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ADJUSTMENT OF HYDROSTATIC PARAMETERS TO A HYDRAULIC INSTALLATION SYSTEM OF LAMINAR CYLINDER CASSETTE - LABORATORY VERSION

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Abstract: *The intensive development of the industrial branches, the explosion in the design and execution of the new installations and equipment in machines building field, determined the same dynamics in the evolution of their components. The design of a hydrostatic operation system involves the structural design of the installation and the calculation of the numerical values for the functional and dimensional parameters of the component elements, so that the installation fulfils one or more required conditions in working. In this paper, there are highlighted the main components of a hydrostatic plant, which is also a miniaturized and readapted version of an installation existing in the ArcelorMittal Steel Factory Galati, which aims to provide the auxiliary operations necessary for mounting the laminar cylinder cassette on the spindles. It has been studied the behaviour of the plate (working table) that can support various weights as part of the device. Maximum deformation and equivalent stress was determined for the case the plate is being at the "minimum stroke", but also for the case where the plate is at the "maximum stroke". Analysis were made for the plate to support a weight of between 10 kg and 100 kg in the race in empty or the race in load.*

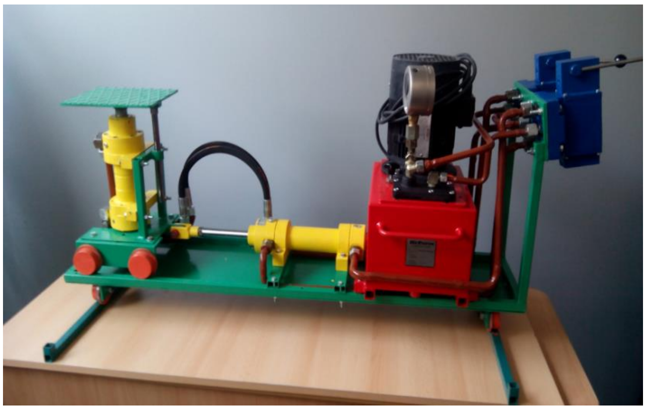
Keywords*: hydraulic cylinder, finite element analysis (FEA), functional analysis*

1. Introduction

The hydraulic drive systems have a significant weight in manufacturing field and it is necessary, by concrete examples, to make a technical calculation of these systems, starting from the fundamental relations regarding the calculation of the mechanical and hydraulic parameters that interfere with the operation of the hydrostatic systems [1,2] as well as modeling using the finite element method, as a general method of approximate solving of some mathematical equations describing physical phenomena [3,4]. The basic function of a hydraulic system is to transmit the mechanical energy from one place to another. This is done by the system by assembling the functions of the component elements and circulating a hydraulic medium between them, acting as energy and information carrier. The energy is transferred from a force element, a conducting element, to a running element, conducted. The energy, respectively the mechanical power provided by the conducting element, is transmitted to a primary element at which a first mechanical-hydraulic conversion occurs, the mechanical taken over energy being transmitted to the fluid. In the end, it arrives to the secondary element, where the inverse, hydro-mechanical energy conversion, takes place. Regardless of its function and design, every hydraulic system has a minimum number of basic components (pump, reservoir, valves, actuators and filter etc.) in addition to a means through which the fluid is transmitted [5]. Among the characteristic parameters of the most important hydraulic installations, can be mentioned: nominal working pressure - p; the maximum flow crossing the system, limited in its functional scheme by the effective working pressure, the pressure drop and the forces required for switching - Q; nominal diameter (diameter), conventional size that defines the nominal section of flow through pipes - DN etc. [6, 7].

