CALCULUS METHODS OF THE FORCES FROM THE PISTON ROD-SLIDE MECHANISM

Milosteanu Diana Nicoleta, *Colegiul Tehnic General Gheorghe Magheru, Tg Jiu, ROMANIA*

Abstract: In the projecting calculations, it is necessary to consider the fact that the deforming force generally has a void value when the parameter and it increases according to a parabolic variation.

Keywords: piston rod-slide mechanism press, died.

1. INTRODUCTION

In the calculation of the forces from the piston rod-slide mechanisms, used for the slow mechanic presses (n<120 double runs/min.), the speeds of the working tools being low the inertness forces are to be neglected, since they don't surpass 10% from the value of the nominal force. In the ideal conditions of functionment, the mechanism of the presses will only be required by the forces owed to pressing in which one the frictions in the articulations have been neglected. Due to the pressing force, overtaken by the slide, in the connecting articulation of the piston rod with the slide, there appear the components: [17]

$$F_b = \frac{F_d}{\cos\beta} = \frac{F_d}{[1-\gamma^2(\sin\alpha+k)^2]^{\frac{1}{2}}} \quad (1)$$

Which challenge the piston rod axially, and:

$$F_n = F_d \tan\beta = F_d \frac{\gamma(\sin\alpha+k)}{[1-\gamma^2(\sin\alpha+k)^2]^{\frac{1}{2}}} \quad (2)$$

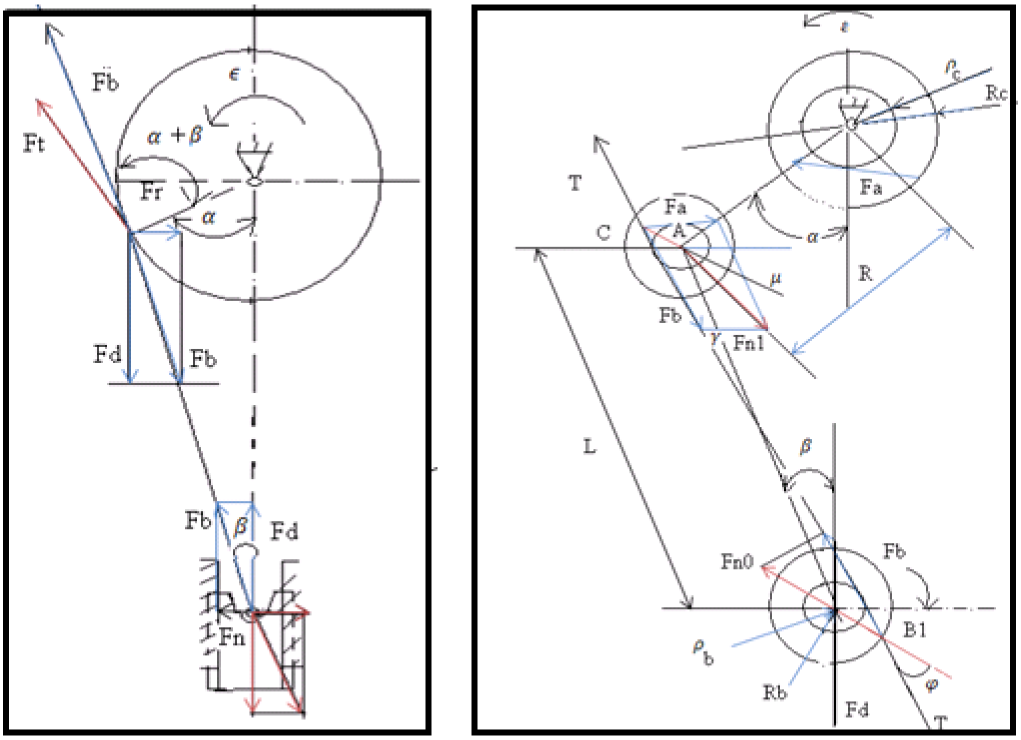
Which actuate perpendicularly on the guiding's of the press (fig 1.1.a)

