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# MULTICRITERION OPTIMIZATION OF PRESS COLUMN CROSS-SECTION

***Purpose***. *Increase of the competitiveness is the important scientific and practical task in machine building. The press is the stationary equipment, but reduction of weight of its elements, in particular – columns, reduces manufacturing cost, facilitates transportation and installation, therefore assists in increase of product attraction at market relations. The purpose is to reduce press column weight without complication of technological process of its manufacturing and without additional expenses for a concrete one-columned press by means of structure optimization.*

***Research methods***. *The mathematical model has been developed on the basis of formula of combined strength of materials. The pure bending with tension results from operation of one-columned press. Multicriterion optimization has been carried out by means of computer facilities. Calculation was carried out by means of the program written in language Basic.*

***Results***. *The press П6330 with box-shaped cross-section has been chosen as a base variant. The optimal geometrical dimensions have been determined for the offered T-shaped welded cross-section of a column. Technological process of manufacturing of such column is simplified.*

***Scientific novelty***. *The T-shaped welded column cross-section has been offered for the purpose of modernization. Such cross-section scheme is more perspective and technological. The following 3 criteria have been chosen at multicriterion optimization carrying out: equal strength with the base variant, the greatest uniformity of distribution of stress by cross-section, the least area of cross-section. The main geometrical dimensions of cross-section have been chosen as 4 variable parameters. It was considered, that thickness of metal sheet is discrete and standard.*

***Practical value***. *Multicriterion optimization that had been carried out provides reduction of column weight approximately by 45 % for the modernized variant without increase in dimensions of cross-section. It gives the opportunity to reduce considerably the column manufacturing cost in comparison with a base variant, and also to facilitate transportation and installation of the press.*

***Key words***: *press, column, cross-section, dimension, optimization, criterion, stress, equal strength.*

## Introduction

Increase of the competitiveness is the important scientific and practical task in machine building. The press is the stationary equipment, but reduction of weight of its elements, in particular – columns, reduces manufacturing cost, facilitates transportation and installation, therefore assists in increase of product attraction at market relations. The most natural way to reach it is structure optimization. Optimization of press column cross-section is rather complicated task just for the one-columned presses.

## Review

Various types of pess column cross-sections are listed in the book [1]. Cross-section of box-shaped welded column and T-shaped cross-section of casted column are mentioned among them. However welded T-shaped cross-sections are not described. The comparative analysis of different cross-sections is absent. Problems of structure or parameter optimization of cross-sections are also not analyzed.

Optimization of hydraulic press flat frames by Finite Element Method (FEM) is described in methodical recommendations [2]. But optimization of column cross-section of the one-columned press is not considered as well.

Optimization of a cross-section of box-shaped column of the one-columned press is described in paper [3]. But only thickness of forward wall and thickness of back wall are used as the basic variable parametres. Column cross-section shape remains the same.

As a development of paper [3], optimization of trapezoid column cross-section of the one-columned press is described in paper [4] and the subsequent author's thesis abstract [5]. But column cross-section shape remains constant in this case as well. There are no comparison with T-shaped cross-section.

More modern researches are even less often devoted to optimization of column structure of the one-columned press.

For example, calculations using both analytical


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method and FEM have been executed for a four-columned hydraulic press under different loading conditions in paper [6]. But the received results cannot be applied to the one-columned press.

Optimization of 100 ton one-columned hydraulic press frame by FEM standard tools is described in article [7]. Quantitative change of structure geometrical parametres as a result of more exact calculations allows to reduce weight of a design slightly. But FEM standard tools do not give possibility of qualitative optimization of the structure including its shape.

Thus, authors of this paper have not found in the literature any attempts of multicriterion optimization of T-shaped welded column cross-section of the one-columned press. Correspondently, our paper is devoted to solution of this problem.

## Purpose

The purpose is to reduce press column weight without complication of technological process of its manufacturing and without additional expenses for a concrete one-columned press by means of structure optimization.