2. Hydrostatic installation for the auxiliary operations required for mounting the rolling cylinders on the spindle shafts

In the case of the miniaturized and readapted version of the installation, Figure 1, the choice of the components of the installation has been made taking into account a number of technical parameters necessary to ensure preliminary sizing conditions to satisfy the technological cycles, starting from the practical model that best meets the technical and economic requirements imposed on the system - stationary performance, dynamic performance, stability, etc., as well as a number of hydrostatic criteria. Thus, it has been discussed: a) calculation of mechanical-hydraulic parameters for elements composing the system, selection or designing the component elements; b) designing and realizing the assembly of the connection and bonding elements, comprising the assembly of elements forming part of the installation, the designing of the electric motor-pump energy group (calculation and selection of the couplings), the selection of the connecting elements (fittings, joints, etc.) structuring and drawing up the execution designs and the overall drawing of the installation; c) the recalculation of some hydraulic parameters - only if, after finishing of the execution drawings, there are some differences from the initial situation offered by the assembly scheme (the length of the pipes changed, the number and type of the hydraulic resistances changed, the structure of some hydraulic elements changed, etc.). In this situation, the pressure and flow losses are reevaluated, and then corrections are made on the calculations in which the respective sizes occur.



a. **b.**

Fig. 1. Hydraulic mounting system of laminar cylinder cassette
ArcelorMittal version (a); laboratory version (b)

In accordance with the engineering design cycle imposed by the projection, it has been chosen a constructive version containing a gear pump, two hydraulic cylinders, one of them making a horizontal movement, Figure 2 and the other for vertical movement, Figure 3, other components of the installation of cylinder cassette assembly, are: the rolling path, the tank, the manual distributors, the electric motor, the pressure gauge, the pressure regulator, the guides, the work table, etc. The pipes for the hydraulic cylinder performing the horizontal displacement of the mobile cart are fix. Also, the hydraulic cylinder is fixed in the metal frame with support.

Fig. 2. Hydraulic cylinder for horizontal movement

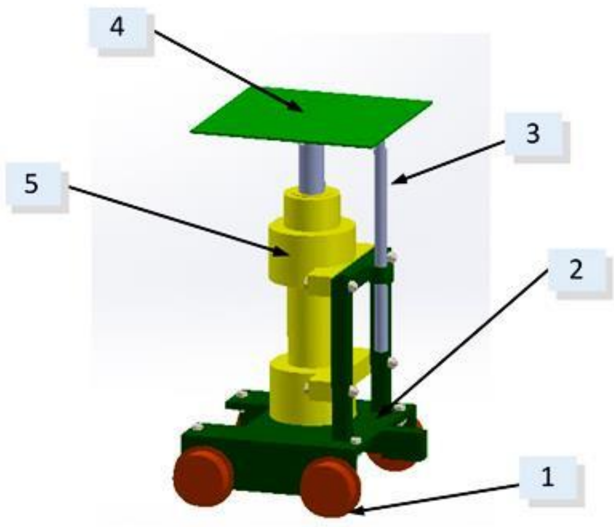


Fig. 3. Hydraulic cylinder for vertical movement

The horizontal displacement of the hydraulic cylinder is nailed by the moving cart through an ear tapped onto the cylinder stem, or by a bolt that passes through the mobile cart's ear. A working table is attached to the head of the hydraulic cylinder that performs the vertical displacement to which a guide is added. The guide assists in the horizontal movement of the entire rod stroke and does not allow the table to rotate. The supply pressure must have a value so that the force of the hydrostatic pressure created by the engine overcomes the sum of the resistances that oppose the drive. The components of the mobile assembly are: 1 - wheels; 2 - metal frame; 3 - guide; 4 - work table (plate); 5 - vertical displacement hydraulic cylinder.

3. Determination of working parameters for the adjustment system of the hydrostatic parameters

The list of hydrostatic parameters that occur in the calculation of the control system for vertical and horizontal displacement hydraulic cylinders are defined in Table 1.

Table 1: Working parameters for horizontal and vertical displacement hydraulic cylinders

Horizontal hydraulic cylinder		Vertical hydraulic cylinder	
Parameter	**Value**	**Parameter**	**Value**
p [bar] – working pressure	10–100	p [bar] – working pressure	10–100
L [mm] – rod stroke length	125	L [mm] – rod stroke length	125
D [mm] – piston diameter	40	D [mm] – piston diameter	40
d [mm] – rod diameter	28	d [mm] – rod diameter	28
g [kg] – working load	10–100	g [kg] – working load	10–100

Calculation of hydraulic cylinder surfaces

$$S_a = \frac{\pi \cdot D^2}{4} \quad (1)$$

$$S_p = \frac{\pi \cdot (D^2 - d^2)}{4} \quad (2)$$

S_a [mm^2] – surface of the active stroke;

S_p [mm^2] – surface of the passive stroke.