2. THE MODALITY OF ACTUATING OF THE FORCES IN THE PISTON ROD-SLIDE MECHANISM

The torsion moment determined by the deforming force of the press shaft can be expressed under the form: [18]:

$$M_t = F_d \frac{\vartheta}{\omega} = F_d m_t \quad (3)$$

For a position of the slide a=0 the deforming force usually reaches to the value Fd max but the torsion moment will be Mt=0 since in this position mt=0 too. Fb force doesn't actuate according to the axis of the piston rod as it appears in the ideal case, being oriented according to the tangent mutual to the friction circles correspondent to the articulation bearings of the piston rod, in order to determine the real requirements from the piston rod (fig.1), there are represented the friction circles equivalent to the two articulations, their rays being: $\rho_a = \mu R_a$ şi $\rho_b = \mu R_b$.



a) b)

Figure. 1 The action of the forces in the piston rod-slide mechanism

Where:

$\mu - \tan\rho$ It is the friction coefficient in the articulation;

R_a- is the ray of the piston rod bearing to the slide;

R_b- is the connecting articulation ray to the slide.

In the construction, of the double action presses, having two or four cràncks, we both can set the main shafts along the frontal face, or perpendicularly on the latter one. In order to lower the total height of the double action presses, there have been projected and executed presses with a training system placed under the inferior cross piece. Lowering the heights of the double action presses is tremendously important since the constructions having a training system situated in the superior cross piece are much higher than all the other machines in technology.

The kinematic elements, being in a various movement, develop inertness forces, proportionally distributed with the mass, in their entire volume. So as to lighter their dynamic study of the mechanisms, the inertness force for each element are considered lowered in their weight centre [18] For a certain j in a plane-parallel movement, the torque is represented by a resultant inertness force and a resultant moment of the inertness forces, given by the relations:

$$\vec{F}_{ij} = -m_j \cdot \vec{a}_{Gj} \quad (4)$$

$$\vec{M}_{ij} = -I_{Gj} \cdot \vec{\varepsilon}_j \quad (5)$$

In which:

- $\vec{F}_{ij}$ - is the inertness force developed by the element j;

- $\vec{M}_{ij}$ is the resultant moment of the inertness forces;

- m_j - is the resultant moment of the inertness forces;

- I_{Gj} - is the mechanic inertness moment of the element j as contrasted to a perpendicular axis on the movement plane, which goes through its weight centre.

- $\vec{\varepsilon}_j$ is the angular acceleration of the element. If we consider reference system oxyz, the above relations can be projected on axes, the results.

$$F_{ijx} = -m_j \cdot a_{GjX}\ ;\ F_{ijy} = -m_j \cdot a_{Gjy}\ ;\ F_{ijz} = 0 \qquad (6)$$

$$M_{ijx} = 0;\ M_{ijy} = 0;\ M_{ijz} = -I_{Gj} \cdot \varepsilon \qquad (7)$$

For the analytical solutions of the kineto-statics problem, one uses the method of the isolation of the elements. In the view of applying this method, each element of the mechanism is isolated with the corresponding forces table and the equilibrium equations known in statics are being written.

In fig.2 an element A of a mechanism is represented, limited by the articulations O and B. This one belongs to an articulated kinematic chain, having a succession of elements. We consider that the torque of the exterior forces (including the inertness forces) is reduced in point A(X_A, Y_A) from the element to a resultant and a resultant moment $(\vec{F}_3, \vec{M}_3)$, the resultant is decomposed in the corresponding components as contrasted to a reference system xOy: $\vec{F}_3 = F_3^x \cdot \vec{i} + F_3^y \cdot \vec{j}$. Also, the reactions in the couplings O (xo, yo) and B (x_B, y_B) are projected on the axes of the reference system considered $\vec{R}_{2,3} = R_{2,3}^x \cdot \vec{i} + R_{2,3}^y \cdot \vec{j}$;

$\vec{R}_{4,3} = R_{4,3}^x \cdot \vec{i} + R_{4,3}^y \cdot \vec{j}$.

