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KINETIC AND STATIC ANALYSIS AT UNLOADED RUNNING ON LABORATORY MODEL 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

1. INTRODUCTION

The kinetic and static analysis aims to determine the forces that act in the kinetic elements of them, i.e. variation of these forces during a kinetic cycle, usually represented by variation of the angle of sight of the leading element. These can be forces and moments of inertia forces, friction forces or reaction from the kinetic couplings. Knowledge of these forces and moments is necessary in order to size the kinetic elements of mechanisms.

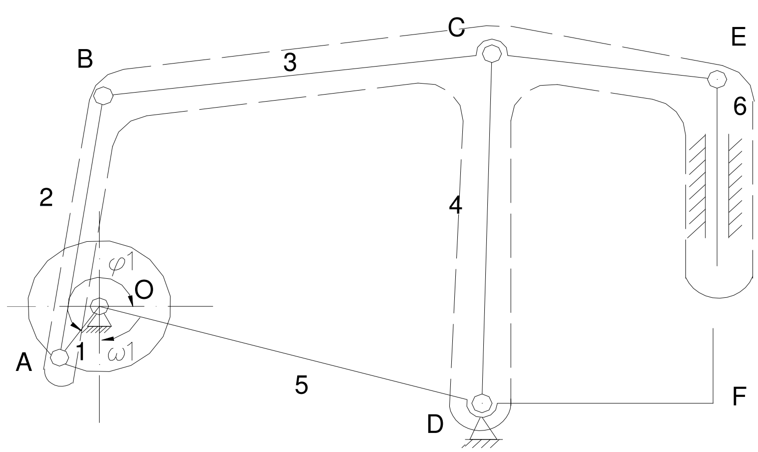


Figure 1. Kinetic Scheme of the laboratory model of the 8000kN shear

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.

Kinetic analysis of the mechanism is performed on kinetic groups, starting with the group containing the follower element (at unloaded running this is the superior cutter), and will be completed by kinetic and static analysis of the leading element and will comprise the following stages of calculus:

- Determination of the position for the gravity center of component elements;
- Determination of accelerations for the gravity centers of component elements;
- Determination of forces and moments of inertia forces for elements, i.e. setting up the directions;
- Presentation of the loading scheme for the kinetic group, containing the representation of all forces that load the elements;
- Determination of reactions in the kinetic couplings

2. DETERMINATION OF THE POSITION FOR GRAVITY CENTERS OF ABCDE TRIAD ELEMENTS

In order to determine the positions of gravity centres for component kinetic elements, these are represented at scale in AutoCAD and considering that they have an approximate constant thickness, using the regional modelling system, can be obtained the desired information,(1).

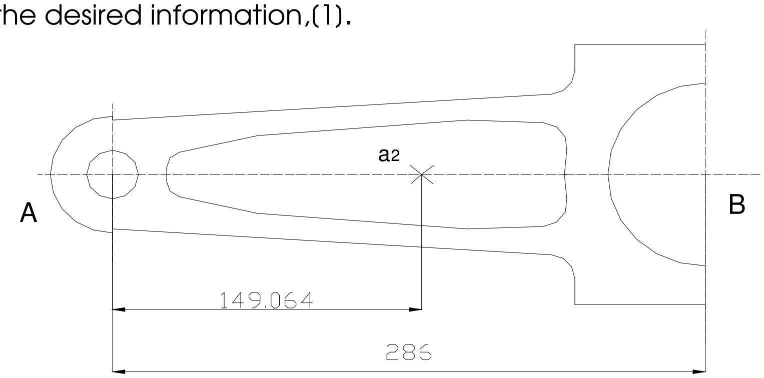


Figure 2. Gravity centre of the element (2) (short driving rod)

Information obtained by the regional modeling system (perimeter, area, gravity center, static inertia moments) are presented in (4).

Due to the fact that we are interested only in the position of gravity center, we will not present anymore the entire list of information for other parts but only the position of gravity center, which will be drawn directly on the technical drawing.

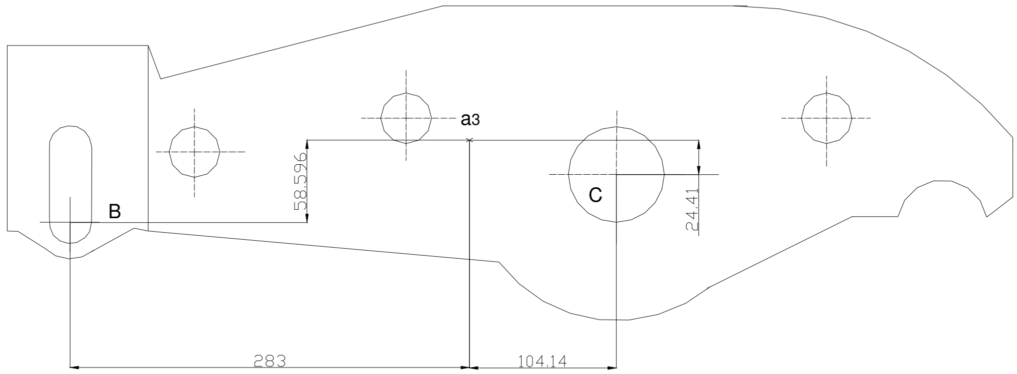


Figure 3. Gravity centre of the element (3) (upper arm)

