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PRE-TENSIONED C-FRAME FOR THE CRANK MECHANICAL PRESS. STUDY OF THE STRESS AND STRAIN STATE

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Abstract: *Considering the long useful life duration of the presses, the reduction of their energetic consumption during exploitation turns into an essential goal. An important path for attaining this objective is raising the rigidity of the press, which equals the consumed energy for the elastic deformation of the machine. The paper herein submits such a new solution of C-frame, achieved through casting and being pre-tensioned. The C-frame of the Romanian crank press PAI 25 was taken as reference, whose general geometrical features were not modified. Modelling the reference C-frame and the new constructive solution was accomplished within the design environment ProEngineering WildFire 4. Both models were subjected to the analysis with finite element, resorting to Catia V5 R16, for determining their stress and strain state. The new constructive solution, adequate to pre-tensioning the front pillars of the machine frame resulted from minimally modifying the reference constructive solution. The front pillars were very little modified in order to be tensioned through tightening with tension-rods. For the study of the strain and deformation state, impelling and straining with external forces were stipulated in full accord with the real case. The study was achieved for three values of the pre-strain generated by every tension-rod.*
The paper herein submits a few results obtained with respect to raising the rigidity of the machine frame and to reducing the tension state within its body, through pre-tensioning its front pillars. The compared analysis of the results clearly enhances the superiority of the new solution.

Key words: *rigidity, pre-tensioned C-frame, mechanical press, FEA, stress state, strain state.*

1. INTRODUCTION

Human society's sustainable development calls, among other things, both for preserving resources and for efficiently using them. There is primarily aimed at reducing material and energetic waste.

Crank mechanical presses are machine-tools commonly used in industry. Energy consumption in exploiting presses also appears as a consequence of the elastic deformation in the resistance structure, consequently depending on the stiffness of the machine frame [1]. Furthermore, the durability of the tools and the quality of the processing are significantly influenced by the rigidity of the machine frame.

Given the useful life of mechanical presses, researches targeting the frame optimization are fully justified. They are pre-eminently envisaged to increase stiffness and to reduce stress; and likewise to minimize overall costs – of both production and exploitation.

Increasing frame stiffness directly causes a decrease of press energy consumption, while diminishing the state of stress yields an increase in press quality and service life.

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2. STUDY DIRECTIONS

Variegated types and constructive solutions exist for the frames of the crank mechanical presses. The authors of the paper herein considered as reference constructive solution, the frame of the crank mechanical press PAI 25, a relatively frequent press in Romania, of high quality, with very good results in exploitation.

The rise in the stiffness of the machine frame is usually obtained following an increased consumption of material [2]. At least three alternative action directions have been further identified:

- ribbing of the side walls of the machine frame;
- pre-tensioning of the machine frame;
- significantly reducing the distance between the working surface of the table and the axis of the bore hole of the main shaft.

The paper herein submits a few results obtained with respect to raising the rigidity of the machine frame and to reducing the tension state within its body, through pre-tensioning its front pillars.

3. INFORMATIONS

A model 3D of the press PAI 25 was elaborated rigorously observing the real model, Fig. 1. To this purpose, the ProEngineer Wildfire 4 environment was resorted to [3]. In order to enhance, in virtual environment, the strain and deformation state of the 3D

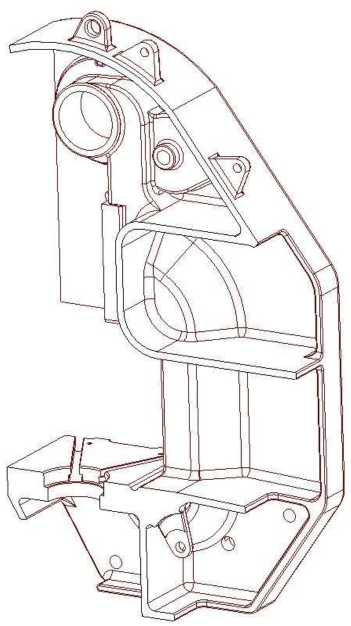


Fig. 1. 3D model of the C-frame of the press PAI 25.