The following equilibrium equations are written:

$$\sum F_{x\,3} = 0 \Rightarrow R_{2,3}^x + F_3^x + R_{4,3}^x = 0 \qquad (8)$$

$$\sum F_{y\,3} = 0 \Rightarrow R_{2,3}^y + F_3^y + R_{4,3}^y = 0 \qquad (9)$$

$$\sum \begin{matrix} M_{O3} = 0 \Rightarrow M_{O(\vec{R}_{2,3})} + M_{O(\vec{F}_3)} + \\ M_3 + M_{O(\vec{R}_{4,3})} = 0 \end{matrix} \qquad (10)$$

If we take into account the analytical expression of the moment of a force as contrasted to the origin of the coordinates system in plane:

$M_O = x \cdot F_y - y \cdot F_z$, equation (9) becomes:

$$\sum M_{O3} = 0 \Rightarrow (x_o \cdot R_{2,3}^y - y_L \cdot R_{2,3}^x) + (x_A \cdot F_3^y - y_A \cdot F_3^x)$$
$$+ M_3 + (x_B \cdot R_{4,3}^y - y_A \cdot R_{4,3}^x) = 0$$

(11)[26]

In the previous equations, both the components of the forces and the moment Mp are introduced with their algebraic values. For a 3-elements mechanism, one can write 9 equations, which form a linear system as contrasted to the unknown represented by reactions and the equilibrating forces. For a positive, drive, mechanism, the system is compatible and determined. In the case of an element limited by a rotation couple and a translation one the torque of the connecting forces between the slide and the applied in a point chosen on the slide, perpendicular on the direction of the guiding and a moment of the connecting forces.

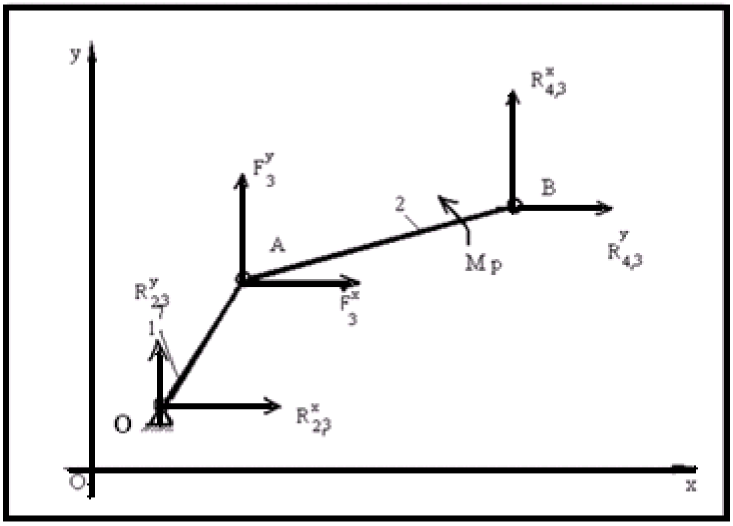


Figure 2

3. DETERMINING THE REACTIONS TO THE ASPECT 1 DIAD (RRR):

Consider the diad formed by elements 2 and 3 which was extracted from a mechanism, to which it was connected to elements 1 and 4 (fig.3). [26] The exterior forces and moments including the inertness forces that action over the elements, are reduced to a resultant and a resultant moment $\vec{F}_2, \vec{M}_2$ for the element 2 and $\vec{F}_3, \vec{M}_3$ for the element 3.

