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FORCES AT THE MAIN MECHANISM OF A RAILBOUND FORGING MANIPULATOR

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ABSTRACT

Forging manipulators have become more prevalent in the industry today. They are used to manipulate objects to be forged. The most common forging manipulators are moving on a railway to have a greater precision and stability. They have been called the railbound forging manipulators. In this paper we determine the driving forces of the main mechanism from such manipulator. Forces diagram shows a typical forging manipulator, with the basic motions in operation process: walking, motion of the tong and buffering. The lifting mechanism consists of several parts including linkages, hydraulic drives and motion pairs. Hydraulic drives are with the lifting hydraulic cylinder, the buffer hydraulic cylinder and the leaning hydraulic cylinder, which are individually denoted by c1, c2 and c3. In this work considering that the kinematics is being solved it determines the forces of the mechanism. In the first place shall be calculated all external forces from the mechanism (The inertia forces, gravitational forces and the force of the weight of the cast part). Is then calculated all the forces from couplers.

Keywords: Mechatronics, Railbound forging manipulator, Lifting mechanism, Forces of mechanism, Driving forces.

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1. INTRODUCTION

Heavy payload manipulators (GE, 2012) which are special industrial robots are widely used in large forgings manufacturing, tunnel boring, mine excavation and large work pieces loading/unloading etc. They can greatly improve the efficiency and product quality, and lower manufacturing costs. Heavy payload manipulators have the characteristics of large payload capacity, multi degree of freedom, large size and high stiffness. They have been under increasing applications in heavy payload manipulators.

Forging manipulators have become more prevalent in the industry today (GAO, 2010). They are used to manipulate objects to be forged (SHEIKHI, 2009).

The most common forging manipulators are moving on a railway to have a greater precision and stability (see Figure. 1). They have been called the railbound forging manipulators.

Figure 1: A railbound forging manipulator
Source: Dango and Dienenthal

Alternatively, these mastodons can also be independents by the railway (see the Figure 2).

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Figure 2 A mobile forging manipulator
Source: Dango and Dienenthal

Regardless of the type of construction, these manipulators have mainly one type of mechanism (see the figure 3) (CHEN, 2009; YAN, 2009).

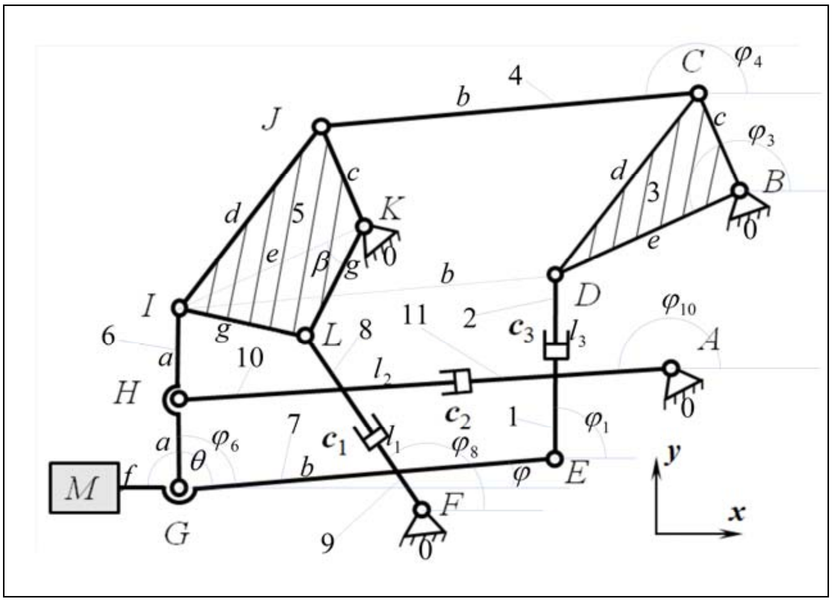

Figure 3: The kinematic schema of the main mechanism

The lifting mechanism consists of several parts including linkages, hydraulic drives and motion pairs. Hydraulic drives are with the lifting hydraulic cylinder, the buffer hydraulic cylinder and the leaning hydraulic cylinder, which are individually

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denoted by c1, c2 and c3. In lifting process, the cylinder c1 controls the vertical movement of work piece through inputting lifting signal.

At the same time, the cylinders c2 and c3 are perfectly closed (HEGINBOTHAM, 1979). While c1 and c3 are closed cylinders, cylinder c2 performs horizontal movement. While, the cylinders c1and c2 are closed the cylinder c3 realizes leaning movement by inputting leaning signal in leaning condition (BALDASSI, 2003).

In this work considering that the kinematics is being solved it determines the forces of the mechanism.

Forces diagram (see the Figure 4) shows a typical forging manipulator, with the basic motions in operation process: walking, motion of the tong and buffering.

In the first place shall be calculated all external forces from the mechanism (The inertia forces, gravitational forces and the force of the weight of the cast part). Is then calculated all the forces from couplers (LI, 2010; LIU, 2010).

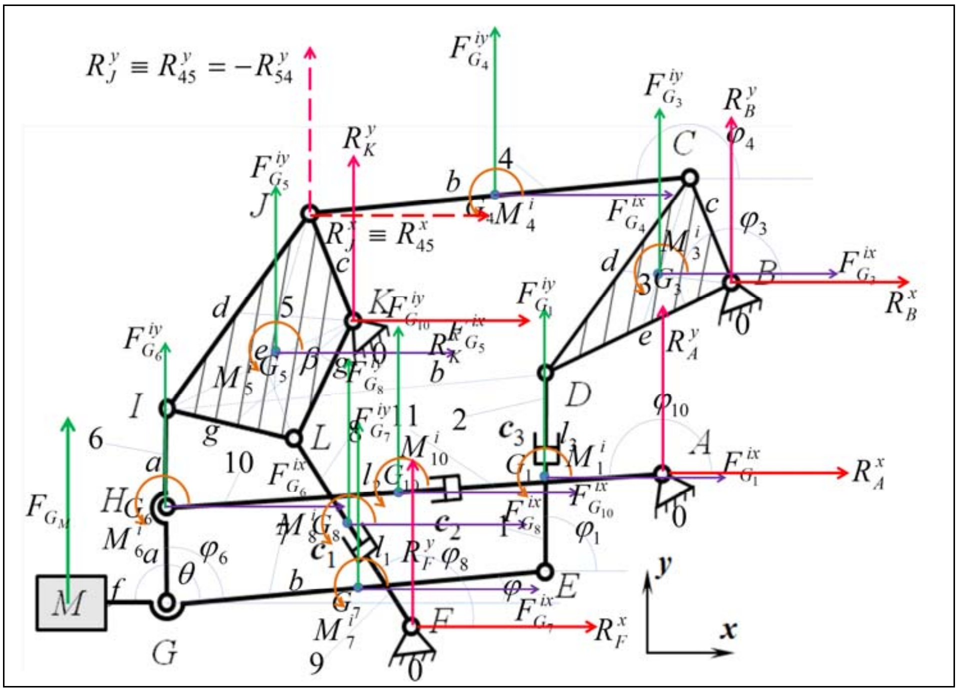

Figure 4: The forces schema of the main mechanism

2. THE FORCES OF THE MAIN MECHANISM

In the forces study of a mechanism one determines all forces instant (at a certain moment acting on the mechanism respectively). It is based on kinematic scheme of the mechanism loaded with all the forces acting on the mechanism (see

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Figure 4). Some forces (outside or external forces) are known, and others (forces from couplers) are not known, but must be determined (ZHAO, 2010).