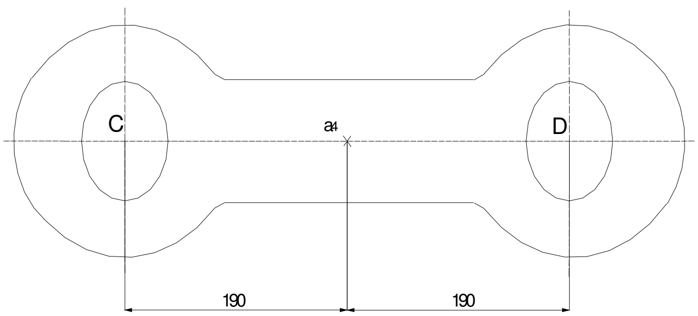


Figure 4. Gravity centre of the element (4) (long driving rod)

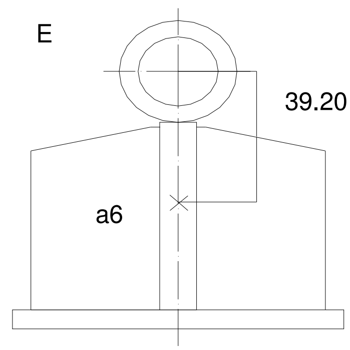
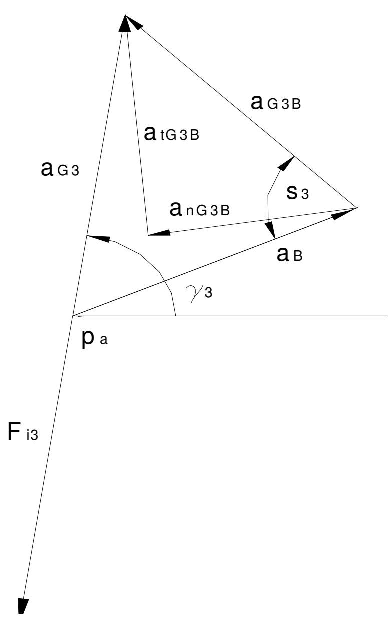


Figure 5. Gravity centre of the element (6)

3. DETERMINATION OF ACCELERATIONS FOR GRAVITY CENTERS AND THEIR DIRECTIONS RELATED TO HORIZONTAL DIRECTION



Knc E lge of accelerations for the gravity centres is necessary to determine the inertia forces, which act on elements. Acceleration of the gravity centre for the superior arm (element 3), is determined according to the polygon of accelerations shown in Figure 6.

Figura 6. Acceleration of gravity centre of the element (3)

According to Figure 6, can be written the following relations, which determine the value of acceleration for the gravity center, i.e. direction related to horizontal:

$a_{G3B} = G_3B \cdot \sqrt{\omega_3{}^4 + \varepsilon_3{}^2}$ Acceleration of center G_3 related to point B;

$$\overline{a}_{G3} = \overline{a}_B + \overline{a}^n_{G3B} + \overline{a}^t_{G3B} \Rightarrow a_{G3} = \sqrt{a_B^2 + a_{G3B}^2 - 2 \cdot a_B \cdot a_{G3B} \cdot \cos s_3}\,, \quad (1)$$

acceleration of the gravity center G3.

4. CALCULUS OF INERTIA FORCES AND MOMENTS OF INERTIA FORCES WHICH ACT ON THE TRIAD ELEMENTS

Inertia forces which act in mechanisms can be reduced at a torsion consisting in an inertia force, having the application point in the gravity centre of elements and the moment of inertia force. Their values are determined according to the relations (2) (in conditions of knowledge the weights of elements and linear and angular accelerations calculated within the kinetic analysis of mechanism).

