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Optimizing body design of a computer-assisted manual press

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Abstract. This paper proposes a simplified design of a press body manually using a model consisting of a double symmetrical frame flush.
Both Mathcad and Solidworks programs were used to determine the dimensions and drawings.
MathCad is a very complex program, but also very useful for engineers, researchers, mathematicians, students, teachers, and all those who use math. Mathcad is a much better way to perform and manage engineering calculations, making them easy to achieve, understand, verify, communicate, and logically follow.
SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows.

1. Introduction

Manually operated screw presses are used in machine building, mechanical workshops bending and stamping small pieces in small numbers. Also the presses are used to press some adjustments and to the technological process of molding.

Manual force-operated presses have the following operating principle:

- → On the crank is acted with a force that rotates the power screw through the blocking portion which blends with the ratchet screw
- → The power screw transfers a moving load to the workpiece to the workpiece

In machine building, presses are used on a large scale because of the advantages they present:

- Simple construction
- Easy to build construction technology
- Using cheap materials
- Low cost
- The possibility of transmitting large axial loads using small drive forces
- Performs a large transmission report
- Good operation, no noise
- Gauge reduced

Computer problem solving has been a strong motivation, so that the evolution of hardware and PC development have led to the emergence of software for math problem solving.

Mathcad provides a unique, intuitive design environment that allows engineers to work out, document, and quickly share engineering calculations, including product requirements, critical data, methods, equations, and assumptions.

Mathcad using the conventional problems can be solved by mechanical (kinematic, dynamic, strength of the material)

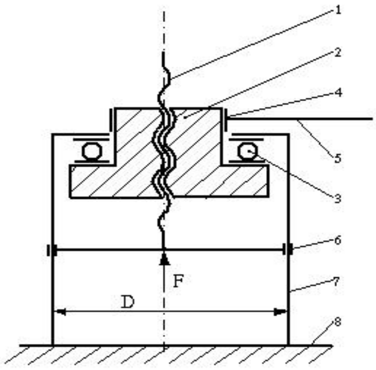
SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes.

According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013.

2. Technical caracteristics of press

The technical caracteristics of the press are:

- The maximum applied force : $F = 12\ KN$
- The maximum travel for the screw: $H_{max} = 160\ mm$
- The external diameter of the press: $D = 210\ mm$



1 – screw
2 – rotating nut
3 – axial ball bearing
4 – ratchet device
5 – actuation mechanism
6 – pressure plate
7 – column
8 – base plate

Figure 1 – the cinematic scheme of the press

3. Designing of the press body

The nut-screw assembly is mounted in a supported cross member on two threaded ends columns. These columns serve as guiding elements for the movable part of the press.

To simplify the problem, everything will be reduced to a simple embedded frame

In Figure 2 is showed the simplified diagram of the press body, a double symmetrical frame with the columns with fixed ends.

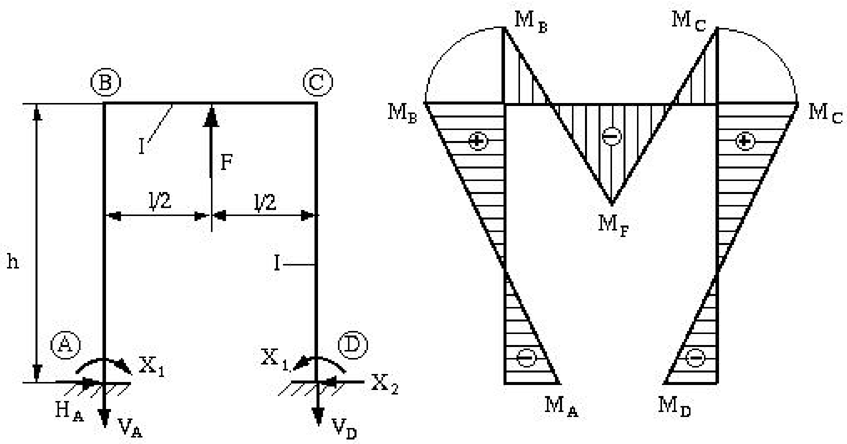


Figure 2 – Frame loading scheme

Assuming that the moment of inertia of the column is equal to that of the cross member, we calculate the displacements and write the system of equilibrium equations:

When,

$$l_c = l_t = l$$

$$l_c = (1{,}35 \div 1{,}45) \cdot H_{max} = 1{,}375 \cdot 160 = 220\ mm$$

=>

$$X_1 = M_A = M_D = -\frac{F \cdot l^2}{8 \cdot h + 16 \cdot l} = -111692{,}3\ N \cdot mm$$

$$X_2 = H_A = H_D = -\frac{3 \cdot F \cdot l^2}{8 \cdot h^2 + 16 \cdot h \cdot l} = -1595{,}6\ N$$

Where:

$F = 12000N$

$l = 220\ mm$

$h = 210\ mm$

$$M_B = M_A - H_A \cdot h = -2 \cdot M_A = \frac{2 \cdot F \cdot l^2}{8 \cdot h + 16 \cdot l} = 223384{,}6\ N \cdot mm$$

$$M_F = M_B - V_A \cdot \frac{l}{2} = M_B - \frac{F}{2} \cdot \frac{1}{2} = \frac{2 \cdot F \cdot l \cdot (h + l)}{8 \cdot h + 16 \cdot l} = 436615{,}4\ N \cdot mm$$

$$V_A = V_B = \frac{F}{2} = \frac{12000}{2} = 6000\ N$$

In this case the joints of the columns with the traverse and the base plate are required for traction and bending.

4. Columns pre-dimensioning

We calculate the predimensioning traction in the recess area which is considered to be the most dangerous.

$$A_{sec} = \frac{\pi \cdot d_0^2}{4} = \frac{F}{2 \cdot \sigma_{at}}$$

$$d_0 = \sqrt{\frac{2 \cdot F}{\pi \cdot \sigma_{at}}} = 7{,}93\ mm$$

For the tensile stress, the minimum safety factor shall be taken into account $C_c = 3$

The column is made of OL37 steel, witch has tensile breaking strength $\sigma_c = 340 \div 360\ MPa$

$$\sigma_{at} = \frac{\sigma_c}{C_c} = \frac{360}{3} = 120\ MPa$$

We pick

$$d_0 = 12\ mm$$

$D_0 = 14\ mm$ $\quad$ $D = 20\ mm$

$h = 210\ mm$ $\quad$ $d_0' = 8\ mm$

for the threaded groove

$$\sigma_t = \frac{F/2}{\pi/4 \cdot d_0'^2} = 119{,}42\ MPa < 120\ MPa$$

⇨ The threaded grrove area (d_0') is withstanding traction loading
⇨ It results that it also resists the diameter section (d_0)

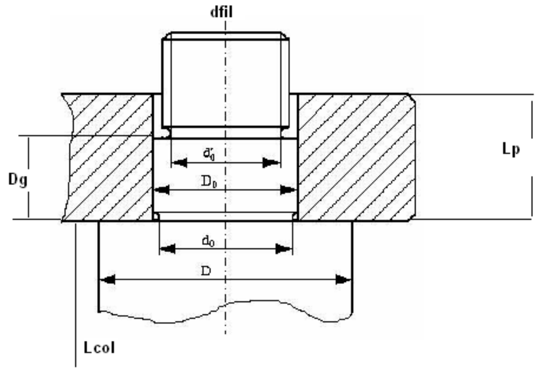


Figure 3 – Column sizes

To automate calculation using MathCad. The variables, formulas and arguments are entered and the results are automatically calculated. Results are introduced in SolidWorks and thus get drawings.

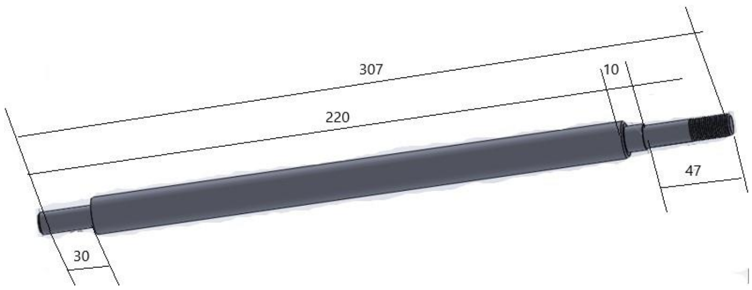


Figure 4 – Column generated in Solidworks

5. Pressure plate dimensioning

The dimensioning is done out from constructive reasons and verifying the solutions afterwards.