In step 1 are calculated forces known, outside forces, composed of forces of inertia and gravitation (system 1).

$$\begin{cases}
\begin{cases} F_{G_1}^{ix} = -m_{12} \cdot \ddot{x}_{G_1} \\ F_{G_1}^{iy} = -m_{12} \cdot \ddot{y}_{G_1} - m_{12} \cdot g \\ M_1^i = -J_{G_1} \cdot \ddot{\varphi}_1 \end{cases} & \begin{cases} F_{G_3}^{ix} = -m_3 \cdot \ddot{x}_{G_3} \\ F_{G_3}^{iy} = -m_3 \cdot \ddot{y}_{G_3} - m_3 \cdot g \\ M_3^i = -J_{G_3} \cdot \ddot{\varphi}_3 \end{cases} \\
\begin{cases} F_{G_4}^{ix} = -m_4 \cdot \ddot{x}_{G_4} \\ F_{G_4}^{iy} = -m_4 \cdot \ddot{y}_{G_4} - m_4 \cdot g \\ M_4^i = -J_{G_4} \cdot \ddot{\varphi}_4 = 0 \end{cases} & \begin{cases} F_{G_5}^{ix} = -m_5 \cdot \ddot{x}_{G_5} \\ F_{G_5}^{iy} = -m_5 \cdot \ddot{y}_{G_5} - m_5 \cdot g \\ M_5^i = -J_{G_5} \cdot \ddot{\varphi}_3 \end{cases} \\
\begin{cases} F_{G_6}^{ix} = -m_6 \cdot \ddot{x}_{G_6} = -m_6 \cdot \ddot{x}_H \\ F_{G_6}^{iy} = -m_6 \cdot \ddot{y}_H - m_6 \cdot g \\ M_6^i = -J_H \cdot \ddot{\varphi}_6 \end{cases} & \begin{cases} F_{G_7}^{ix} = -m_7 \cdot \ddot{x}_{G_7} \\ F_{G_7}^{iy} = -m_7 \cdot \ddot{y}_{G_7} - m_7 \cdot g \\ M_7^i = -J_{G_7} \cdot \ddot{\varphi} \end{cases} \\
\begin{cases} F_M^{ix} = -M \cdot \ddot{x}_M \\ F_M^{iy} = -M \cdot \ddot{y}_M - M \cdot g \\ M_M^i = -J_M \cdot \ddot{\varphi} \end{cases} & \begin{cases} F_{G_8}^{ix} = -m_{89} \cdot \ddot{x}_{G_8} \\ F_{G_8}^{iy} = -m_{89} \cdot \ddot{y}_{G_8} - m_{89} \cdot g \\ M_8^i = -J_{G_8} \cdot \ddot{\varphi}_8 \end{cases} \\
\begin{cases} F_{G_{10}}^{ix} = -m_{10,11} \cdot \ddot{x}_{G_{10}} \\ F_{G_{10}}^{iy} = -m_{10,11} \cdot \ddot{y}_{G_{10}} - m_{10,11} \cdot g \\ M_{10}^i = -J_{G_{10,11}} \cdot \ddot{\varphi}_{10} \end{cases} & \begin{cases} J_{G_i} = \frac{1}{12} m_i \cdot l_i \end{cases}
\end{cases} \tag{1}$$

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Now it writes three separate systems (2-4) which calculates the reactions of motor couplings dyad (7, 1, 2) Figure 5.