$$\overline{F}_{i6} = -m_6 \cdot \overline{a}_{G6}, \overline{F}_{i4} = -m_4 \cdot \overline{a}_{G4}, \overline{F}_{i3} = -m_3 \cdot \overline{a}_{G3}, \overline{F}_{i2} = -m_2 \cdot \overline{a}_{G2}$$

$$\begin{cases} J_{G2} = m_2 \cdot \dfrac{l_2^2}{12} \\ J_{G3} = m_3 \cdot \dfrac{l_3^2}{12} \\ J_{G4} = m_4 \cdot \dfrac{l_4^2}{12} \\ J_{G6} = m_6 \cdot \dfrac{l_6^2}{12} \end{cases} \Rightarrow \begin{cases} \overline{M}_{i2} = -J_{G2} \cdot \overline{\varepsilon}_2 \\ \overline{M}_{i3} = -J_{G3} \cdot \overline{\varepsilon}_3 \\ \overline{M}_{i4} = -J_{G4} \cdot \overline{\varepsilon}_4 \\ \overline{M}_{i6} = -J_{G6} \cdot \overline{a}_6 \end{cases} \qquad (2)$$

5. DETERMINATION OF REACTIONS IN KINETIC COUPLINGS OF TRIADS 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 7.

With the notations of Figure 7. 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_2=4Kg; m_3=48Kg; m_4=18Kg; m_6=10.8Kg)

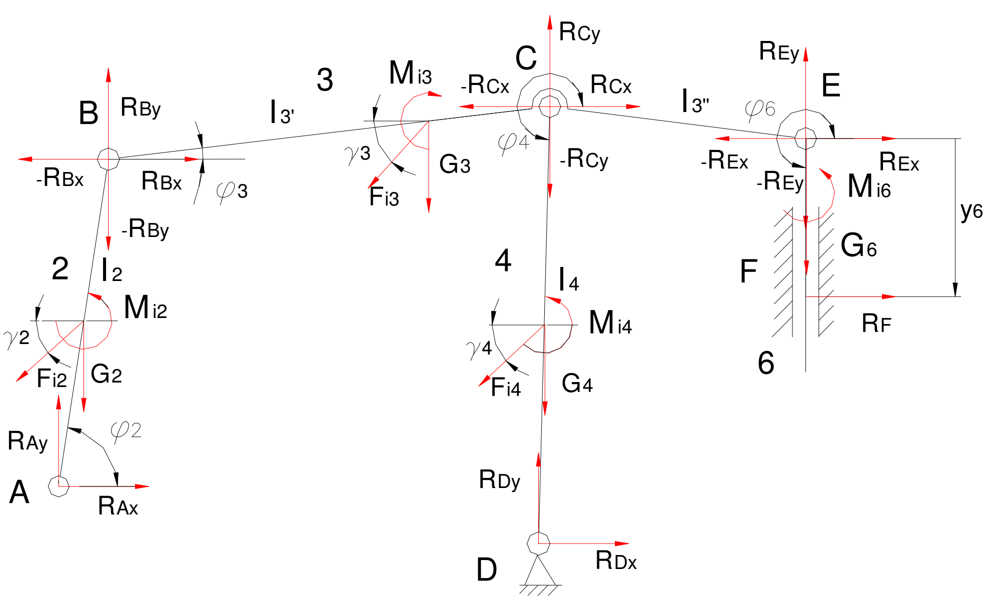


Figure 7. Loading Scheme of ABCDE triad

$$
\begin{cases}
\sum F_x(2) = 0 \Rightarrow R_{Ax} + R_{Bx} - F_{i2}\cos\gamma_2 = 0 \\
\sum F_y(2) = 0 \Rightarrow R_{Ay} + R_{By} - G_2 - F_{12}\sin\gamma_2 = 0 \\
\sum F_x(3) = 0 \Rightarrow -R_{Bx} + R_{Cx} + R_{Ex} - F_{i3}\cos\gamma_3 = 0 \\
\sum F_y(3) = 0 \Rightarrow -R_{By} + R_{Cy} + R_{Ey} - F_{i3}\sin\gamma_3 - G_3 = 0 \\
\sum F_x(4) = 0 \Rightarrow -R_{Cx} + R_{Dx} - F_{i4}\cos\gamma_4 = 0 \\
\sum F_y(4) = 0 \Rightarrow -R_{Cy} + R_{Dy} - G_4 - F_{i4}\sin\gamma_4 = 0 \\
\sum F_x(6) = 0 \Rightarrow -R_{Ex} + R_F = 0 \\
\sum F_y(6) = 0 \Rightarrow -R_{Ey} + F_{i6} - G_6 = 0 \\
\sum M_B(2) = 0 \Rightarrow R_{Ax} \cdot l_2 \cdot \sin\varphi_2 - R_{Ay} \cdot l_2 \cdot \cos\varphi_2 + G_2 \cdot Ba_2 \cdot \cos\varphi_2 - F_{i2} \cdot Ba_2 \cdot \sin(\varphi_2 - \gamma_2) + \\
\qquad + M_{i2} = 0 \\
\sum M_C(3) = 0 \Rightarrow R_{Bx} \cdot l'_3 \cdot \sin\varphi_3 + R_{By} \cdot l'_3 \cdot \cos\varphi_3 + G_3 \cdot Ca_3 \cdot \cos\varphi_3 - M_{i3} + F_{i3} \cdot Ca_3 \cdot \sin(\gamma_3 - \varphi_3) - \\
\qquad - R_{Ex} \cdot l''_3 \cdot \sin\varphi_3 + R_{Ey} \cdot l'' \cdot \cos\varphi_3 = 0 \\
\sum M_D(4) = 0 \Rightarrow R_{Cx} \cdot l_4 \cdot \cos(270^0 - \varphi_4) - R_{Cy} \cdot l_4 \cdot \sin(270^0 - \varphi_4) - G_4 \cdot Da_4 \cdot \sin(270^0 - \varphi_4) + \\
\qquad + M_{i4} + F_{i4} \cdot Da_4 \cdot \sin(\varphi_4 - 180^0 - \gamma_4) = 0 \\
\sum M_E(6) = 0 \Rightarrow R_F \cdot y + M_{i6} = 0
\end{cases} \qquad (3)
$$