The assembly between the screw head and the pressure plate is made with a cylindrical pin type B 6x50.

The dimensions of the pin is:

→ Diameter: $d_s = 6\ mm$
→ Length: $l_s = 50\ mm$
→ Chamfering height: $c_{max} = 1{,}5\ mm$

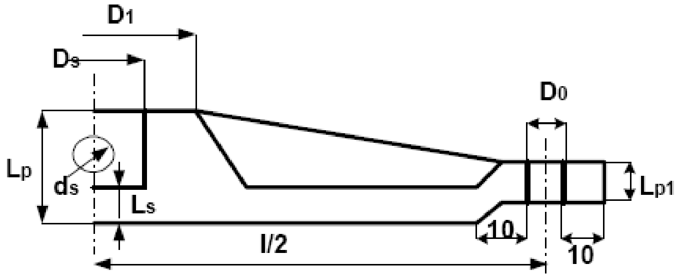


Figure 5 – The dimensions of the pressure plate

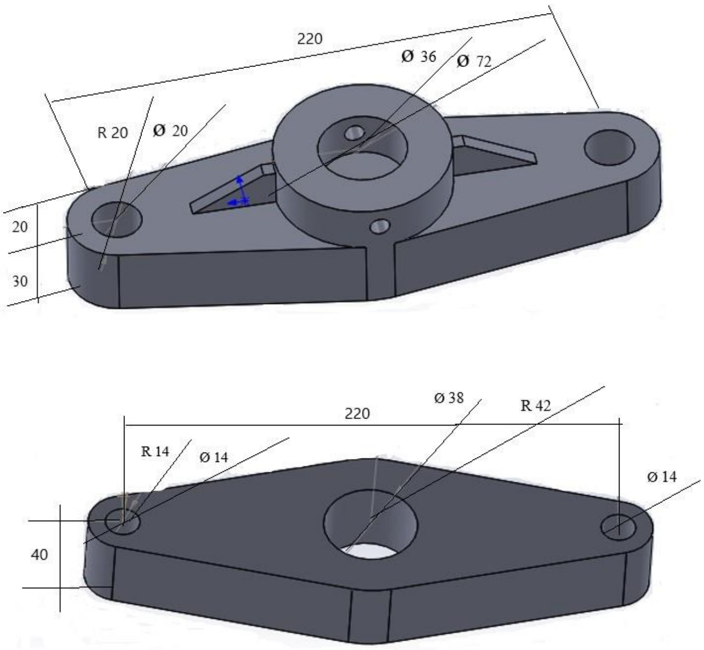


Figure 6 – The pressure plate and the upper plate generated in Solidworks

6. Checking the pin

The pin is loaded by the threading torque

$$M_t = 16710\ N \cdot mm$$

- For shearing

$$A_{min} = \frac{\pi}{4} \cdot D_c^2 = \frac{F}{\sigma_{ac}}$$

$$D_{c\ min} = \sqrt{\frac{4 \cdot F}{\pi \cdot \sigma_{ac}}} = 22{,}573\ mm$$

Where: $\sigma_{ac} = 30\ MPa$

We pick $D_c = 26\ mm$

$$\tau_f = \frac{F_t}{A_f} = \frac{M_t/D_c}{\pi \cdot d_s^2/4} = 22{,}74\ MPa < 80\ MPa$$

Where: $\tau_a = 80\ MPa$

⇨ The pin withstand the shearing load

- ▶ Contact pressure between pin-screw:

$$\sigma_{ss} = \frac{6 \cdot M_t}{d_s \cdot D_c^2} = 24{,}72\ MPa < 100\ MPa$$

Where: $\sigma_{as} = 100\ MPa$

⇨ The pin withstand the contact load

- ▶ Contact pressure between pin-pressure plate

$$\sigma_{sc} = \frac{M_t}{s \cdot d_s \cdot (D_c + s)} = 7{,}74\ MPa < 100\ MPa$$

Where:
$s = 10\ mm$ – is the tickness of the pressure plate for the mounting area

⇨ The pin withstand the contact load

7. MathCad software application for designing

The calculation program MATHCAD initial design data is entered. Enter formulas and standards chosen dates thereafter. The program calculates and generates results.