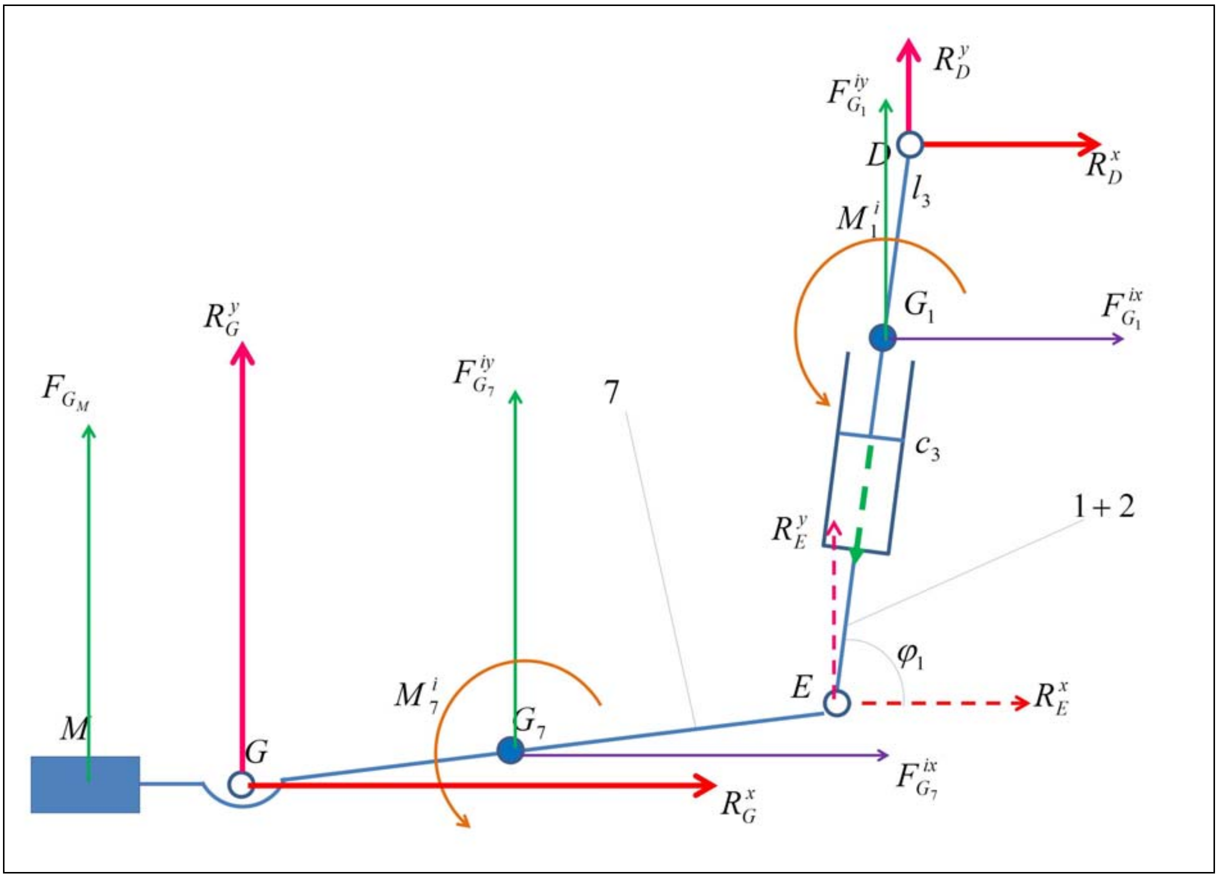

Figure 5: The forces schema of the dyad 7,1-2

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$$\begin{cases}
\begin{cases}
\sum M_D^{(7,1)} = 0 \Rightarrow F_M^{ix}\cdot(y_D - y_M) - F_M^{iy}\cdot(x_D - x_M) + M_M^i + \\
+ R_G^x\cdot(y_D - y_G) - R_G^y\cdot(x_D - x_G) + F_{G_7}^{ix}\cdot(y_D - y_{G_7}) - \\
- F_{G_7}^{iy}\cdot(x_D - x_{G_7}) + M_7^i + F_{G_1}^{ix}\cdot(y_D - y_{G_1}) - F_{G_1}^{iy}\cdot(x_D - x_{G_1}) + M_1^i = 0
\end{cases} \\
\begin{cases}
\sum M_E^{(7)} = 0 \Rightarrow F_M^{ix}\cdot(y_E - y_M) - F_M^{iy}\cdot(x_E - x_M) + M_M^i + \\
+ R_G^x\cdot(y_E - y_G) - R_G^y\cdot(x_E - x_G) + F_{G_7}^{ix}\cdot(y_E - y_{G_7}) - \\
- F_{G_7}^{iy}\cdot(x_E - x_{G_7}) + M_7^i = 0
\end{cases} \\
\begin{cases}
a_{11}\cdot R_G^x + a_{12}\cdot R_G^y = a_1 \\
a_{21}\cdot R_G^x + a_{22}\cdot R_G^y = a_2
\end{cases}
\quad
\begin{cases}
a_{11} = y_D - y_G; \quad a_{12} = x_G - x_D \\
a_1 = (y_M - y_D)F_M^{ix} + (x_D - x_M)F_M^{iy} - M_M^i + \\
+ (y_{G_7} - y_D)F_{G_7}^{ix} + (x_D - x_{G_7})F_{G_7}^{iy} - M_7^i + \\
+ (y_{G_1} - y_D)F_{G_1}^{ix} + (x_D - x_{G_1})F_{G_1}^{iy} - M_1^i
\end{cases} \\
\begin{cases}
a_{21} = y_E - y_G; \quad a_{22} = x_G - x_E; \quad a_2 = (y_M - y_E)F_M^{ix} + (x_E - x_M)F_M^{iy} - \\
- M_M^i + (y_{G_7} - y_E)F_{G_7}^{ix} + (x_E - x_{G_7})F_{G_7}^{iy} - M_7^i
\end{cases} \\
\Delta = \begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix} = a_{11}\cdot a_{22} - a_{12}\cdot a_{21}; \quad \Delta_x = \begin{vmatrix} a_1 & a_{12} \\ a_2 & a_{22} \end{vmatrix} = a_1\cdot a_{22} - a_2\cdot a_{12} \\
\Delta_y = \begin{vmatrix} a_{11} & a_1 \\ a_{21} & a_2 \end{vmatrix} = a_2\cdot a_{11} - a_1\cdot a_{21}; \quad R_{67}^x \equiv R_G^x = \frac{\Delta_x}{\Delta}; \quad R_{67}^y \equiv R_G^y = \frac{\Delta_y}{\Delta}
\end{cases} \tag{2}$$

$$\begin{cases}
\sum F_x^{(7,1)} = 0 \quad R_D^x + F_{G_1}^{ix} + F_{G_7}^{ix} + R_G^x + F_M^{ix} = 0 \Rightarrow \\
\Rightarrow R_D^x = -F_{G_1}^{ix} - F_{G_7}^{ix} - R_G^x - F_M^{ix} \\
\sum F_y^{(7,1)} = 0 \quad R_D^y + F_{G_1}^{iy} + F_{G_7}^{iy} + R_G^y + F_M^{iy} = 0 \Rightarrow \\
\Rightarrow R_D^y = -F_{G_1}^{iy} - F_{G_7}^{iy} - R_G^y - F_M^{iy}
\end{cases} \tag{3}$$

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$$\begin{cases} \sum F_x^{(1)} = 0 \quad R_D^x + F_{G_1}^{ix} + R_E^x = 0 \Rightarrow \\ \Rightarrow R_E^x = -F_{G_1}^{ix} - R_D^x \\ \sum F_y^{(1)} = 0 \quad R_D^y + F_{G_1}^{iy} + R_E^y = 0 \Rightarrow \\ \Rightarrow R_E^y = -F_{G_1}^{iy} - R_D^y \end{cases} \tag{4}$$

The calculation continues with the next motor dyad composed of elements (6, 10, 11), systems (5-7) Figure 6.