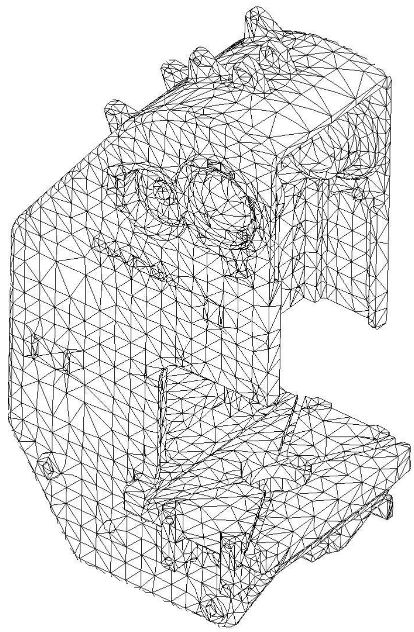


Fig. 2. Discretized model of a PAI 25 press frame [5].

model of the machine frame, this one was rendered discreet with tetra-hedron-type elements [4], Fig. 2.

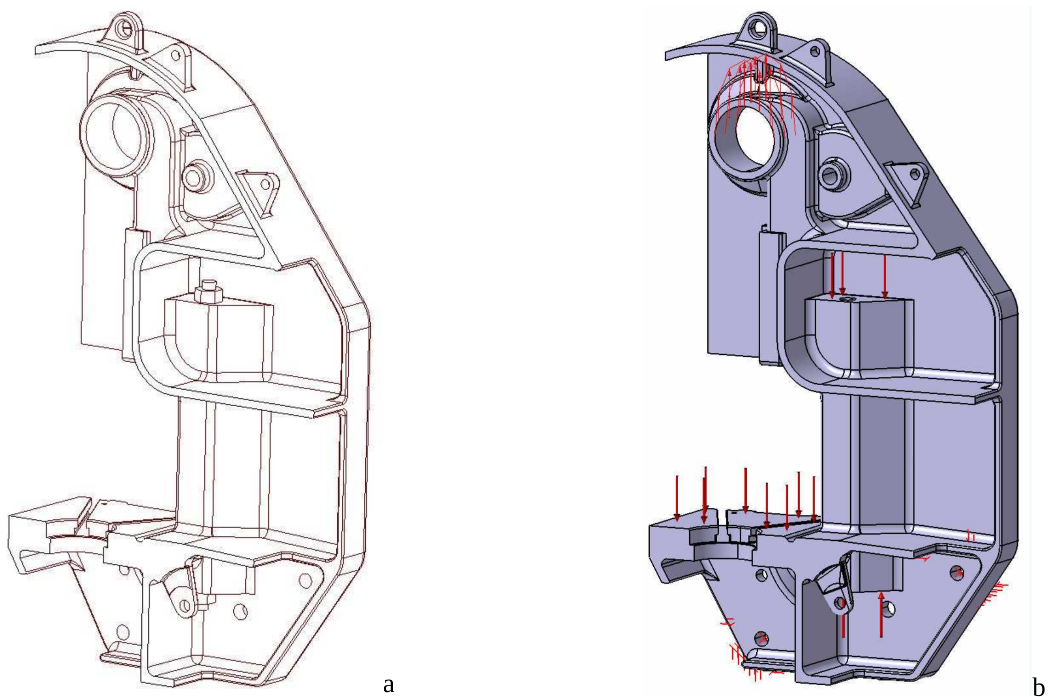
The new constructive solution, adequate to pre-tensioning the front pillars of the machine frame, figure 3a, resulted from minimally modifying the reference constructive solution. The front pillars were very little modified in order to be tensioned through tightening with tension-rods. A bore hole was provided for every pillar and the support bases were ensured for the screw nuts that achieve the strain of the tension-rods, which leads to the pre-tensioning of the pillars.

For the study of the strain and deformation state, impelling and straining with external forces were stipulated, Fig. 3b, in full accord with the real case.

In a first stage of the analysis, the strain and deformation state of the machine frame was studied, only considering the pre-strain given by tension-rods. Relevant images in this respect may be found in Fig. 4.

The study was achieved for three values of the pre-strain generated by every tension-rod: F_P = 50; 62.5; 100 kN.