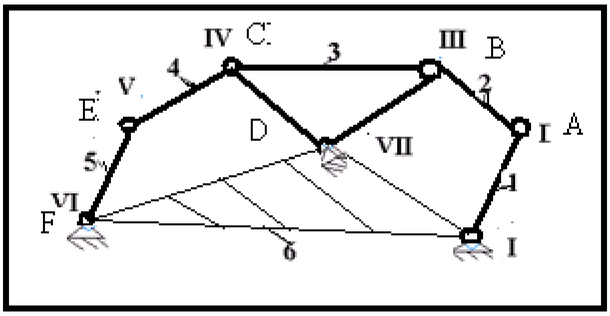


Figure 3

These forces and moments are represented on the drawing on scale of the diad by direction, their point of application and meaning without being necessary to respect a hierarchy of the forces. In the exterior couples of the diad (A, B) there will occur the reactions $\vec{R}_{12}$ and respectively $\vec{R}_{43}$ due to elements 1 and 4, to which the diad was connected. For these reactions we only know their application points which coincide with the centres of the articulations, in order to determine the unknown forces (reactions from points A, B, C) the following principles can be used:

-any kinematic groups is a static determined kinematic chain and consequently, the equilibrium equations known in mechanics can be applied for each element in particular;

-the articulations do not allow the transmission of the moments between the elements they connect, consequently, the sun of the moments of the forces on an element, as opposed to one of its articulations, is equal to zero.

In order to simplify the calculus scheme the exterior reactions from A and C were decomposed according to two directions: alongside and perpendicular on the element over which they actuate.

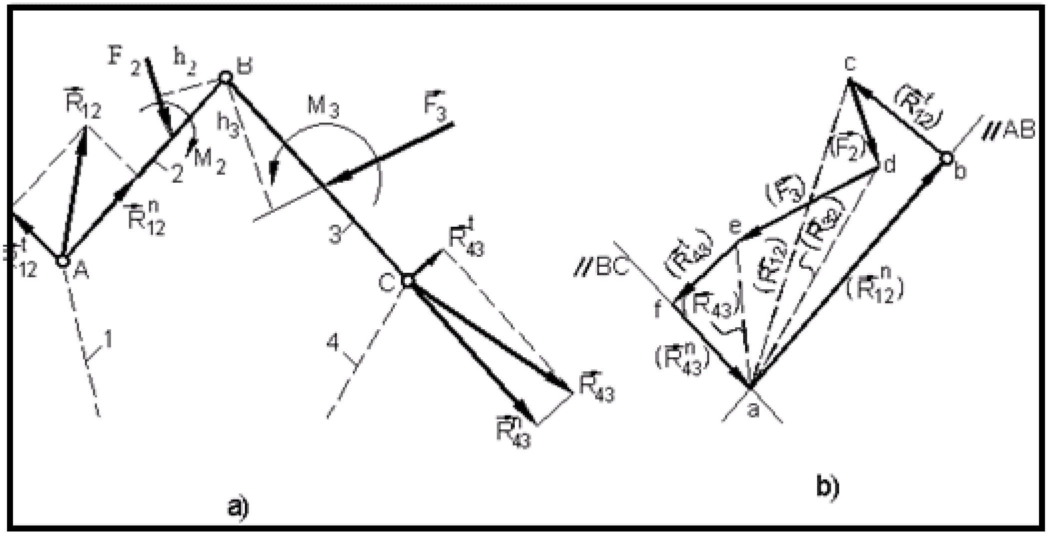


Figure 4 Representation of forces [4]

$$\vec{R}_{12} = \vec{R}^n_{12} + \vec{R}^t_{12}$$

IIAB ⊥ AB (12)

$$\vec{R}_{43} = \vec{R}^n_{43} + \vec{R}^t_{43}$$

IIBC ⊥ BC (13)