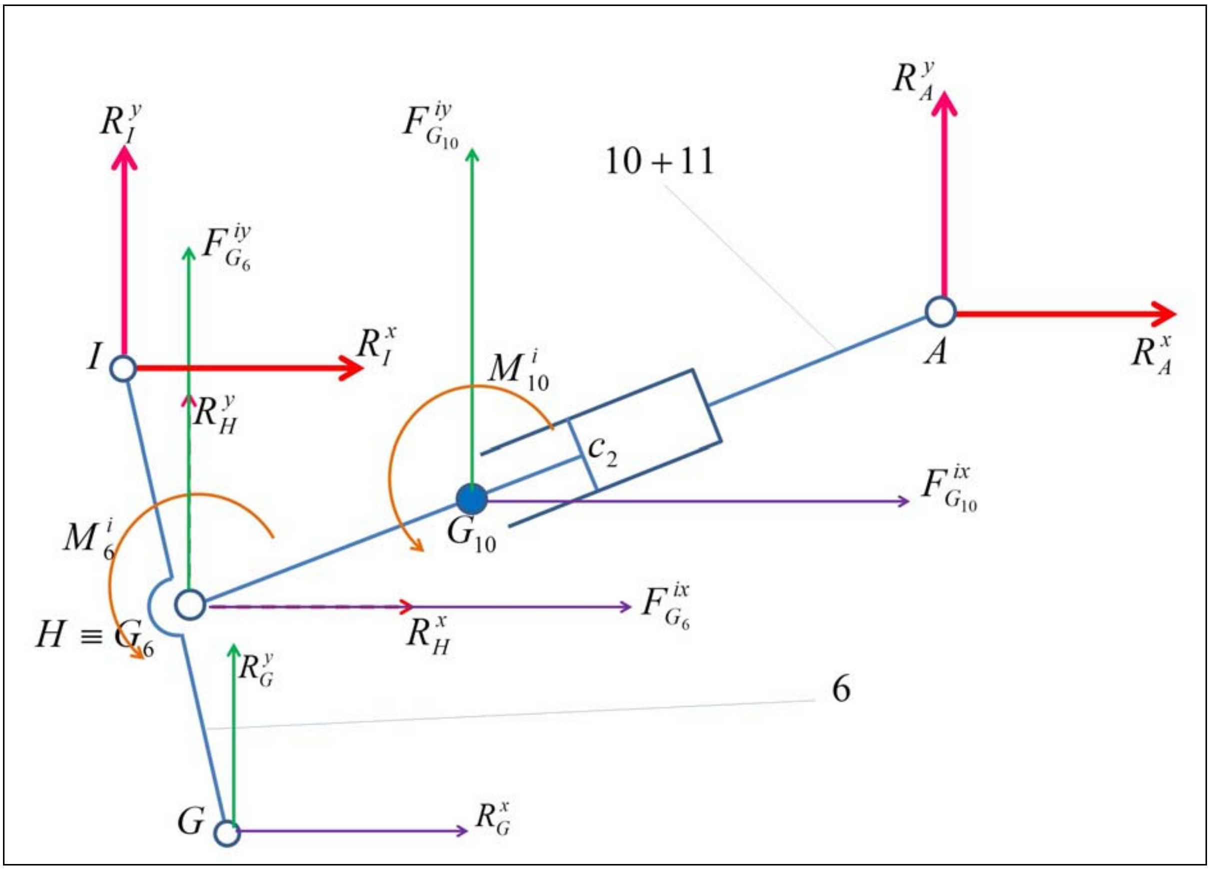

Figure 6: The forces schema of the dyad 6,10-11

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$$\begin{cases} \begin{cases} \sum M_I^{(6,10)} = 0 \Rightarrow R_A^x \cdot (y_I - y_A) + R_A^y \cdot (x_A - x_I) + F_{G_{10}}^{ix} \cdot (y_I - y_{G_{10}}) + \\ + F_{G_{10}}^{iy} \cdot (x_{G_{10}} - x_I) + M_{10}^i + F_{G_6}^{ix} \cdot (y_I - y_H) + F_{G_6}^{iy} \cdot (x_H - x_I) + M_6^i + \\ + (-R_G^x) \cdot (y_I - y_G) + (-R_G^y) \cdot (x_G - x_I) = 0 \end{cases} \\ \begin{cases} \sum M_H^{(10)} = 0 \Rightarrow R_A^x \cdot (y_H - y_A) + R_A^y \cdot (x_A - x_H) + F_{G_{10}}^{ix} \cdot (y_H - y_{G_{10}}) + \\ + F_{G_{10}}^{iy} \cdot (x_{G_{10}} - x_H) + M_{10}^i = 0 \end{cases} \\ \begin{cases} b_{11} \cdot R_A^x + b_{12} \cdot R_A^y = b_1 \\ b_{21} \cdot R_A^x + b_{22} \cdot R_A^y = b_2 \end{cases} \quad \begin{cases} b_{11} = y_I - y_A; \;\; b_{12} = x_A - x_I \\ b_1 = (y_{G_{10}} - y_I) F_{G_{10}}^{ix} + (x_I - x_{G_{10}}) F_{G_{10}}^{iy} - \\ - M_{10}^i + (y_H - y_I) F_{G_6}^{ix} + (x_I - x_H) F_{G_6}^{iy} - \\ - M_6^i + (y_I - y_G) R_G^x + (x_G - x_I) R_G^y \end{cases} \\ \begin{cases} b_{21} = y_H - y_A; \;\; b_{22} = x_A - x_H; \\ b_2 = (y_{G_{10}} - y_H) F_{G_{10}}^{ix} + (x_H - x_{G_{10}}) F_{G_{10}}^{iy} - M_{10}^i \end{cases} \\ \delta = \begin{vmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{vmatrix} = b_{11} \cdot b_{22} - b_{12} \cdot b_{21}; \;\; \delta_x = \begin{vmatrix} b_1 & b_{12} \\ b_2 & b_{22} \end{vmatrix} = b_1 \cdot b_{22} - b_2 \cdot b_{12} \\ \delta_y = \begin{vmatrix} b_{11} & b_1 \\ b_{21} & b_2 \end{vmatrix} = b_2 \cdot b_{11} - b_1 \cdot b_{21}; \;\; R_A^x = \frac{\delta_x}{\delta}; \;\; R_A^y = \frac{\delta_y}{\delta} \end{cases} \quad (5)$$

$$\begin{cases} \sum F_x^{(6,10)} = 0 \;\; - R_I^x + F_{G_6}^{ix} - R_G^x + F_{G_{10}}^{ix} + R_A^x = 0 \Rightarrow \\ \Rightarrow R_I^x = F_{G_6}^{ix} - R_G^x + F_{G_{10}}^{ix} + R_A^x \\ \sum F_y^{(6,10)} = 0 \;\; - R_I^y + F_{G_6}^{iy} - R_G^y + F_{G_{10}}^{iy} + R_A^y = 0 \Rightarrow \\ \Rightarrow R_I^y = F_{G_6}^{iy} - R_G^y + F_{G_{10}}^{iy} + R_A^y \end{cases} \quad (6)$$

$$\begin{cases} \sum F_x^{(10)} = 0 \;\;\; R_H^x + F_{G_{10}}^{ix} + R_A^x = 0 \Rightarrow \\ \Rightarrow R_H^x = -F_{G_{10}}^{ix} - R_A^x \\ \sum F_y^{(10)} = 0 \;\;\; R_H^y + F_{G_{10}}^{iy} + R_A^y = 0 \Rightarrow \\ \Rightarrow R_H^y = -F_{G_{10}}^{iy} - R_A^y \end{cases} \quad (7)$$

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The next calculations to the dyad (single, not driven, comprising the elements 3, 4), can be seen in the systems (8-10) Figure 7.