In the second stage, the strain and deformation state was studied for the new solution of the machine frame, without considering the pre-tensioning through tension-rods, but only the strain given by the maximally admitted technological force, the nominal one: $F_t = F_N$ = 250 kN.



a b

Fig. 3. 3D model of the C frame of the press PAI 25:
a – variant with pre-tensioned pillars; *b* – forces load and constraints.

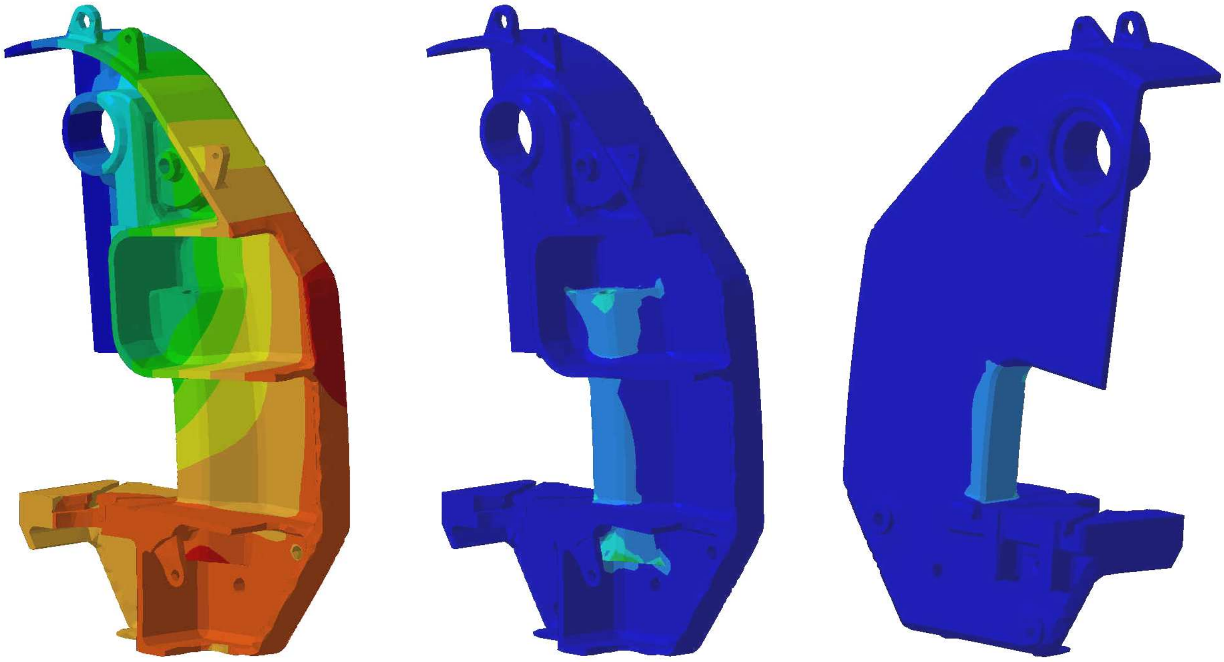


Fig. 4. Deformation and tension state in the pre-tensioned frame, only given by the pre-tensioning force.

Finally, in the third stage of the study, the tension and deformation state of the machine frame was analyzed, considering the real strain of the machine frame, under operating conditions of the mechanical press, in which situation the machine frame is solicited both by the pre-tensioning force given by the tension-rods, and by the maximal technological force. Relevant images in this respect may be found in Fig. 5.

The study of the strain and deformation state was done by resorting to CATIA V5R16 [6].

The conducted research has been primarily oriented towards finding constructive solutions, which should lead to diminishing the energy consumption during the mechanical-press exploitation, consequently to reducing the elastic deformation of the machine frame. Consequently, there were pre-eminently recorded, for all studied cases, the elastic yield of the machine frame on the direction of the pressing axis, identical with the vertical which intersects the axis of the bore hole of the main shaft, drawn through the median plan of the machine frame. Relevant values of the yield of the machine frame are also grasped in Table 1, and a suggestive graph is offered for some of them, in Fig. 6.

