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KINETIC AND STATIC ANALYSIS AT LOADED RUNNING OF MECHANISMS OF PARALLEL GANG SHEARS' TYPE ASSIGNED FOR CUTTING THE METALLURGICAL PRODUCTS

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ABSTRACT: In this study is presented the kinetic and static analysis of shear type mechanisms for cutting metallurgical products at the mill train of the semi-finished steel products Rolling Mill No. 1 – S.F.1 of S.C. MITTAL STELL S.A. HUNEDOARA, in conditions of disregarding the frictions existent in the kinetic couplings.
KEYWORDS: mechanism, forces and moments of inertia forces, reaction

❖ INTRODUCTION

The kinematical scheme for the mechanism of parallel gang shears assigned to cut metallurgical products is shown in Figure 1 and consists in: hand-hold 1, short driving rod 2, upper arm 3, long driving rod 4, lower arm 5 and upper slide 6. This type of mechanism works in phases i.e.: in the first phase is lowered the superior cutter up to the surface of the steel semi-finished product and then stopped and locked in this position moment when the inferior cutter, which performs the cutting of steel semi-finished product, starts to lift. After cutting has done the inferior cutter comes back to the initial position and then the upper arm is lifted in the initial position. All these movements are coordinated by the crankshaft, i.e. handhold 1 and are accomplished at a stroke of 360^0 of the handhold. From this reason, the kinetic analysis and kinetic and static analysis as well for this type of mechanism will be performed on phases of movement [1].

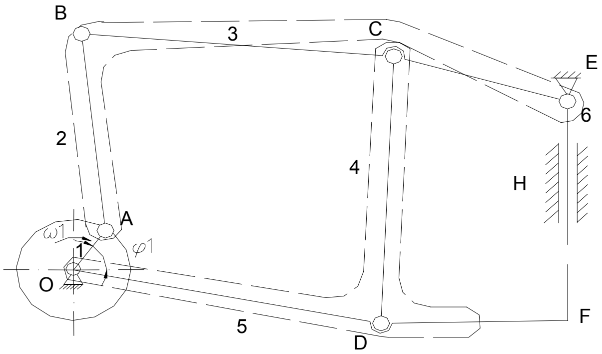

Figure 1. Kinetic Scheme of the 8000kN shear

❖ KINETIC AND STATIC ANALYSIS OF THE DYAD ODC

DETERMINATION OF THE POSITION FOR GRAVITY CENTERS OF THE ELEMENTS TO THE DYAD ODC

- long driving rod 4 (Figure 2).
- lower arm 5 (Figure 3)

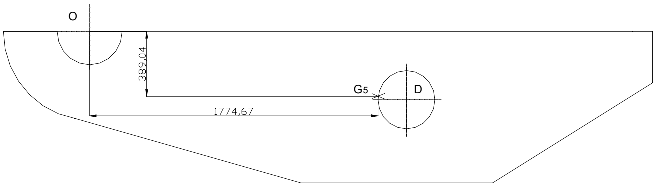

Figura 3. Gravity centre of the element (5) (lower arm)

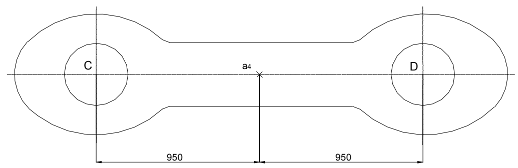

Figure 2. Gravity centre of the element (4) (long driving rod)

THE DETERMINATION OF THE ACCELERATIONS OF THE GRAVITY CENTRE AND THESE DIRECTIONS

- accelerations of the gravity centre to the long driving rod (element4)[2]

$$a_{G4C} = G_4C\sqrt{\omega_4{}^4 + \varepsilon_4{}^2}$$ the acceleration center G_4 against the point C; (1)

$$\overline{a}_{G4} = \overline{a}_C + \overline{a}^n_{G4C} + \overline{a}^t_{G4C} \Rightarrow \quad a_{G4} = \sqrt{a_C^2 + a_{G4C}^2 - 2a_C a_{G4C}\cos s_4}$$, the acceleration center G_4 (2)

- accelerations of the gravity centre to the lower arm (element 5)

$$a_{G5D} = G_5D\sqrt{\omega_5{}^4 + \varepsilon_5{}^2}$$ the acceleration center G_5 against the point D; (3)

$$\overline{a}_{G5} = \overline{a}_D + \overline{a}^n_{G5D} + \overline{a}^t_{G5D} \Rightarrow \quad a_{G5} = \sqrt{a_D^2 + a_{G5D}^2 - 2a_D a_{G5D}\cos s_5}$$, the acceleration center G_5 (4)

The directions of the accelerations to the gravity centers G_4 respective G_5 and to the forces of inertia reacts on the elements (4) and (5) are determined from the polygon of the accelerations.