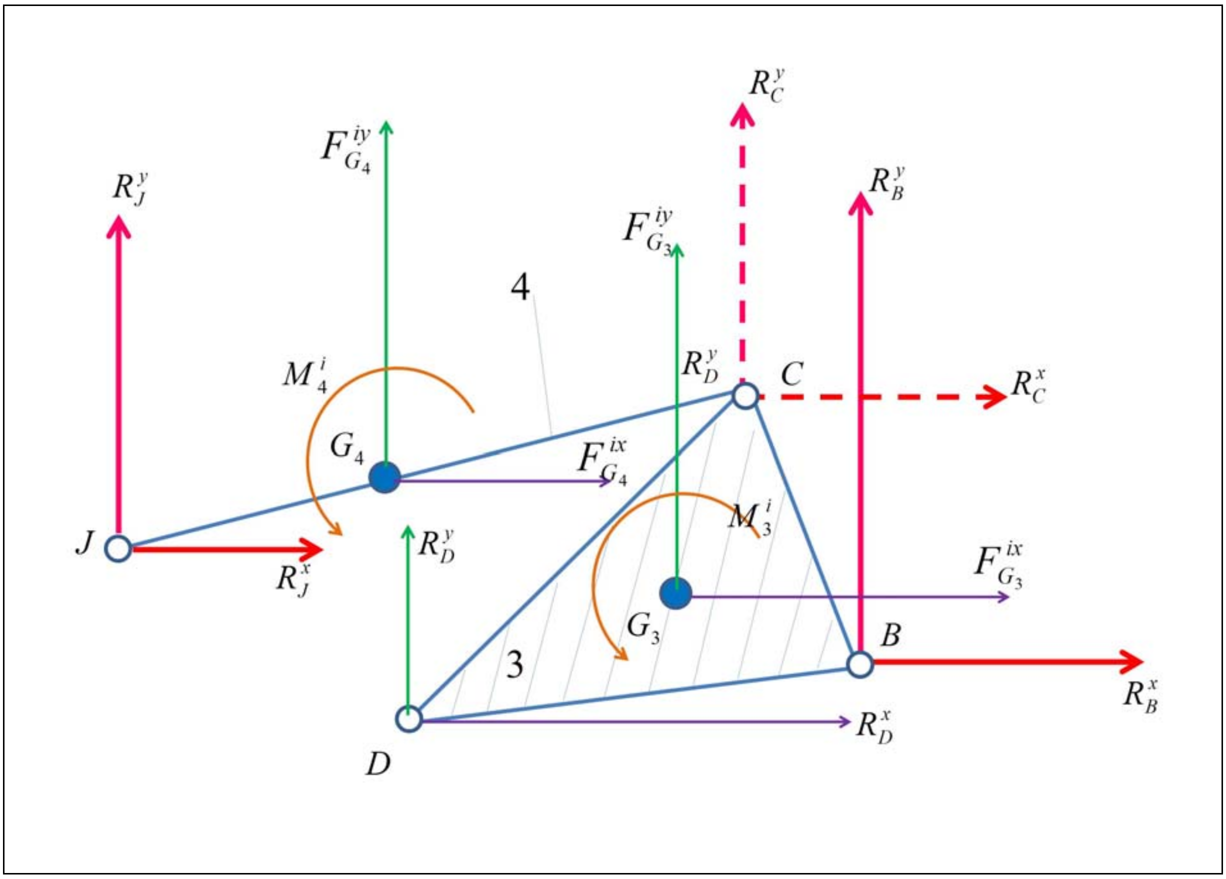

Figure 7: The forces schema of the dyad 3,4

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$$\begin{cases} \begin{cases} \sum M_B^{(3,4)} = 0 \Rightarrow (-R_J^x)\cdot(y_B - y_J) + (-R_J^y)\cdot(x_J - x_B) + \\ + F_{G_4}^{ix}\cdot(y_B - y_{G_4}) + F_{G_4}^{iy}\cdot(x_{G_4} - x_B) + M_4^i + F_{G_3}^{ix}\cdot(y_B - y_{G_3}) + \\ + F_{G_3}^{iy}\cdot(x_{G_3} - x_B) + M_3^i + (-R_D^x)\cdot(y_B - y_D) + (-R_D^y)\cdot(x_D - x_B) = 0 \end{cases} \\ \begin{cases} \sum M_C^{(4)} = 0 \Rightarrow (-R_J^x)\cdot(y_C - y_J) + (-R_J^y)\cdot(x_J - x_C) + \\ + F_{G_4}^{ix}\cdot(y_C - y_{G_4}) + F_{G_4}^{iy}\cdot(x_{G_4} - x_C) + M_4^i = 0 \end{cases} \\ \begin{cases} c_{11}\cdot R_J^x + c_{12}\cdot R_J^y = c_1 \\ c_{21}\cdot R_J^x + c_{22}\cdot R_J^y = c_2 \end{cases} \begin{cases} c_{11} = y_J - y_B;\; c_{12} = x_B - x_J \\ c_1 = (y_{G_4} - y_B)F_{G_4}^{ix} + (x_B - x_{G_4})F_{G_4}^{iy} - \\ - M_4^i + (y_{G_3} - y_B)F_{G_3}^{ix} + (x_B - x_{G_3})F_{G_3}^{iy} - \\ - M_3^i + (y_B - y_D)R_D^x + (x_D - x_B)R_D^y \end{cases} \\ \begin{cases} c_{21} = y_J - y_C;\; c_{22} = x_C - x_J; \\ c_2 = (y_{G_4} - y_C)F_{G_4}^{ix} + (x_C - x_{G_4})F_{G_4}^{iy} - M_4^i \end{cases} \\ \lambda = \begin{vmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{vmatrix} = c_{11}\cdot c_{22} - c_{12}\cdot c_{21};\; \lambda_x = \begin{vmatrix} c_1 & c_{12} \\ c_2 & c_{22} \end{vmatrix} = c_1\cdot c_{22} - c_2\cdot c_{12} \\ \lambda_y = \begin{vmatrix} c_{11} & c_1 \\ c_{21} & c_2 \end{vmatrix} = c_2\cdot c_{11} - c_1\cdot c_{21};\; R_J^x = \frac{\lambda_x}{\lambda};\; R_J^y = \frac{\lambda_y}{\lambda} \end{cases} \tag{8}$$

$$\begin{cases} \sum F_x^{(3,4)} = 0 \quad R_B^x + F_{G_3}^{ix} + F_{G_4}^{ix} - R_J^x - R_D^x = 0 \Rightarrow \\ \Rightarrow R_B^x = R_J^x + R_D^x - F_{G_3}^{ix} - F_{G_4}^{ix} \\ \sum F_y^{(3,4)} = 0 \quad R_B^y + F_{G_3}^{iy} + F_{G_4}^{iy} - R_J^y - R_D^y = 0 \Rightarrow \\ \Rightarrow R_B^y = R_J^y + R_D^y - F_{G_3}^{iy} - F_{G_4}^{iy} \end{cases} \tag{9}$$

$$\begin{cases} \sum F_x^{(4)} = 0 \quad R_C^x + F_{G_4}^{ix} - R_J^x = 0 \Rightarrow \\ \Rightarrow R_C^x = R_J^x - F_{G_4}^{ix} \\ \sum F_y^{(4)} = 0 \quad R_C^y + F_{G_4}^{iy} - R_J^y = 0 \Rightarrow \\ \Rightarrow R_C^y = R_J^y - F_{G_4}^{iy} \end{cases} \tag{10}$$

The calculation continues with the next motor dyad composed of elements (5, 8, 9), systems (11-13) Figure 8.