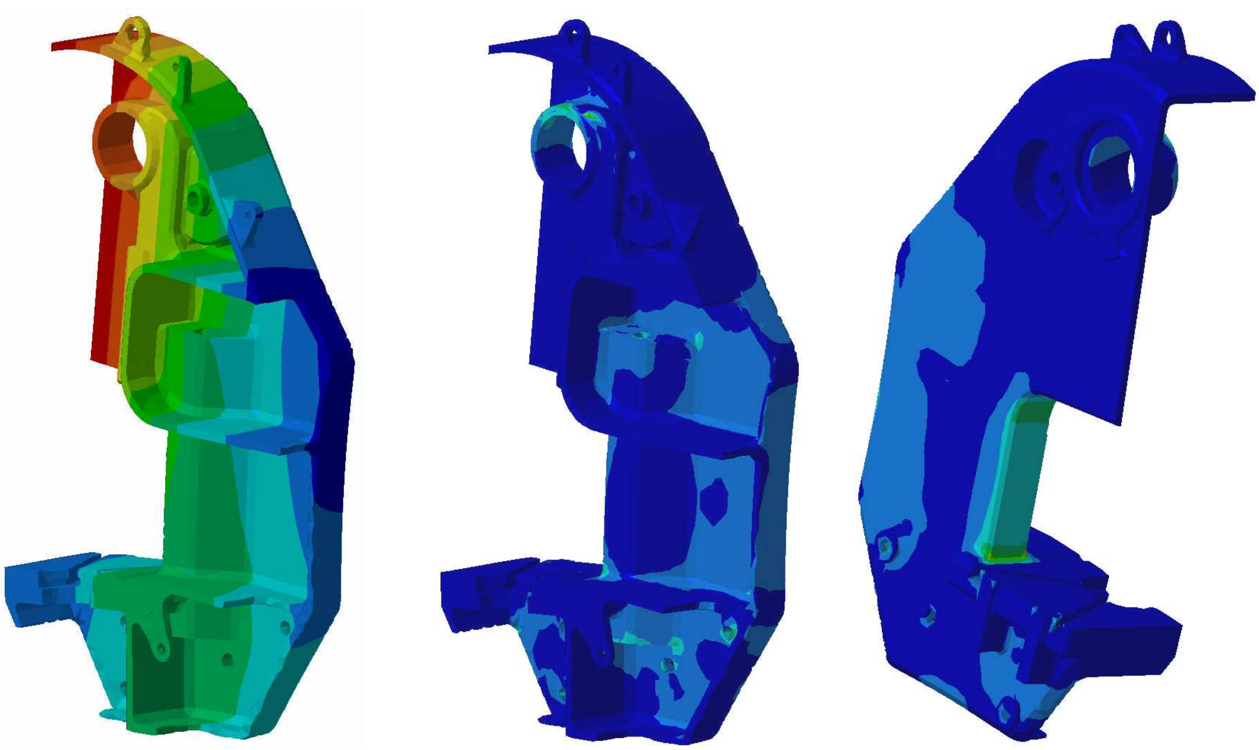


Fig. 5. Deformation and tension state in the pre-tensioned frame, also solicited by the maximally admitted technological force.

Table 1

Values of the yield on the direction of the pressing axis, for the pre-strained frame, with rib-deprived walls

Level of pre-strain [kN]	Yield on the direction of the pressing axis [mm]		
	only F_p	**only F_t**	**F_p & F_t**
$F_P = 50$	$\delta_p = 0.0120185$	$\delta_t = 0.078505$	$\delta = 0.0663775$
$F_P = 62.5$	$\delta_p = 0.01502825$		$\delta = 0.0654575$
$F_P = 100$	$\delta_p = 0.0240085$		$\delta = 0.0558075$

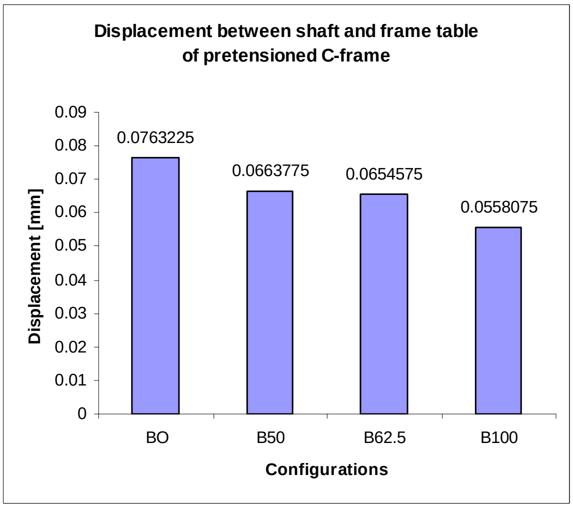


Fig. 6. The total yield of the pre-strained rib-deprived frame, depending on the various pre-tensioning values.