Calculation of forces at minimum and maximum stroke

$$F_{ag} = p \cdot S_a \quad (3)$$

$$F_{pg} = p \cdot S_p \quad (4)$$
$$F_{as} = p \cdot S_a \quad (5)$$
$$F_{ps} = p \cdot S_p \quad (6)$$

F_{ag} [daN] – the active force at the minimum stroke;

F_{pg} [daN] – the passive force at the minimum stroke;

F_{as} [daN] – the active force at the maximum stroke;

F_{ps} [daN] – the passive force at the maximum stroke.

Table 2 shows the tabular layout and variations in the minimum and maximum stroke force for the vertical displacement cylinder.

Table 2: Calculation of hydrostatic parameters - variations of the force with the minimum stroke, respectively for the maximum stroke

p [bar]	L [mm]	g [kg]	D [mm]	d [mm]	S_a [mm^2]	S_p [mm^2]	F_{ag} [daN]	F_{pg} [daN]	F_{as} [daN]	F_{ps} [daN]
10	70	10	40	32	1256	452	125,6	45,2	126,6	46,2
20	70	20	40	32	1256	452	251,2	90,4	253,2	92,4
30	70	30	40	32	1256	452	376,8	135,6	379,8	138,6
40	70	40	40	32	1256	452	502,4	180,8	506,4	184,8
50	70	50	40	32	1256	452	628	226	633	231
60	70	60	40	32	1256	452	753,6	271,2	759,6	277,2
70	70	70	40	32	1256	452	879,2	316,4	886,2	323,4
80	70	80	40	32	1256	452	1004,8	361,6	1012,8	369,6
90	70	90	40	32	1256	452	1130,4	406,8	1139,4	415,8
100	70	100	40	32	1256	452	1256	452	1266	462

4. Determination of total deformations and equivalent stress to vertical plate loading

The finite element analysis software series that supports the design and validation of products in a virtual environment that analyzes complex physical phenomena correlated with each other and offers a wide range of technologies for exploring dynamic behavior. It has been studied the behaviour of the plate (working table) that can support various weights as part of the device. Maximum deformation and equivalent stress was determined for the case the plate is being at the "minimum stroke", but also for the case where the plate is at the "maximum stroke". Analysis were made for the plate to support a weight of between 10 kg and 100 kg in the race in empty or the race in load.

4.1 Deformations and stresses at the minimum stroke of the vertical cylinder

The emphasis is on the analysis of the loading situations of the plate moved by the vertical hydraulic cylinder through a study of the total deformations and the equivalent stress that arise as a result of the distributed applied forces in the form of pressure by gradually loading the plate with different weights. The vertical cylinder is at the end of the stroke in the lower minimum position of the piston. With the Ansys Workbench software package, which performs the finite element

analysis, the structural static analysis is considered, the gravitational acceleration value taken into account being 9806,6 mm/s^2. Figure 4 shows the model of the plate in the minimum stroke.
Figure 5 shows the embedded plate on the contour and loaded with a weight of 1 kg. Figures 6 ÷ 11 show the variation maps of the total deformation, as well as the map of equivalent stress variation if the plate was loaded with a weight of 10, 50, 100 kg).