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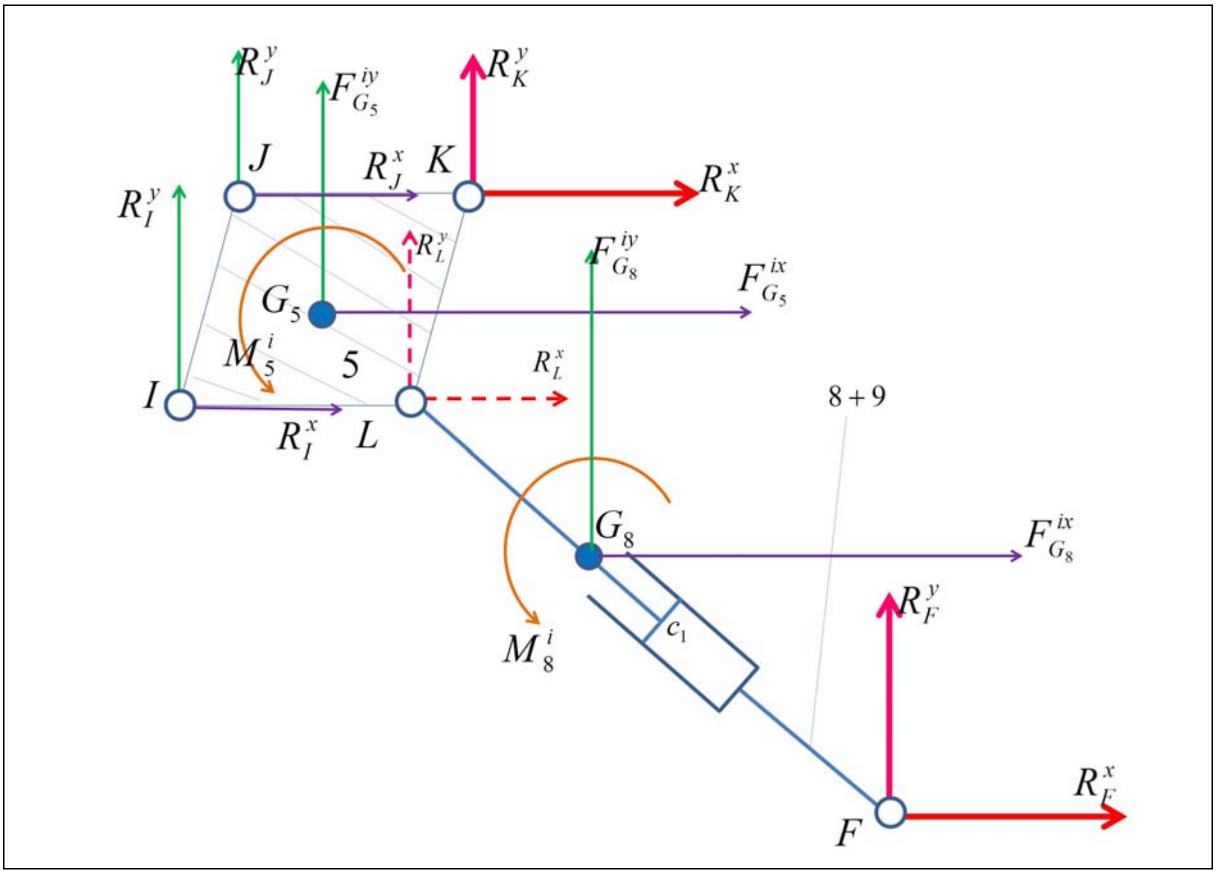

Figure 8: The forces schema of the dyad 5,8-9

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$$\begin{cases} \begin{cases} \sum M_K^{(5,8)} = 0 \Rightarrow R_F^x \cdot (y_K - y_F) + R_F^y \cdot (x_F - x_K) + F_{G_8}^{ix} \cdot (y_K - y_{G_8}) + \\ + F_{G_8}^{iy} \cdot (x_{G_8} - x_K) + M_8^i + F_{G_5}^{ix} \cdot (y_K - y_{G_5}) + F_{G_5}^{iy} \cdot (x_{G_5} - x_K) + M_5^i + \\ + R_I^x \cdot (y_K - y_I) + R_I^y \cdot (x_I - x_K) + R_J^x \cdot (y_K - y_J) + R_J^y \cdot (x_J - x_K) = 0 \end{cases} \\ \begin{cases} \sum M_L^{(8)} = 0 \Rightarrow R_F^x \cdot (y_L - y_F) + R_F^y \cdot (x_F - x_L) + F_{G_8}^{ix} \cdot (y_L - y_{G_8}) + \\ + F_{G_8}^{iy} \cdot (x_{G_8} - x_L) + M_8^i = 0 \end{cases} \\ \begin{cases} d_{11} \cdot R_F^x + d_{12} \cdot R_F^y = d_1 \\ d_{21} \cdot R_F^x + d_{22} \cdot R_F^y = d_2 \end{cases} \quad \begin{cases} d_{11} = y_K - y_F; \quad d_{12} = x_F - x_K \\ d_1 = (y_{G_8} - y_K) F_{G_8}^{ix} + (x_K - x_{G_8}) F_{G_8}^{iy} - \\ - M_8^i + (y_{G_5} - y_K) F_{G_5}^{ix} + (x_K - x_{G_5}) F_{G_5}^{iy} - \\ - M_5^i + (y_I - y_K) R_I^x + (x_K - x_I) R_I^y + \\ + (y_J - y_K) \cdot R_J^x + (x_K - x_J) \cdot R_J^y \end{cases} \\ \begin{cases} d_{21} = y_L - y_F; \quad d_{22} = x_F - x_L; \\ d_2 = (y_{G_8} - y_L) F_{G_8}^{ix} + (x_L - x_{G_8}) F_{G_8}^{iy} - M_8^i \end{cases} \\ \Phi = \begin{vmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{vmatrix} = d_{11} \cdot d_{22} - d_{12} \cdot d_{21}; \quad \Phi_x = \begin{vmatrix} d_1 & d_{12} \\ d_2 & d_{22} \end{vmatrix} = d_1 \cdot d_{22} - d_2 \cdot d_{12} \\ \Phi_y = \begin{vmatrix} d_{11} & d_1 \\ d_{21} & d_2 \end{vmatrix} = d_2 \cdot d_{11} - d_1 \cdot d_{21}; \quad R_F^x = \frac{\Phi_x}{\Phi}; \quad R_F^y = \frac{\Phi_y}{\Phi} \end{cases} \tag{11}$$

$$\begin{cases} \sum F_x^{(5,8)} = 0 \quad R_K^x + R_J^x + R_I^x + R_F^x + F_{G_5}^{ix} + F_{G_8}^{ix} = 0 \Rightarrow \\ \Rightarrow R_K^x = -R_J^x - R_I^x - R_F^x - F_{G_5}^{ix} - F_{G_8}^{ix} \\ \sum F_y^{(5,8)} = 0 \quad R_K^y + R_J^y + R_I^y + R_F^y + F_{G_5}^{iy} + F_{G_8}^{iy} = 0 \Rightarrow \\ \Rightarrow R_K^y = -R_J^y - R_I^y - R_F^y - F_{G_5}^{iy} - F_{G_8}^{iy} \end{cases} \tag{12}$$

$$\begin{cases} \sum F_x^{(8)} = 0 \quad R_L^x + F_{G_8}^{ix} + R_F^x = 0 \Rightarrow \\ \Rightarrow R_L^x = -R_F^x - F_{G_8}^{ix} \\ \sum F_y^{(8)} = 0 \quad R_L^y + F_{G_8}^{iy} + R_F^y = 0 \Rightarrow \\ \Rightarrow R_L^y = -R_F^y - F_{G_8}^{iy} \end{cases} \tag{13}$$

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2.1 Determining driving forces of the main mechanism