## Research and its methods

The press П6330 with box-shaped welded column cross-section [8] has been chosen as a base variant. The correspondent cross-section for this base variant is shown in scale at figure 1. Nominal load $P$=1000 kN acts in a point $A$ at distance 400 mm from the front wall.

It is clear from the figure 1 analysis, that metal is uniformly distributed by all walls of a column. On the other hand, it is follows from the literary review, that column cross-section optimization of the one-columned press is usually connected with metal redistribution between walls.

The way, earlier used in paper [9], has been applied, which allows to receive qualitatively new structure by quantitative optimization.

That's why the T- shaped welded column cross-section has been offered for the purpose of modernization. The correspondent calculation scheme is shown at figure 2. If the central wall would be divided on two parallel parts, this calculation scheme would be applicable as well for box-shaped column cross-section, and for trapezoid cross-section too. Thus, according to the theory of qualities [10], optimization by this calculational scheme allows to compare automatically few cross-sections.

More than that, such T-shaped welded cross-section scheme is more perspective and technological.

The main geometrical dimensions of cross-section have been chosen as four variable parameters: cross-section height $H$, forward wall width $B$, back wall width $b$, wall thickness $h$.

It was considered, that thickness of metal sheet is discrete and standard. That's why the following thickness combinations listed in table 1 have been used [11].

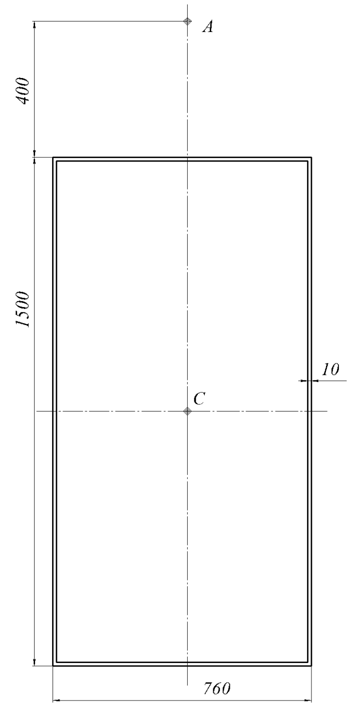


**Figure 1.** Cross-section for the base variant

**Table 1 –** Thickness combinations

| h, mm | δ, mm |
|---|---|
| 10 | 4 |
| 12 | 5 |
| 14 | 6 |
| 16 | 6 |
| 18 | 6 |
| 20 | 8 |

Such approach has allowed to reduce number of variable parametres to four and to simplify calculations [12].

Centroidal moment of inertia of a cross-section increases together with its modulus [13]. Consequently, rigidity of a structure increases together with its strength. That's why the following three criteria have been chosen at multicriterion optimization [14] carrying out:

- equal strength with the base variant,
- the greatest uniformity of distribution of stress by cross-section,
- the least area of cross-section.

The pure bending with tension results from operation of an one-columned press. Hence, tangent stress is absent, and normal stress in the point 2 at figure 2 (centre of inertia $C$ of cross-section) would be less than in the point 1, therefore it would be neglectable. Taking into account character of distribution of normal stress by cross-section, in terms of design it means, that first two criteria would be realized under the following condition: normal stresses in the point 1 $\sigma_1$ and point 3 $\sigma_3$ at figure 2 have to be approximately equal by modulus to one another and to the maximum normal stress for a base variant $\sigma_{max}$.