THE CALCULUS OF THE INERTIA FORCES AND TO THE MOMENTS OF THE INERTIA FORCES REACTS ON THE ELEMENTS OF THE DYAD ODC

The inertia forces and the moments of the inertia forces to the elements of the dyad ODC are caused with help of the relations [10], (m_4=2543 Kg, m_5=8597Kg) [1]:

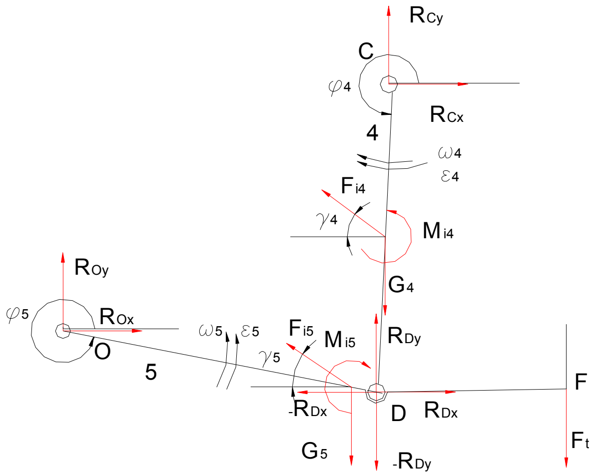

Figure 4. Loading Scheme of ODC dyad

$$\bar{F}_{i5} = -m_5 \bar{a}_{G5}$$
$$\bar{F}_{i4} = -m_4 \bar{a}_{G4} \qquad (5)$$
$$\begin{cases} J_{G4} = m_4 \dfrac{l_4^{\,2}}{12} \\ J_{G5} = m_5 \dfrac{l_5^{\,2}}{12} \end{cases} \Rightarrow \begin{cases} \bar{M}_{i4} = -J_{G4}\bar{\varepsilon}_4 \\ \bar{M}_{i5} = -J_{G5}\bar{\varepsilon}_5 \end{cases}$$

DETERMINATION OF REACTIONS IN KINETIC COUPLINGS OF DYAD ODC WITHOUT TAKING INTO ACCOUNT THE FRICTIONS OF KINETIC COUPLINGS

Determination of reactions in couplings is performed having as base the loading scheme presented in Figure 4.

With the notations of figure 4. and in conditions when are known the weights of component elements (thus are known the weight forces too) can be written the following equations of equilibrium (m_4=2543; m_5=8597Kg) [1].

$$\begin{cases} \sum F_x(5) = 0 \Rightarrow R_{Ox} + R_{Dx} - F_{i5}\cos\gamma_5 = 0 \\ \sum F_y(5) = 0 \Rightarrow R_{Oy} + R_{Dy} - G_5 + F_{i5}\sin\gamma_5 - F_t = 0 \\ \sum F_x(4) = 0 \Rightarrow R_{Cx} - R_{Dx} - F_{i4}\cos\gamma_4 = 0 \\ \sum F_y(4) = 0 \Rightarrow R_{Cy} - R_{Dy} + F_{i4}\sin\gamma_4 - G_4 = 0 \\ \sum M_D(5) = 0 \Rightarrow -R_{Ox}l'_5\sin(360-\varphi_5) - R_{Oy}l'_5\cos(360-\varphi_5) - M_{i5} + G_5Da_5\cos(360-\varphi_5) - \\ \qquad - F_{i5}Da_5\sin[\gamma_5 - (360-\varphi_5)] - F_tDF = 0 \\ \sum M_D(4) = 0 \Rightarrow -R_{Cx}l_4\sin(360-\varphi_4) - R_{Cy}l_4\cos(360-\varphi_4) + M_{i4} - G_4Ca_4\cos(360-\varphi_4) - \\ \qquad - F_{i4}Ca_4\sin(360-\varphi_4-\gamma_4) = 0 \end{cases} \qquad (6)$$

in which: l_i -represent the loungers of kinematic elements; -a_i represented the positions to the gravity centers of the elements in report with one from couples the marginal, their values the by-pathes determinate in the previous paragraphs.

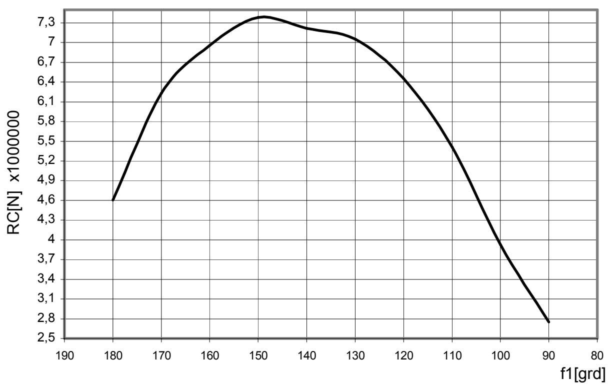

Figure 5. Variation of reaction in coupling C, without friction

The unknown are $R_{Ox};R_{Oy};R_{Cx};R_{Cy};R_{Dx};R_{Dy}$, and has been solved in MathCAD, and with solutions obtained can be calculated the values of reactions in couplings O, D, C:

$$R_O = \sqrt{R_{Ox}^2 + R_{Oy}^2}$$
$$R_C = \sqrt{R_{Cx}^2 + R_{Cy}^2} \qquad (7)$$
$$R_D = \sqrt{R_{Dx}^2 + R_{Dy}^2}$$

Graphic representation of reaction variation in coupling C, without friction, depending on variation of handhold angle φ_1 is shown in Figure 5.