Since the articulation from B does not transmit moments between the two elements, it results that the sum of the moment as contrasted to point B, for element 2 is zero

$$\sum M_{B(el.2)} = 0 \quad (14)$$

And also, for element 3

$$\sum M_{B(3)} = 0 \quad (15)$$

The first equation can also be written under the form:

$$M_{B(\vec{R}_{12})} + M_{B(\vec{F}_2)} + M_2 = 0 \quad (16)$$

Where $M_{B(\vec{R}_{12})}$ is the moment given by $\vec{R}_{12}$ to B and $M_{B(\vec{F}_2)}$ is the moment given by $\vec{F}_2$ to the some point. Similarly, we can write

$$M_{B(\vec{R}_{43})} + M_{B(\vec{F}_2)} + M_3 = 0 \quad (17)$$

For the meaning of the forces fig3. And considering these moments the trigonometrically positive and negative we get: $M_{B(\vec{R}_{12})} = -R^t_{12} \cdot AB$, since the component R^n_{12} does not give a moment to B, crossing this point,; $M_{B(\vec{F}_2)} = -F_2 \cdot h_2$, where h_2 is the distance from B to the support of force $\vec{F}_2$. Supposing the moments M_2, M_3 expressed in $[N \cdot m]$ it results that the forces must be expressed in [N] and the distances in meters. Measuring the distances in the drawing and turning them to the scale of lengths, it follows that: $AB = k_L \cdot (AB)$; $h_2 = k_L \cdot (h_2)$. With these replacements, the equation (4.14) becomes:

$$-R^t_{12} \cdot (AB) \cdot k_L + F_2 \cdot (h_2) \cdot k_L - M_2 = 0 \quad (18)$$

With these replacement, the equation (4.14) becomes:

$$R_{12}^t = \frac{F_2 \cdot (h_2) \cdot k_L - M_2}{(AB) \cdot k_L} \quad (19)$$

The previous relation can be written can be written under the form:

$$R_{12}^t = \frac{F_2 \cdot (h_2) \cdot k_L - \frac{M_2}{k_L}}{(AB)} \quad (20)$$

Which allows certain simplifications of a system with a high number of forces, instead of multiplying the distances of the forces to the scale, it is but enough to divide the only moment to scale Kl, the distances being taken from the drawing. In the relation (18), if $F_2 \cdot (h_2) \rangle \frac{M_2}{k_L}$ it follows that $R_{12}^t \rangle 0$ and the meaning taken in the figure for R_{12}^t is further on maintained in the case in which $R_{12}^t \langle 0$ it means that we must change the direction of the vector as compared to the one initially resembling, in the following statements, we assumed that $R_{12}^t \rangle 0$ and consequently, the initial direction is preserved. Similarly, the equation (17) $R_{12}^t \rangle 0$ becomes [6]:

$$R_{43}^t \cdot (BC) \cdot k_L - F_3 \cdot (h_3) \cdot k_L + M_3 = 0 \quad (21)$$

Where we obtain:

$$R_{43}^t = \frac{F_3 \cdot (h_3) - \frac{M_3}{k_L}}{(AB)} \quad (22)$$

Further on, we considered $F_3 \cdot (h_3) \langle \frac{\mathrm{M}_3}{\mathrm{k}_\mathrm{L}}$ therefore the meaning of the reaction $\vec{R}_{43}^t$ is opposite to the one initially arbitrary to fig. 3a.

In order to determine the unknown $\vec{R}_{12}^n$ and $\vec{R}_{43}^n$ the equilibrium equation for all the forces that actuate over the diad formed by elements 2, 3 is written:

$$\sum \vec{F}_{(el.\ 2,3)} = 0 \quad (23)$$

For this we choose a scale of the forces $k_F = \frac{F}{(F)}\left[\frac{N}{mm}\right]$ and the known forces are transformed to this seal $\left(R_{12}^n\right) = (ab)$, unknown; $\left(R_{12}^t\right) = (bc) = \frac{R_{12}^t}{k_F}$,

$(F_2) = (cd) = \frac{F_2}{k_F}$; $(F_3) = (de) = \frac{F_3}{k_F}$;