In the end we can determine and (three) driving forces. In Figure 9 can be monitored engine element c1 composed of kinematic elements 8-9. Determine motive power F_{m1} with relations of the system 14; being two relations of calculation may be carried out a check.

$$\begin{cases} \sum F_x^{(8)} = 0 \Rightarrow F_{m_1} \cdot \cos\varphi_8 + F_{G_8}^{ix} + R_L^x = 0 \Rightarrow F_{m_1} = \dfrac{-F_{G_8}^{ix} - R_L^x}{\cos\varphi_8} \\ \sum F_y^{(8)} = 0 \Rightarrow F_{m_1} \cdot \sin\varphi_8 + F_{G_8}^{iy} + R_L^y = 0 \Rightarrow F_{m_1} = \dfrac{-F_{G_8}^{iy} - R_L^y}{\sin\varphi_8} \end{cases} \tag{14}$$

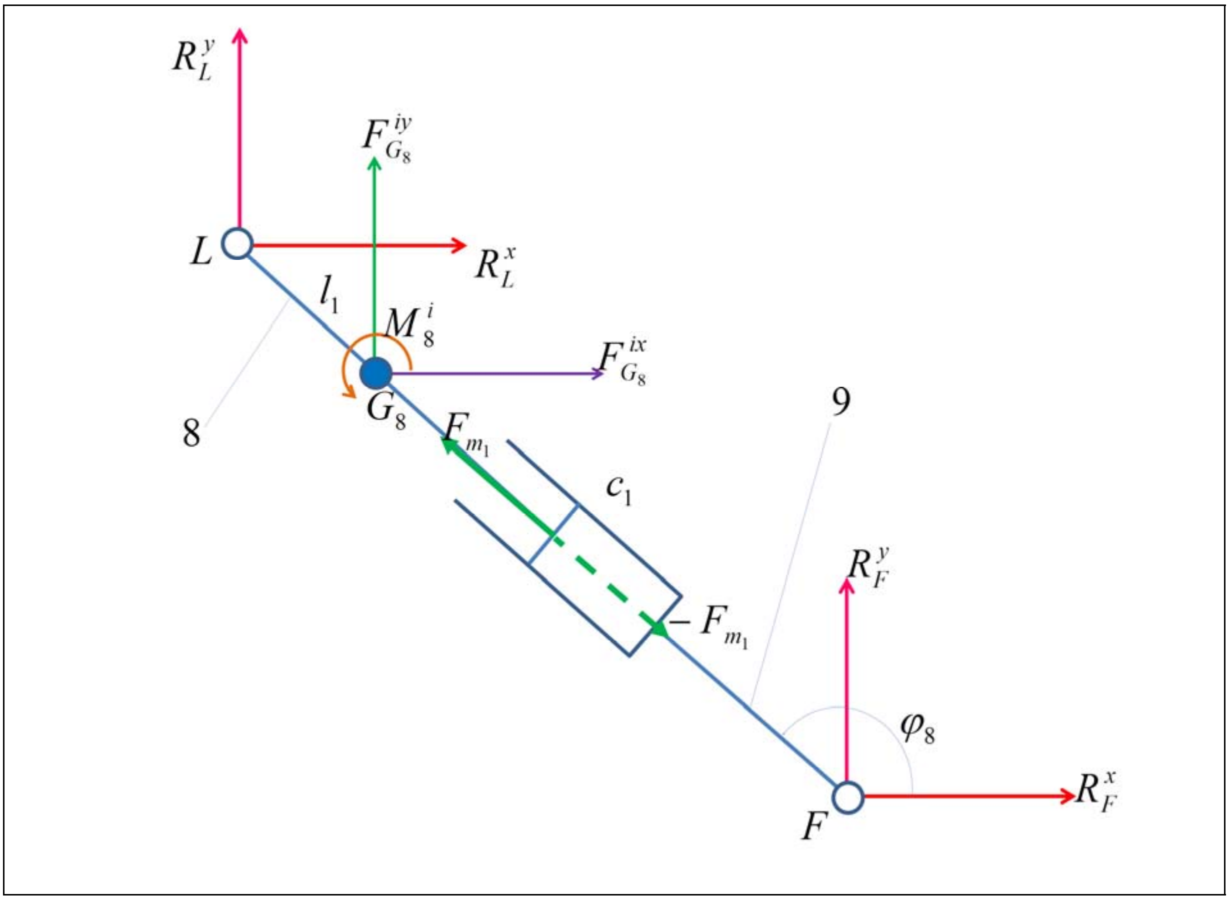

Figure 9: Forces schema of the motor mechanism c1

In Figure 10 can be monitored engine element c2 composed of kinematic elements 10-11, and determine motive power F_{m2} with the relations of the system 15.

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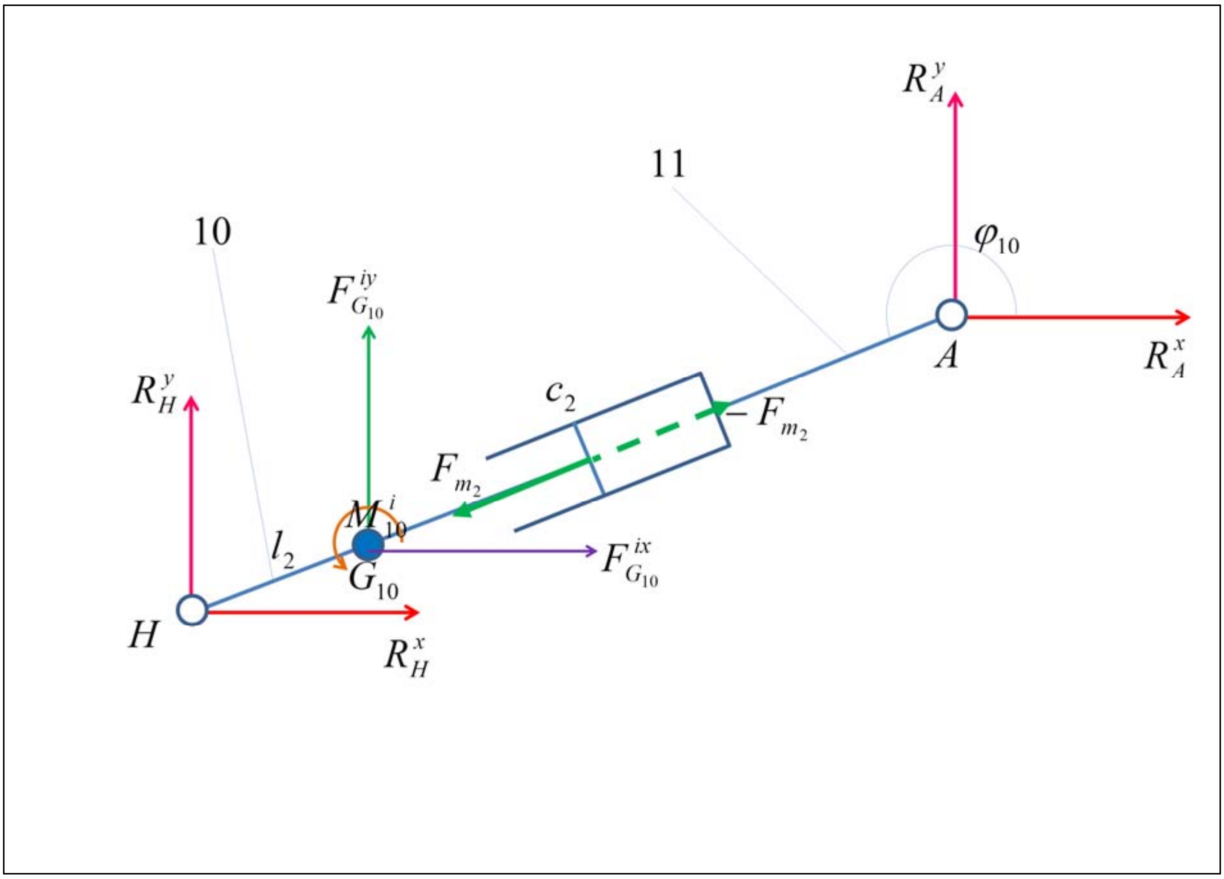