The first enunciated study direction, raising the stiffness of the machine frame through the ribbing of its side walls, had previously constituted the object of an extended study, whose positive results were partly rendered public [7–9]. Within the study herein, focused on a pre-tensioned machine frame, it has been deemed opportune and necessary to see whether and to what extent the combination of the two solutions brings about the accumulation of their effects.

As the provision of the ribs with 10º tilt, regardless whether they are towards the back of the machine frame or towards its front, yielded the best results, these variants were combined with the constructive solution of machine frame with pre-tensioned front pillars. The same three values of the pre-tensioning force were kept, as in the case of the rib-deprived machine frame and, likewise, the same maximal level of the value of the technological force. The results are identical to a great extent. Relevant images of the deformation and tension states of the pre-tensioned and wall-ribbed machine frame, with 10º backwards tilted ribs, are shown in Fig. 7.

For the variants of pre-strained and wall-ribbed machine frame, with 10º, backwards and frontward tilted ribs, relevant values for the yield of the frame are given in Tables 2 and 3, and in Figs. 8, a and b, there are shown suggestive graphical representations for some of them.

The frame frontal columns being constantly subject to compression through the tie-bars, the decrease of the pre-compressed frame elastic deformation is significantly reduced compared to the corresponding elastic deformation of the frame used as reference.

Lateral wall ribbing [5, 10, and 11] also contributes to increasing frame stiffness, however to a lesser degree than frontal column pre-compression by means of tie-bars. Other lateral wall ribbing schemes [7], like cross-ribbing, tilted or not (Fig. 9) are likely to yield similar results in pre-compressed frames.

In regard to quality, more important than the reduced elastic deformation is the qualitative improvement of state of stress distribution in the pre-compressed frame with ribbed walls, particularly in the critical areas. Thus maximum stress value is reduced by nearly half, as highlighted by simple comparison of the state of stress in the pre-compressed frame, Fig. 5, with that of the merely ribbed one, Fig. 10.

4. DISCUSSION

Through the pre-tensioning of the front pillars, an alternation of the strain in their area is ensured: compression when the machine does not develop technological force and stretch when the technological force exceeds a certain value. It is preferable for the adopted pre-tensioning force to determine equal values or as close as possible to the maximal compression and draw-out strains that appear in the front pillars.

Table 2

Values of the yield on the direction of the pressing axis, for the pre-strained frame, with leftwards ribbed walls

Level of pre-strain [kN]	Yield on the direction of the pressing axis [mm]		
	only F_p	**only F_t**	**F_p & F_t**
$F_P = 50$	$\delta_p = 0.01206725$	$\delta_t = 0.0794175$	$\delta = 0.065725$
$F_P = 62.5$	$\delta_p = 0.015177$		$\delta = 0.063795$
$F_P = 100$	$\delta_p = 0.02476825$		$\delta = 0.055115$

Table 3

Values of the yield on the direction of the pressing axis, for the pre-strained frame, with rightwards ribbed walls

Level of pre-strain [kN]	Yield on the direction of the pressing axis [mm]		
	only F_p	**only F_t**	**F_p & F_t**
$F_P = 50$	$\delta_p = 0.0119945$	$\delta_t = 0.07865$	$\delta = 0.06675$
$F_P = 62.5$	$\delta_p = 0.01497925$		$\delta = 0.063875$
$F_P = 100$	$\delta_p = 0.023929$		$\delta = 0.05525$