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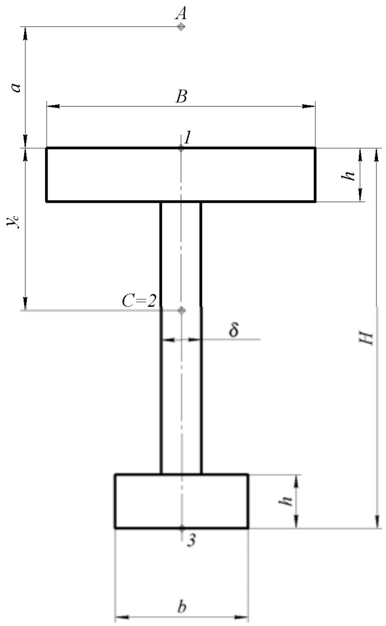


**Figure 2.** Calculation scheme

The mathematical model has been developed on the basis of formulae of combined strength of materials [15].

Area $F$ of the cross-section:

$$F = (B + b) \cdot h + (H - 2 \cdot h) \cdot \delta \tag{1}$$

Statical moment $S_x$ of the cross-section:

$$S_x = B \cdot \frac{h^2}{2} + b \cdot h \cdot (H - \frac{h}{2}) + (H - 2 \cdot h) \cdot \delta \cdot \frac{H}{2} \tag{2}$$

Coordinate of centre of inertia of the cross-section:

$$y_c = S_x / F \tag{3}$$

Centroidal moment of inertia $I_{xc}$ of the cross-section:

$$I_{xc} = \frac{B \cdot h^3}{12} + \frac{\delta \cdot (H - 2 \cdot h)^3}{12} + B \cdot h \cdot \left( y_c - \frac{h}{2} \right)^2 + b \cdot h \cdot \left( H - y_c - \frac{h}{2} \right)^2 + (H - 2 \cdot h) \cdot \delta \cdot \left( \frac{H}{2} - y_c \right)^2 + \frac{b \cdot h^3}{12}. \tag{4}$$

Normal stresses:

$$\sigma_1 = P \cdot (a + y_c) \cdot y_c / I_{xc} + P / F , \tag{5}$$

$$\sigma_3 = P \cdot (a + y_c) \cdot (y_c - H) / I_{xc} + P / F , \tag{6}$$

Thus, mathematically criteria of optimisation are reduced to following conditions:

- $\sigma_1$ have to be less than $\sigma_{max}$ no more than on 3%;
- $\sigma_3$ by modulus have to be less than $\sigma_{max}$ no more than on 3 %;
- area $F$ have to be minimal in comparison with area $F_0$ of a base variant.

Multicriterion optimization has been carried out by means of computer facilities. Calculation was carried out by means of the program written in language Basic. Results of calculations are listed in table 2.

**Table 2 –** Results

| $h$, mm | $H$, mm | $B$, mm | $b$, mm | $F/F_0$ |
|---|---|---|---|---|
| 10 | 1854 | 1328 | 140 | 0,491 |
| 12 | 1718 | 1112 | 120 | 0,519 |
| 14 | 1554 | 970 | 118 | 0,544 |
| 16 | 1590 | 844 | 98 | 0,545 |
| 18 | 1546 | 760 | 96 | 0,546 |
| 20 | 1360 | 698 | 98 | 0,591 |

All these variants satisfy to three criteria of optimization listed above. The variant with wall thickness $h$=18 mm has been chosen finally taking into account one more additional criterion: overall dimensions of the base and modernized variants have to be approximately equal.

## Results

Thus, the optimal geometrical dimensions have been determined for the offered T-shaped welded cross-section of a column. The correspondent column cross-section for the modernized variant is shown in scale at figure 3.

It is clear from comparison of figure 1 and figure 3, that overall dimensions of column cross-sections of base and modernized variants are comparable by value. Hence, the modernized press can be installed on the same working space.

Also the modernized variant has equal strength with the base variant according to problem statement. It has been confirmed by check design.