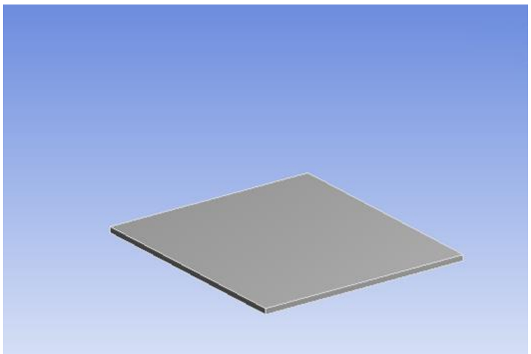


Fig. 4. Plate in the minimum stroke

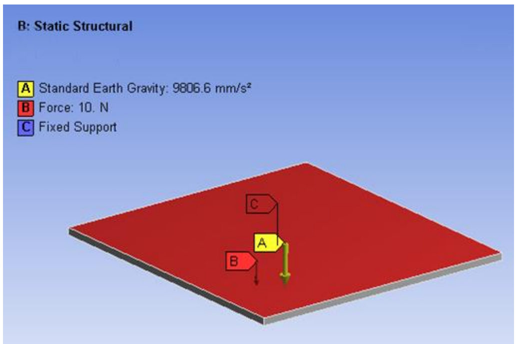


Fig. 5. Plate loaded with 1kg

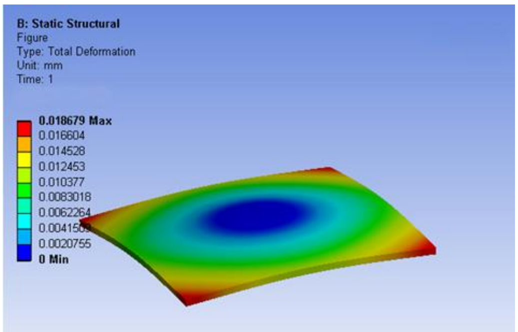


Fig. 6. Variation map of total deformation-10kg

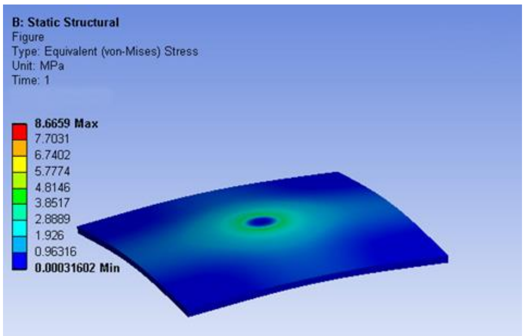


Fig. 7. Variation map of equivalent stress-10kg

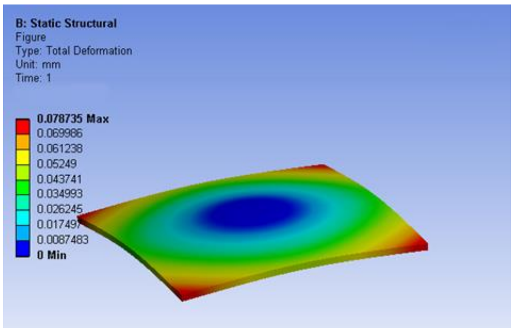


Fig. 8. Variation map of total deformation-50kg

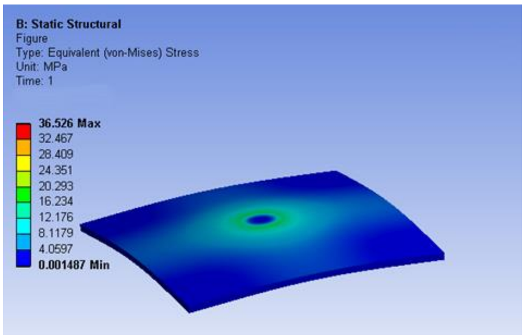


Fig. 9. Variation map of equivalent stress-50kg

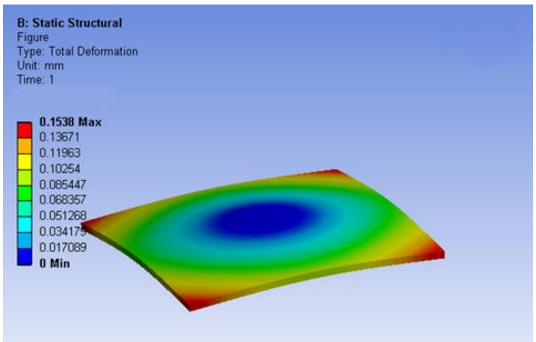


Fig. 10. Variation map of total deformation-100kg

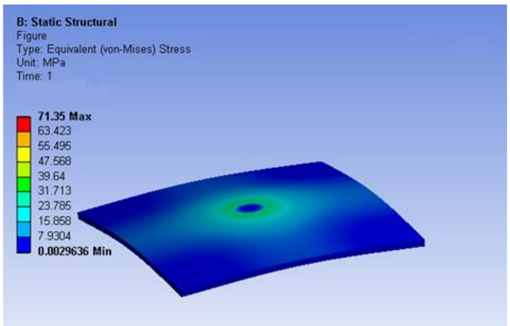


Fig. 11. Variation map of equivalent stress-100kg

4.2 Deformations and stresses at the maximum stroke of the vertical cylinder

The same loading conditions are considered, but in the case where the vertical cylinder is at the end of the stroke, in the upper maximum position of the piston. Figure 12 shows the model of the plate at the maximum stroke. Figure 13 - the embossed board on the contour and loaded with a weight of 1 kg.