❖ KINETIC AND STATIC ANALYSIS OF THE DYAD ABE

DETERMINATION OF POSITION FOR GRAVITY CENTERS OF THE ELEMENTS TO DYAD ABE

- element (2) - short driving rod - presented in Figure 6.
- element (3)- upper arm - presented in Figure 7.

THE DETERMINATION OF THE ACCELERATIONS OF THE GRAVITY CENTRE AND THESE DIRECTIONS

- accelerations of the gravity centre to the short driving rod

$$a_A = OA\omega_1^{\,2} \text{, the acceleration of the point A;} \qquad (8)$$

$$a_{G2A} = G_2A\sqrt{\omega_2^{\,4} + \varepsilon_2^{\,2}} \text{, the acceleration center } G_2 \text{ against the point A} \qquad (9)$$

$$\bar{a}_{G2} = \bar{a}_A + \bar{a}^n_{G2A} + \bar{a}^t_{G2A} \Rightarrow \quad a_{G2} = \sqrt{a_A^2 + a_{G2A}^2 - 2a_A a_{G2A}\cos s_2}$$, the acceleration center G_2 (10)

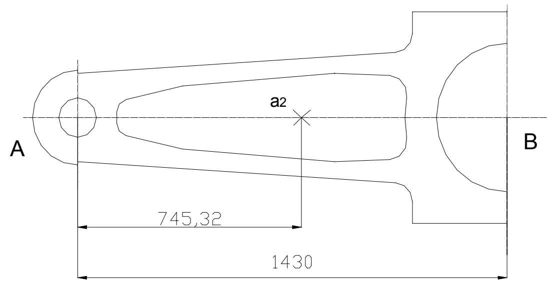

Figure 6. Gravity centre of the element (2) (short driving rod)

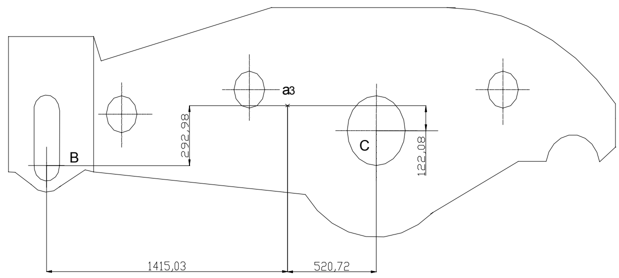

Figure 7. Gravity centre of the element (3) (upper arm)

- accelerations of the gravity centre to the upper arm (element 3):

$$a_{G3B} = G_3B\sqrt{\omega_3{}^4 + \varepsilon_3{}^2}$$ the acceleration center G_3 against the point B; (11)

$$\bar{a}_{G3} = \bar{a}_B + \bar{a}^n_{G3B} + \bar{a}^t_{G3B} \Rightarrow \quad a_{G3} = \sqrt{a_B^2 + a_{G3B}^2 - 2a_B a_{G3B}\cos s_3}$$, the acceleration center G_3 (12)

THE CALCULUS OF THE INERTIA FORCES AND TO THE MOMENTS OF THE INERTIA FORCES REACTS ON THE ELEMENTS OF THE DYAD ABE

The inertia forces and the moments of the inertia forces to the elements of the dyad ABE are caused with help of the relations (m_2=425Kg, m_3=6 155Kg):

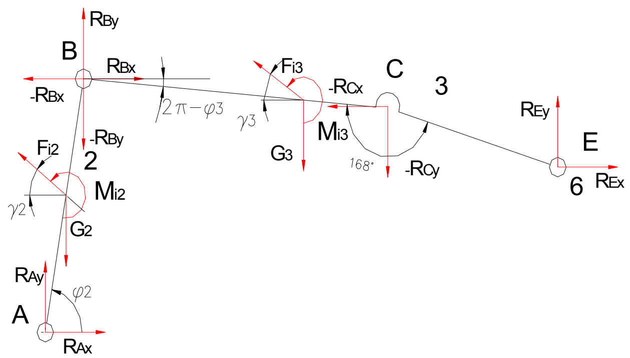

Figure 8. Loading Scheme of ABE dyad

$$\bar{F}_{i3} = -m_3\bar{a}_{G3}$$
$$\bar{F}_{i2} = -m_2\bar{a}_{G2} \quad (13)$$
$$\begin{cases} J_{G2} = m_2\dfrac{l_2{}^2}{12} \\ J_{G3} = m_3\dfrac{l_3{}^2}{12} \end{cases} \Rightarrow \begin{cases} \bar{M}_{i2} = -J_{G2}\bar{\varepsilon}_2 \\ \bar{M}_{i3} = -J_{G3}\bar{\varepsilon}_3 \end{cases}$$