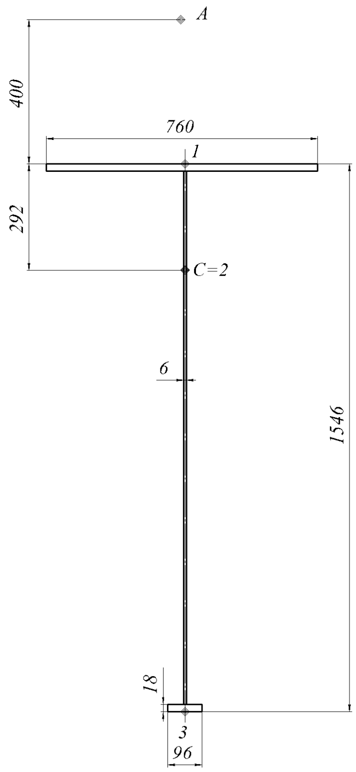


**Figure 3.** Cross-section for the modernized variant


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It is visible at figure 3, that the central wall is too thin to be divided into two parts. Hence, the T-shaped column cross-section has advantage in comparison with trapezoid one.

A back wall serve additionally as a stiffening rib for the compressed part of a structure.

### Discussion

The quantity of welded seams decreases in the modernized variant in comparison with a base variant. The quantity of cuts at manufacturing of metal blanks also decreases in comparison with a base variant. It provides certain technological advantages.

Column cross-sections of modernized variant worse works at torsion in comparison with base one. But torsion loads are neglectable for the press column.

### Conclusions

Multicriterion optimization that had been carried out provides reduction of press column weight approximately by 45 % for the modernized variant without increase in dimensions of cross-section. Technological process of manufacturing of such column simplifies. It gives the opportunity to reduce considerably the column manufacturing cost in comparison with a base variant, and also to facilitate transportation and installation of the press.

Authors of this paper plan to research influence of displacement of a load from an axis on results of optimization of press column cross-section in future.

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# БАГАТОКРИТЕРІАЛЬНА ОПТИМІЗАЦІЯ ПОПЕРЕЧНОГО ПЕРЕРІЗУ КОЛОНИ ПРЕСА

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***Мета роботи.*** *Підвищення конкурентоспроможність є важливим науковим і практичним завданням у машинобудуванні. Прес є стаціонарним обладнанням, але зменшення маси його елементів, зокрема – колони, знижує собівартість, полегшує транспортування та монтаж, тому сприяє зростанню привабливості виробу в ринкових умовах. Метою роботи є зменшення маси колони преса без ускладнення технологічного процесу її виготовлення та без додаткових витрат.*

***Методи дослідження.*** *Математична модель була побудована на основі залежностей складного опору матеріалів. Для одноколонного преса при навантаженні має місце чисте згинання з розтяганням. Багатокритеріальну оптимізацію було здійснено за допомогою комп'ютерних засобів. Розрахунок виконувався за допомогою програми, написаної на мові Basic.*

***Отримані результати.*** *В якості базового варіанту було обрано прес П6330 з коробчастим поперечним перерізом. Для запропонованого Т- образного зварного поперечного перерізу колони було визначено оптимальні геометричні розміри. Технологічний процес виготовлення такої колони спрощується.*

***Наукова новизна.*** *З метою модернізації було запропоновано Т- образний зварний поперечний переріз колони. Така схема поперечного перерізу є більш перспективною та технологічною. При проведенні багатокритеріальної оптимізації були обрані наступні 3 критерії: рівноміцність з базовим варіантом, щонайбільша рівномірність розподілу напружень за перерізом, щонайменша площа поперечного перерізу. В якості 4-х варійованих параметрів були обрані головні геометричні розміри поперечного перерізу. Враховувалось, що товщини листів є дискретними та стандартними.*

***Практична цінність.*** *Проведена багатокритеріальна оптимізація дала можливість знизити масу колони модернізованого варіанту приблизно на 45 % без збільшення габаритів поперечного перерізу. У порівнянні з базовим варіантом це дає можливість помітно зменшити собівартість колони та полегшити транспортування і монтаж преса.*

***Ключові слова:*** *прес, колона, поперечний переріз, розмір, оптимізація, критерій, напруження, рівноміцність.*

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