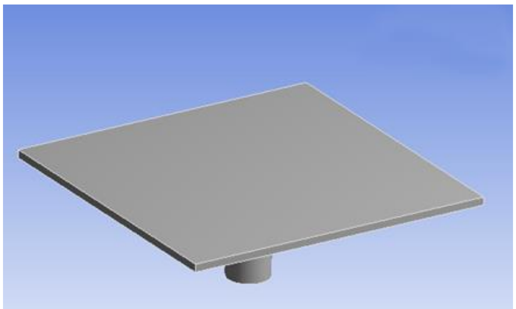


Fig. 12. Plate in maximum stroke

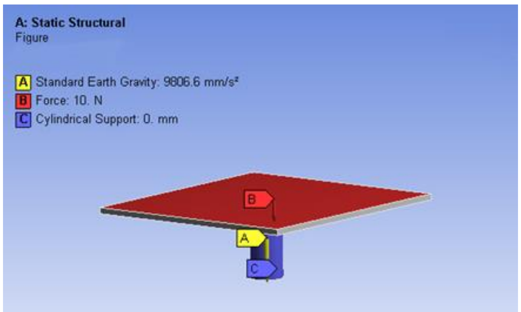


Fig. 13. Plate loaded with 1kg

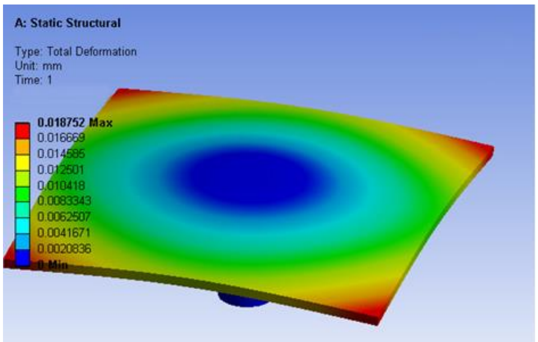


Fig. 14. Variation map of total deformation-10kg

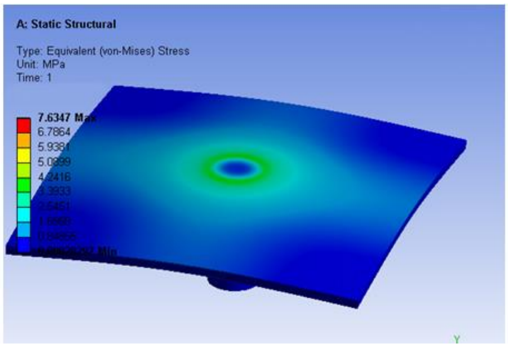


Fig. 15. Variation map of equivalent stress-10kg

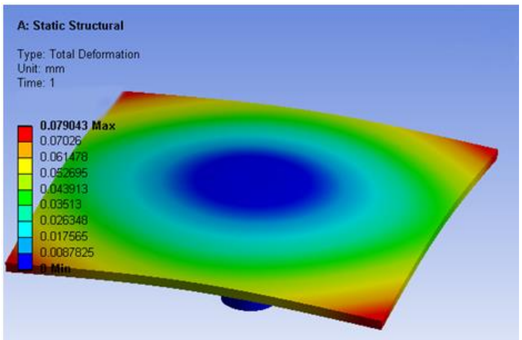


Fig. 16. Variation map of total deformation-50kg

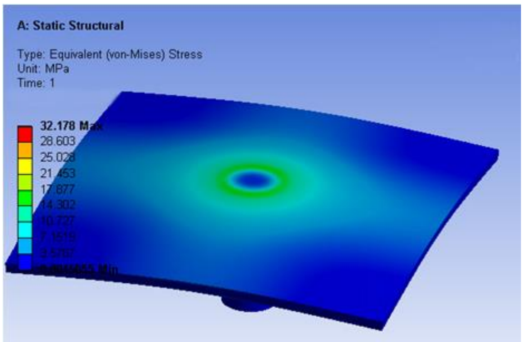


Fig. 17. Variation map of equivalent stress-50kg

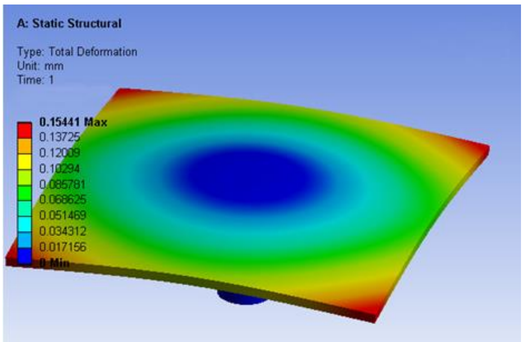


Fig. 18. Variation map of total deformation-100kg

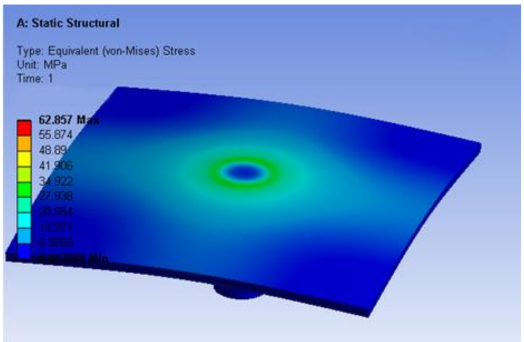


Fig. 19. Variation map of equivalent stress-100kg

Figures 14 ÷ 19 show the variation maps of the total deformation and the equivalent stress in case the plate was loaded with 10, 50 and 100 kg.
Figure 20 shows the variation of the total deformation at successive loadings of the vertical moving mobile unit plate weighing from 10-100 kg and in Figure 21 the variance of the von Mises stress under the same loading conditions.