DETERMINATION OF REACTIONS IN KINETIC COUPLINGS OF DYAD ABE WITHOUT TAKING INTO ACCOUNT THE FRICTIONS OF KINETIC COUPLINGS

Determination of reactions in couplings is performed having as base the loading scheme presented in Figure 8.

With the notations of figure 8 and in conditions when are known the weights of component elements can be written the following equations of equilibrium: (m_2=425; m_3=6155Kg)[1]:

$$\begin{cases} \sum F_x(2) = 0 \Rightarrow R_{Ax} + R_{Bx} - F_{i2}\cos\gamma_2 = 0 \\ \sum F_y(2) = 0 \Rightarrow R_{Ay} + R_{By} - G_2 + F_{i2}\sin\gamma_2 = 0 \\ \sum F_x(3) = 0 \Rightarrow -R_{Bx} - R_{Cx} + R_{Ex} - F_{i3}\cos\gamma_3 = 0 \\ \sum F_y(3) = 0 \Rightarrow -R_{By} - R_{Cy} + R_{Ey} + F_{i3}\sin\gamma_3 - G_3 = 0 \\ \sum M_B(2) = 0 \Rightarrow R_{Ax}l_2\sin\varphi_2 - R_{Ay}l_2\cos\varphi_2 + G_2Ba_2\cos\varphi_2 - F_{i2}Ba_2\sin\left(180^0 - \gamma_2 - \varphi_2\right) + \\ \quad + M_{i2} = 0 \\ \sum M_E(3) = 0 \Rightarrow -R_{Bx}l_3\sin\left(360^0 - \varphi_3 + 4^0\right) + R_{By}l_3\cos\left(360^0 - \varphi_3 + 4^0\right) + \\ \quad + M_{i3} + G_3Ea_3\cos\left(360^0 - \varphi_3 + 8^0\right) - F_{i3}Ea_3\sin\left[\gamma_3 - \left(360^0 - \varphi_3\right) - 8^0\right] \\ \quad - R_{Cx}l''_3\sin(\varphi_3 - \theta) + R_{Cy}l''_3\cdot\cos(\varphi_3 - \theta) = 0 \end{cases} \quad (14)$$

The set of equations is a linear one with 6 equations and 6 unknown $R_{Ax}; R_{Ay}; R_{Bx}; R_{By}; R_{Ex}; R_{Ey}$, and has been solved in MathCAD, and with solutions obtained can be calculated the values of reactions in couplings A; B; E:

$$R_A = \sqrt{R_{Ax}^2 + R_{Ay}^2}$$
$$R_B = \sqrt{R_{Bx}^2 + R_{By}^2} \quad (15)$$
$$R_E = \sqrt{R_{Ex}^2 + R_{Ey}^2}$$

Graphic representation of reaction variation in coupling E, without friction, depending on variation of handhold angle φ_1 is shown in Figure 9:

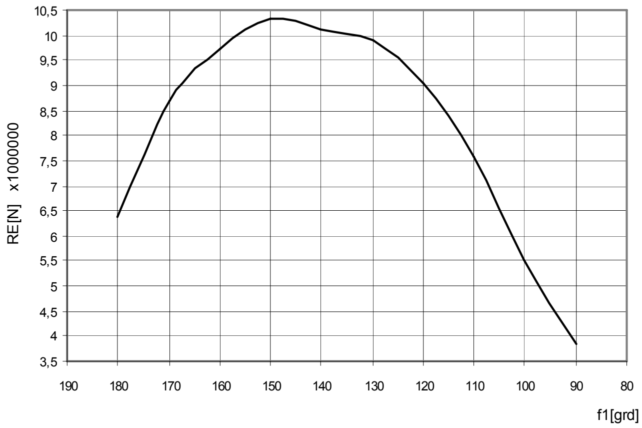

Figure 9.Variation of reaction in coupling E, without friction

❖ CONCLUSIONS

The kinetic and static analysis of the mechanism of the guy scissors for cuting metallurgical products of 8000kN are accomplished without the taking in consider the frictions from couple kinematic for the case in which is cut (300x300) mm2 metallurgical product, from OLC20, to a temperature of 970^0C. The reactions from couples kinematic have the values maxims when the relativ deepness of penetrate to the knifes in material is ε= 04.

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