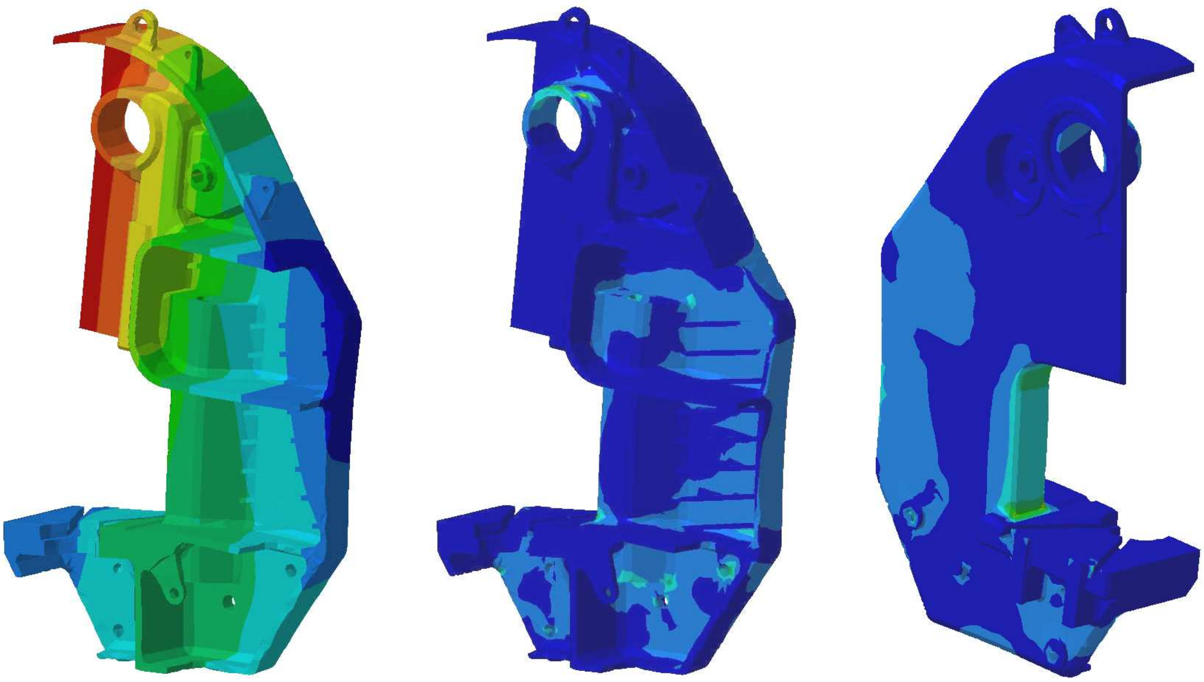


Fig. 7. Deformation and tension state in the pre-tensioned frame, with ribbed to the right, also solicited by the maximally admitted technological force.