$\left(R_{43}^t\right) = (ef) = \frac{R_{43}^t}{k_F}$; $\left(R_{43}^n\right) = (fa)$, unknown

$$\underset{\text{IIAB}}{\underline{\vec{R}_{12}^n}} + \underline{\underline{\vec{R}_{12}^t}} + \underline{\underline{\vec{F}_2}} + \underline{\underline{\vec{F}_3}} + \underline{\underline{\vec{R}_{43}^t}} + \underset{\text{II BC}}{\underline{\vec{R}_{43}^n}} = 0 \quad (23')$$

$$\underset{\text{IIAB}}{\underline{\overrightarrow{(ab)}}} + \underline{\underline{\overrightarrow{(bc)}}} + \underline{\underline{\overrightarrow{(cd)}}} + \underline{\underline{\overrightarrow{(de)}}} + \underline{\underline{\overrightarrow{(ef)}}} + \underset{\text{IIBC}}{\underline{\overrightarrow{(fa)}}} = 0 \quad (24)$$

According to the usual convention, the wholly known vectors were underlined with two lines, white the ones whose only direction was known, with one line.

By taking a parallel direction to AB, which will be the support of vector $\vec{R}_{12}^n$ unknown with the origin in an arbitrary point b of this direction, the vector $\overrightarrow{(bc)} = \left(\vec{R}_{12}^t\right)$ was built. With the origin in point c, the vector $\overrightarrow{(cd)} = \overrightarrow{(F_2)}$ was added, then furthermore, $\overrightarrow{(de)} = \overrightarrow{(F_3)}$. The vector $\overrightarrow{(ef)} = (\vec{R}_{43}^t)$ was taken in a opposite direction to the one in fig.4.3 a considering, as mentioned above that $\vec{R}_{43}^t$ resulted with a minus from equation (4.23). Next, a parallel was drawn to BC through point f, which intersects the parallel to AB, in point a [24]. Measuring (ab) and (fs) it results: $\vec{R}_{12}^n = \overrightarrow{(ab)} \cdot k_F$ şi $\vec{R}_{43}^n = \overrightarrow{(fa)} \cdot k_F$.
To obtain the total reactions from A and C one uses the equations (23) and (24)

$(\vec{R}_{12}) = (\overrightarrow{ab}) + (\overrightarrow{bc}) = (\overrightarrow{ac})$; $(\vec{R}_{43}) = (\overrightarrow{ef}) + (\overrightarrow{fa}) = (\overrightarrow{ea})$

By measuring the infer: $R_{12} = (ac) \cdot k_F$ şi $R_{43} = (ea) \cdot k_F$

By calculating the reaction from the inferior couple of the diad (B), the equilibrium equation is written for one of the elements which a considered isolated, by introducing in B the connecting force due to the remote element. We write the equilibrium equation from element 2:

$$\sum \vec{F}_{(el\,2)} = 0 \qquad (25)$$

$$\underline{\underline{\vec{R}_{12}^n}} + \underline{\underline{\vec{R}_{12}^t}} + \underline{\underline{\vec{F}_2}} + \vec{R}_{32} = 0 \qquad (25')$$,

On taking into account the previous notation:

$$\underline{\underline{(\overrightarrow{ab})}} + \underline{\underline{(\overrightarrow{bc})}} + \underline{\underline{(\overrightarrow{cd})}} + (\overrightarrow{da}) = 0$$

(26)

It follows $(\vec{R}_{32}) = (\overrightarrow{da})$ R32=ds measuring the respective segment $R_{32} = (da) \cdot k_F$.

Obviously, in point B there is a reaction too $\vec{R}_{32} = -\vec{R}_{32}$, which appears when the equilibrium of element 3 is considered isolated.

4. CONCLUSIONS

In order to determine the unknown forced (reactions) one can use the following principles:

-any kinematic group is a static determined kinematic chain therefore we can apply the equations known in mechanics, for the whole system;

-any element of a system in equilibrium is at its turn in equilibrium, consequently, the equilibrium equations can also be applied for each element in particular;

-the articulations do not allow the transmission of the moments between the elements they connect and consequently, the sum of the moments of the forces how one element as contrasted to one of its articulations, is zero.

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