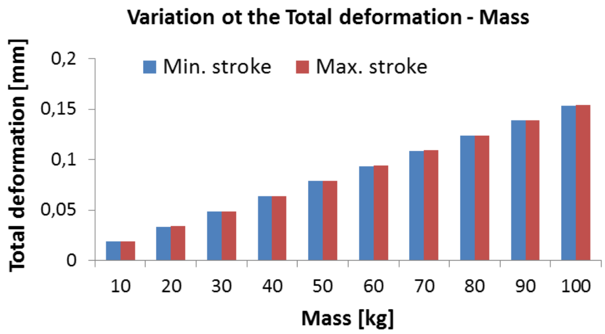


Fig. 20. Variation of total deformation by mass

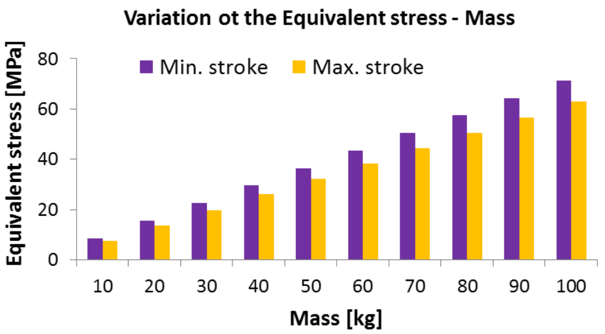


Fig. 21. Variation of total equivalent stress by mass

5. Conclusions

As a result of modeling the finite element of the work table in the minimum stroke, work table loaded with weights ranging from 10-100 kg, it can be noticed that both the total deformation and the equivalent tension register a linear increase. When loading the work table with 10 kg, the total deformation is 0.0118679 mm, and when loading the work table with 100 kg of 0.1538 mm. Von Mises equivalent stress for a 10 kg load are 8.6659 MPa and 100.00 kg loading table are 71.35 MPa. Similarly, at maximum stroke, the total deformation varies from 0.018752 when loading the work table of 10 kg to 0.15441 when loading the work table by 100 kg. The equivalent von Mises stress range from 7,63347 MPa for a load of 10 kg to 62,857 MPa for a 100 kg load table.

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