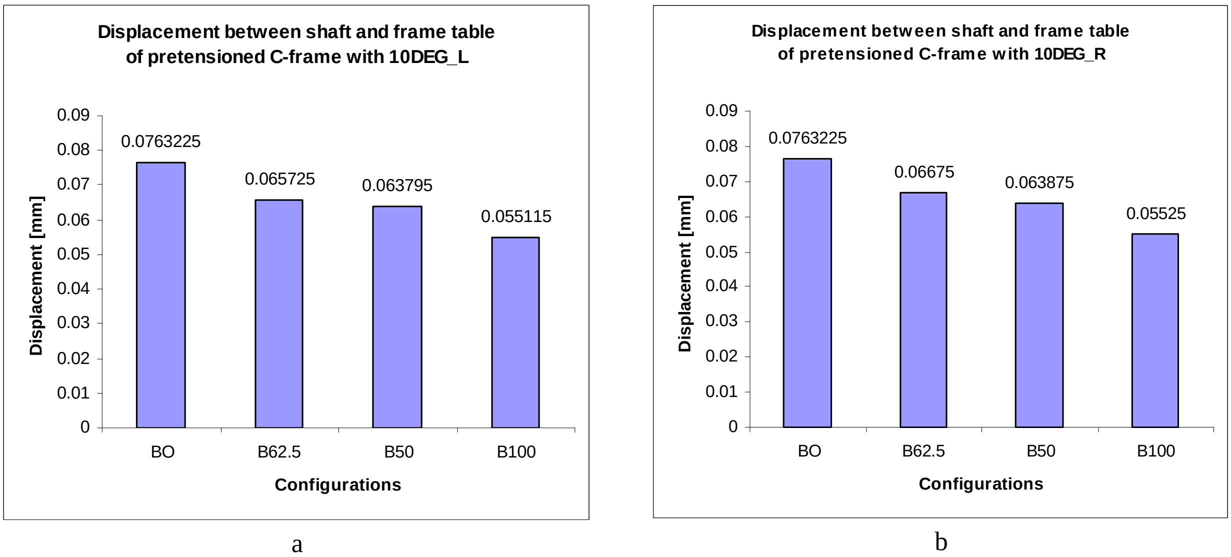


Fig. 8. The total yield of the pre-strained frame, depending on the various pre-tensioning values: *a* – rib-walled frame at 10º to the left; *b* – rib-walled frame at 10º to the right

In order to ensure the pre-tensioning of the front pillars of the machine frame, a bore hole is practiced within them, which obviously leads to a slight reduction of their resistance, of 2 ÷ 3 %. Mounting and tensioning the pre-strain tension-rods subsequently changes this state of facts.

It appears that ribbing the side walls in the machine frame with pre-strained front pillars unexpectedly leads to a slight diminution in rigidity. This result is somewhat surprising considering that ribbing the side walls proved to be a solution with positive effects in relation to the reference constructive solution [5].

The total yield of the pre-strained machine frame simultaneously charged with the pre-straining and with the technological force, observes the principle of the sum of effects. The overall resultant yield, linearly dependent on the pre-strain, is significantly lower than the yield of the reference machine frame. It should be however stressed that the values submitted in Tables 1, 2 and 3 represent the magnitude in relation to an origin which corresponds to an initial state, of non-strain, of the machine frame.

For the correct evaluation of the rigidity of the pre-strained machine frame, its state subsequent to the pre-tensioning of the front pillars must be “frozen”, the new position of zero must be identified and the yield due to the strain with the technological force must be determined in relation to the former. This value truly characterizes both the rigidity of the pre-strained machine frame and its exploitation energy consumption. The studies will continue in this respect and will be completed by analytical models for calculating the elastic deformation of this constructive solution of machine frame.

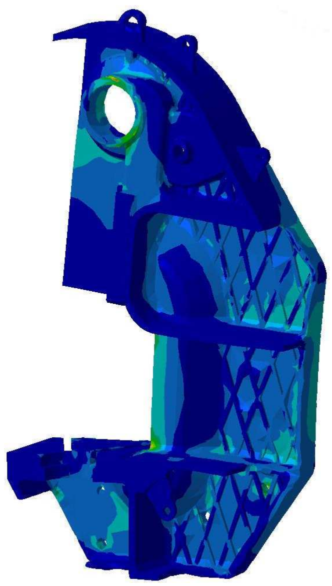


Fig. 9. C-frame with cross-ribbed lateral walls.

Through pre-straining the front pillars of the machine frame, the general tension state which manifests in its body is considerably improved in relation to the reference constructive solution. This is an important gain in quality, with obvious effects, which manifests even is the rise in stiffness is minor.

5. CONCLUSIONS

The energy consumption in exploiting presses also appears as a consequence of the frequent elastic deformation of the resistance structure; it consequently depends on the rigidity of the machine frame.

The rise in the stiffness of the machine frame is usually obtained following an increased consumption of material. A possible alternative solution is raising the rigidity of the machine frame and reducing the tension state which manifests in its body through pre-tensioning its front pillars.

The total resultant yield, measured as magnitude in relation to an origin that corresponds to an initial state, of non-strain of the machine frame, is significantly lower than the yield of the reference machine frame and linearly dependent on the pre-strain.

Through pre-straining the front pillars of the machine frame, the overall tension state manifested in its body is considerably improved in relation to the reference constructive solution.