The set of equations is a linear one with 12 equations and 12 unknown $(R_{Ax}, R_{Ay}, R_{Bx}, R_{By}, R_{Cx}, R_{Cy}, R_{Dx}, R_{Dy}, R_{Ex}, R_{Ey}, R_F, y)$, and has been solved in MathCAD, and with solutions obtained can be calculated the values of reactions in couplings A, B, C, D,E, F:

$$R_A = \sqrt{R_{Ax}^2 + R_{Ay}^2}, R_B = \sqrt{R_{Bx}^2 + R_{By}^2}, R_C = \sqrt{R_{Cx}^2 + R_{Cy}^2}, R_D = \sqrt{R_{Dx}^2 + R_{Dy}^2}, R_E = \sqrt{R_{Ex}^2 + R_{Ey}^2} \quad (4)$$

Graphic representation of reaction variation in coupling C, without friction, depending on variation of handhold angle φ_1 is shown in Figure 8.

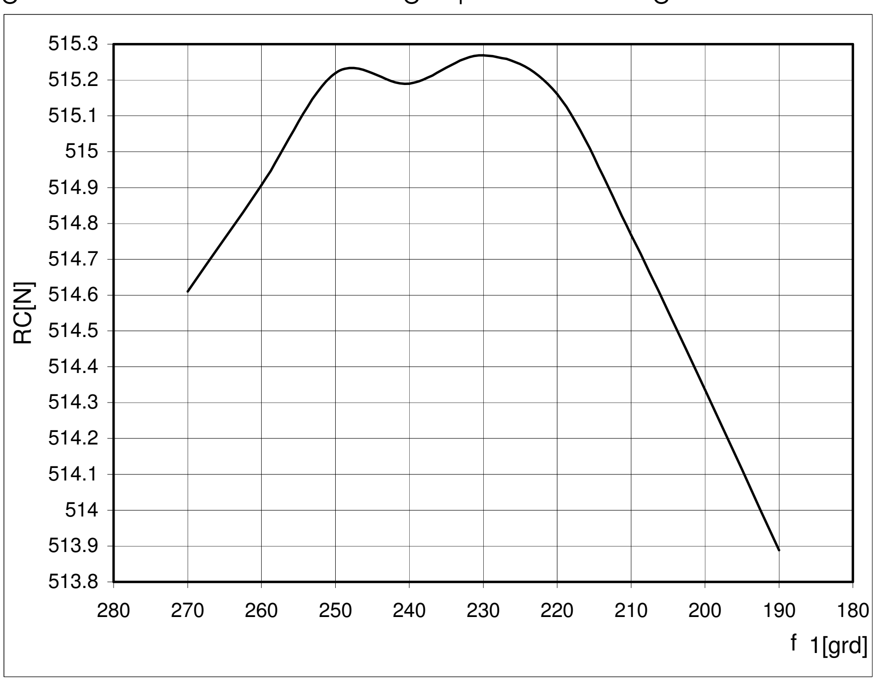


Figure 8. Variation of reaction in coupling C, without friction

6. CONCLUSIONS

Based on results obtained, presented by this study, can be inferred the following conclusions:

- The variations of inertia forces and moments of inertia forces which act on kinetic elements that compose a mechanism keep the variation mode of accelerations of gravity centres of elements and of angular accelerations of component kinetic elements as well.
- Not taking into account frictions the reactions in kinetic couplings of the laboratory model are 25 smaller that of the real parallel gang shears assigned to cut metallurgical products. These values are for operation at unloaded running of mechanism, for loaded running the values of reaction being much higher they depend on the section of the material which follows to be cut and not at least on the temperature of this material.

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