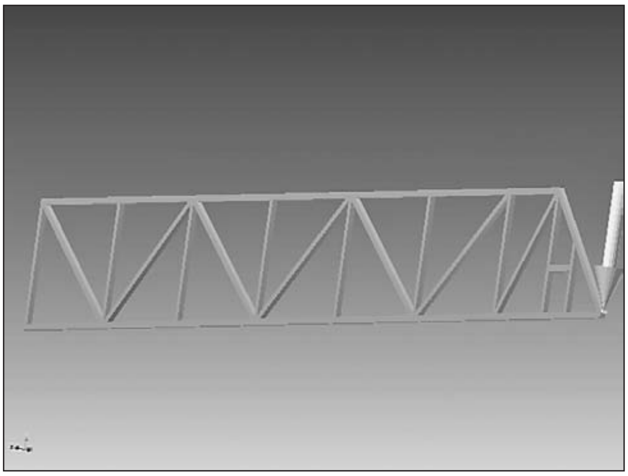

Figure 4 The application of loads on steel structure

To study it was used Autodesk Inventor 2011 program running on an Intel QuadCore 3.5 GHz computer. The application method of loads on the metal structure is shown in Figure 4, and the values of loads after the three directions OX, OY respectively OZ are shown in Table 3.

Table 3 **Operating conditions, Force:1 / N**

Load Type	Force
Vector X	0,000
Vector Y	-300 000,000
Vector Z	0,000

To apply the Finite Element Method it is necessary to be known in great detail the physical properties of the metal structure analyzed and a detailed presentation of them is presented in Table 4. Analyzing the physical properties of the metal structure analyzed is can be observed the fact that it has a very large load, and a fairly large area which demonstrates once again the complex character metal of the analyzed structure.

Table 4 **The physical properties of the metal structure analyzed**

Material	Default
Mass	2 072,59 / kg
Area	61 888 500 / mm^2
Volume	2 072 590 000 / mm^3
Center of Gravity	x=14 783,613 / mm, y=1 523,341 / mm z=59,055 / mm

Also, Finite Element Analysis of steel structures is possible if physical and mechanical properties of the material which is made are known, and the analyzed case the material was steel St 52.3 with the properties shown in Table 5.

Application of Finite Element Method for metallic structure analyzed is realized only after initially have been realized some advanced settings fot the applied finite element and setting values performed are presented in Table 6.

Table 5 **Physical and mechanical properties of steel St 52.3**

Name	Steel, Mild	
General	Mass Density	7,86 / g/cm³
	Yield Strength	207 / MPa
	Ultimate Tensile Strength	345 / MPa
Stress	Young's Modulus	220 / GPa
	Poisson's Ratio	0,275 / ul
	Shear Modulus	86 274,5 / MPa

Table 6 **Advanced settings**

Avg, Element Size (fraction of model diameter)	0,1
Min, Element Size (fraction of avg, size)	0,2
Grading Factor	1,5

Applying the load on metal structure cause some reactions of force type or the moment within constraints made, and the values obtained for them by applying the finite element method are presented in Table 7.

Table 7 **Reaction force and moment on constraints**

	Magnitude / N	Component (X,Y,Z) / N	Magnitude / N·m	Component (X,Y,Z) / N·m
Fixed Constraint:1	96 907,72	94 011,112	106,493	-15,88
		-23 515,5		-105,31
		186,792		0
Fixed Constraint:2	336 616	-94 026	68,267	33,69
		323 217		-59,37
		0		0

Application of finite element method for the analysis of metal structure allowed obtaining both numerical values for the deformations obtained on the element structure, Table 8, and highlighting the ways in which the deformation and its shape are produced is shown in Figure 5.

Table 8 **Result Summary**

Name	Minimum	Maximum
Volume	2 072 590 000 / mm³	
Mass	16 290,5 / kg	
Von Mises Stress	0,091 / MPa	46,007 / MPa
1st Principal Stress	-1 010,573 / MPa	36,901 / MPa
3rd Principal Stress	-39,856 / MPa	7,041 / MPa
Displacement	0 / mm	2,963 / mm
Safety Factor	4,499 / ul	15 / ul
X Displacement	-1,722 / mm	0 / mm
Y Displacement	-2,422 / mm	2,46 / mm
Z Displacement	-0,263 / mm	0,011 / mm

CONCLUSIONS

Following experimental research and modeling carried out by finite element method we can draw the following conclusions:

- welded construction of mining process equipment are strongly mechanically requested, but at the same time and are subjected to corrosion;
- metallic construction of mining equipment are complex structures whose modeling by finite element allows obtaining significant results;

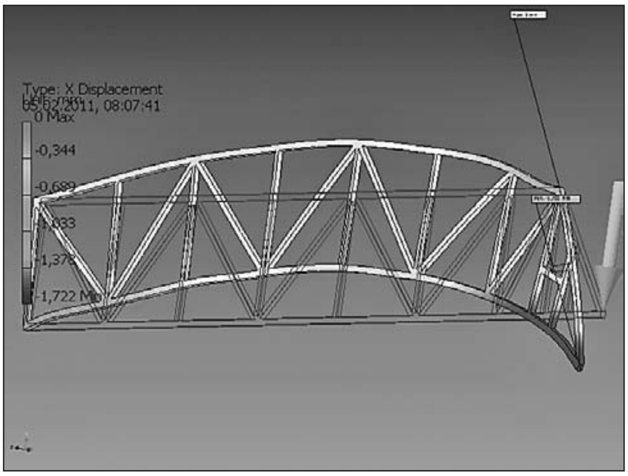

Figure 5 The mode of deformation of the metal structure obtained by applying the finite element method

- deposition of coatings of paint that has lower protection features on metallic construction causes metal corrosion phenomena in depth metal structure;
- deformation structures are determined by mechanical actions, but they are enhanced by corrosion phenomena which cause a reduction in the thickness of metallic material;
- application of the finite element method allows highlighting areas where are produced maximum deformations of structures, but also allows for confirmation of the results obtained in experimental research;
- deformations occur mainly in the case of those structural elements that have horizontal position in the metal structure and in this regard it is recommended to adopt constructive changes, and adoption of heat and thermochemical treatments that increase resistance to deformation of them;
- adopting appropriate technological solutions can cause accidental occurrence of large deformations, and if one takes into account the complexity of the hardware and repair costs are very high.

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Note: The responsible translator for English language is DELTRA CELES SRL, Bucharest, Romania