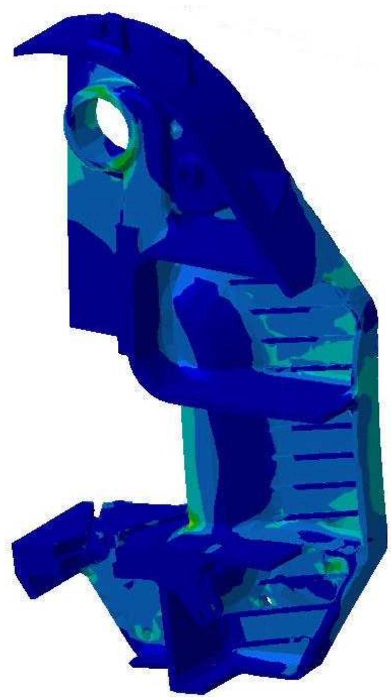


Fig. 10. State of maximum stress in a non-precompressed C-frame with tilted-ribbed lateral walls.

REFERENCES

[1] V. Tabără, D. Catrina, V. Ganea, *Calculul, proiectarea şi reglarea preselor* (Computation, design and adjustment of presses), Editura Tehnică, Bucureşti, 1976.

[2] C. Ispas, et al., *Maşini-unelte. Elemente de structură* (Machine-Tools. Elements of Structure), Editura Tehnică, ISBN 973-31-1029-0, Bucureşti, Romania, 1997.

[3] ***. *Fundamentals of Design*, Pro/ENGINEER Wildfire, PTC (Parametric Technology Corporation).

[4] Gh. Mogan, *Analiza cu elemente finite în inginerie* (Finite Elements Analysis in Engineering), Editura Universităţii Transilvania din Braşov, ISBN 978-973-598-159-4, Braşov, Romania, 2007.

[5] I. Dan, *Cercetări privind influenţa nervurilor înclinate şi curbe asupra rigidităţii presei PAI 25* / *Research on the Influence of Tilted and Curved Ribbing on the Stiffness of PAI 25 Presses* (bilingual), RECENT journal, vol. 12(2011), no. 2(32), Braşov, Romania, july 2011, p. 103-111, ISSN 1582-0246.

[6] S. Tickoo, D. Maini, *CATIA V5R16 for Designers*, CADCIM Technologies, ISBN: 1-932709-18-5, USA, 2006.

[7] R. Cioară, I. Dan, *Increased rigidity solutions for C-frame mechanichal presses*, Proceedings in Manufacturing Systems ICMaS, Bucharest, Romania, Vol. 6, issue 2, 2011, pp. 111-116, ISSN 2067-9238, Editura Academiei Române.

[8] I. Dan, R. Cioară, *New Studies about Crank Mechanical Press PAI 25 Frame*, International Conference “Challanges in Higher Education and Research in the XXIst Century”, T. Tashev, R. Deliyski, B. Lepadatescu (Eds.), pp. 272-275, Sozopol, Bulgaria, June 5-8, 2011, Vol. 9, Heron Press Ltd., Sofia, ISBN 978-954-580-308-6.

[9] I. Dan, R. Cioară, *Optimization Studies about Crank Mechanical Press PAI 25 Frame*, Proceedings of the 15th International Conference Modern Technologies, Quality and Inovation, Iaşi-Chişinău-Belgrad, ModTech 2011, New Face of T.M.C.R., ISSN 2069-6736, Vol. II, D. Nedelcu, L. Slătineanu, S. Mazuru & Olivera Milosevic (Eds.), pp. 521-524, 25-27 May, 2011, Vadul lui Vodă, Republic of Moldova.

[10] I. Dan, *CAD Research on the Tilted Ribs Influence upon Press Frame PAI 25*, International Conference “Challanges in Higher Education and Research in the XXIst Century”, T. Tashev, R. Deliyski, B. Lepadatescu (Eds.), pp. 276-279, Sozopol, Bulgaria, June 5-8, 2011, Vol. 9, Heron Press Ltd., Sofia, ISBN 978-954-580-308-6.

[11] I. Dan, *CAD Research Regarding the Influence of Wall Thickness and Ribbing on the Frame of PAI 25 Crank Mechanical Press*, Proceedings of the 15th International Conference Modern Technologies, Quality and Inovation, Iaşi-Chişinău-Belgrad, ModTech 2011, New Face of T.M.C.R., ISSN 2069-6736, Vol. I, D. Nedelcu, L. Slătineanu, S. Mazuru & Olivera Milosevic (Eds.), pp. 517-520, 25-27 May, 2011, Vadul lui Vodă, Republic of Moldova.