MATHCAD application program looks like this:

Introduce your data in the yellow fields

Press body

VARIABLE

F_applied := **12000**

l:= **220**

hc :=**210**

σc := **360**

Cc := **3**

FORMULAS

$$X1 := \frac{-F\_applied \cdot (l)^2}{8 \cdot h + 16 \cdot l}$$

$$X2 := \frac{(-3) \cdot F\_applied \cdot (l)^2}{8 \cdot (h)^2 + 16 \cdot (h) \cdot (l)}$$

$$MB := \frac{(2) \cdot F\_applied \cdot (l)^2}{8 \cdot (h) + 16 \cdot (l)}$$

$$MF := \frac{(2) \cdot F\_applied \cdot (l) \cdot (h + l)}{8 \cdot (h) + 16 \cdot (l)}$$

$$VA := \frac{F\_apllied}{2}$$

$$\sigma at := \frac{\sigma c}{Cc}$$

$$d0min := \sqrt{\frac{2 \cdot F\_apllied}{\pi \cdot \sigma ac}}$$

d0min =7.93

We choose

d0min := 12

D0:= 14

h := 210

D:= 20

d0_prime := 8

$$\sigma t := \frac{\left(\frac{F\_applied}{2}\right)}{\left(\frac{\pi}{4}\right) \cdot (d0\_prime)^2}$$

Mt := 16710

σac := 30

τa:= 80

σas := 100

ds:= 6

ls:= 8

s_tpp:= 10

$$Dc_{min} := \sqrt{\frac{4 \cdot F\_applied}{\pi \cdot \sigma ac}}$$

Dc_min = 22.573

We choose

Dc:= 26

$$\tau f := \frac{4 \cdot (Mt)}{\pi \cdot (Dc) \cdot (ds)^2}$$

$$\sigma ss := \frac{6 \cdot (Mt)}{(ds) \cdot (Dc)^2}$$

$$\sigma sc := \frac{Mt}{(s\_tpp) \cdot ds \cdot [Dc + (s\_tpp)]}$$

REZULTS

X1 = -111692.3

X2 = -1595.6

MB = 223384.6

MF = 436615.4

VA = 6000

σat = 120

d0min =7.93

σt =119.42

Dc_min = 22.573

τf=22.74

σss= 24.72

σsc= 7.74

8. Conclusions

Compared to spreadsheet programs, where the equations are cryptically expressed and the conversion between different system systems is impossible, or programming languages accessible to programmers in particular, MATHCAD is a much better way to perform and manage engineering calculations; being easy to achieve, understood, verified, communicated and followed logically.

MATHCAD allows engineers to explore, calculate and document simultaneously with all formulas and mathematical calculations the design phase of a product.

Mathcad is oriented around a worksheet, in which equations and expressions are created and manipulated in the same graphical format in which they are presented - as opposed to authoring in plain text, an approach later adopted by other systems such as Mathematica and Maple.

Mathcad is part of a broader product development system developed by PTC, and often utilized for the many analytical touch points within the systems engineering processes. It integrates with PTC's other solutions that aid product development, including Creo Elements/Pro, Windchill, and Creo

Elements/View. Its live feature-level integration with Creo Elements/Pro enables Mathcad analytical models to be directly used in driving CAD and SOLIDWORK geometry, and its structural awareness within Windchill allows live calculations to be re-used and re-applied toward multiple design models.

SOLIDWORKS 3D CAD combines design power with ease of use, whether you use drawing, rendering or simulation capabilities, and create innovative products with minimal cost and effort.

SOLIDWORKS, through its intuitive design capabilities, always provides models with ease of manufacture

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