Figure 10: Forces schema of the motor mechanism c2

$$\begin{cases} \sum F_x^{(10)} = 0 \Rightarrow F_{m_2} \cdot \cos\varphi_{10} + F_{G_{10}}^{ix} + R_H^x = 0 \Rightarrow F_{m_2} = \dfrac{-F_{G_{10}}^{ix} - R_H^x}{\cos\varphi_{10}} \\ \\ \sum F_y^{(10)} = 0 \Rightarrow F_{m_2} \cdot \sin\varphi_{10} + F_{G_{10}}^{iy} + R_H^y = 0 \Rightarrow F_{m_2} = \dfrac{-F_{G_{10}}^{iy} - R_H^y}{\sin\varphi_{10}} \end{cases} \quad (15)$$

In Figure 11 can be monitored engine element c3 composed of kinematic elements 1-2, and determine motive power F_{m3} with the relations of the system 16.

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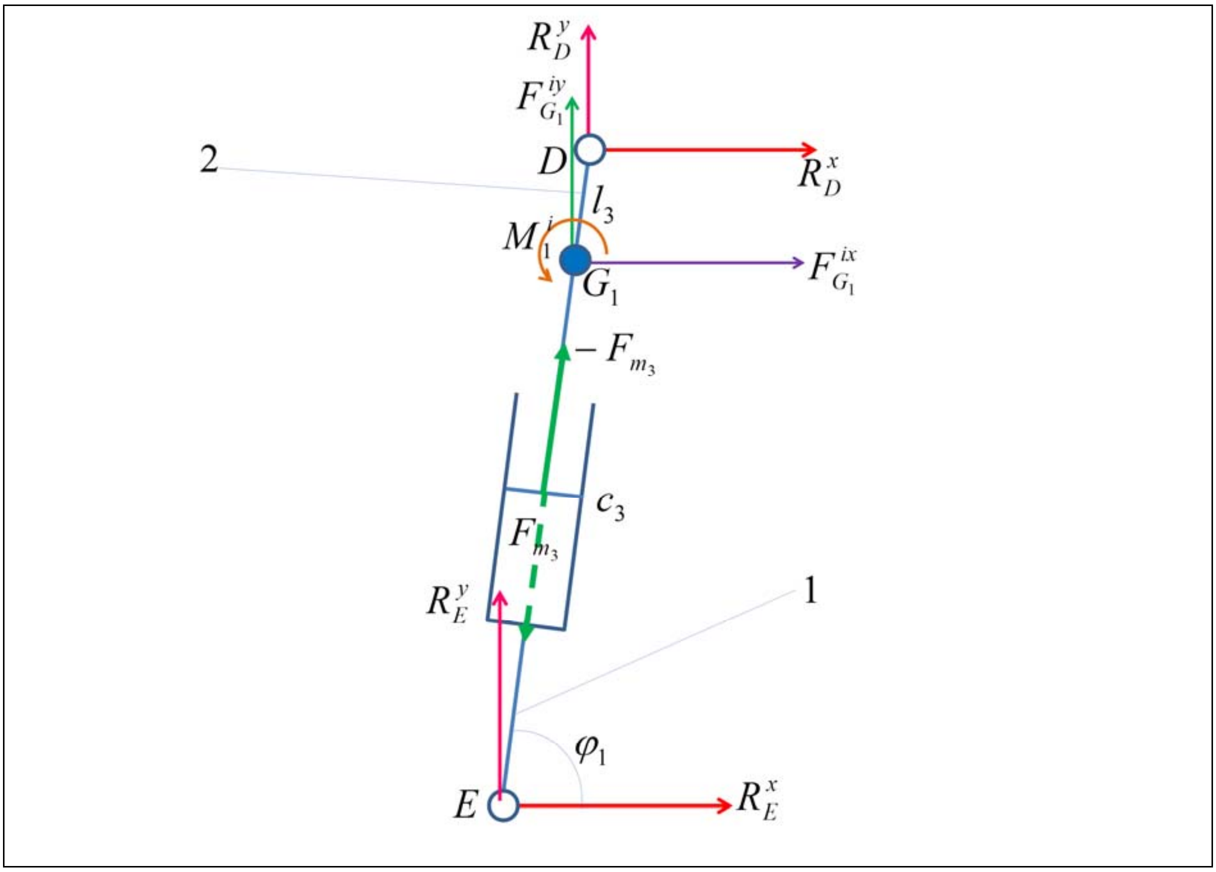

Figure 11: Forces schema of the motor mechanism c3

$$\begin{cases} \sum F_x^{(1)} = 0 \Rightarrow -F_{m_3} \cdot \cos\varphi_1 + F_{G_1}^{ix} + R_E^x = 0 \Rightarrow F_{m_3} = \dfrac{F_{G_1}^{ix} + R_E^x}{\cos\varphi_1} \\ \\ \sum F_y^{(1)} = 0 \Rightarrow -F_{m_3} \cdot \sin\varphi_1 + F_{G_1}^{iy} + R_E^y = 0 \Rightarrow F_{m_3} = \dfrac{F_{G_1}^{iy} + R_E^y}{\sin\varphi_1} \end{cases} \quad (16)$$

3. DISCUSSION AND CONCLUSIONS

Forces diagram shows a typical forging manipulator, with the basic motions in operation process: walking, motion of the tong and buffering.

In the first place shall be calculated all external forces from the mechanism (The inertia forces, gravitational forces and the force of the weight of the cast part). Is then calculated all the forces from couplers.

In the forces study of a mechanism one determines all forces instant (at a certain moment acting on the mechanism respectively). It is based on kinematic scheme of the mechanism loaded with all the forces acting on the mechanism. Some

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forces (outside or external forces) are known, and others (forces from couplers) are not known, but must be determined (ZHAO, 2010; PETRESCU, 2009, 2011-2014).

Determination of kinematic couplings reaction forces from the main mechanism of a forging manipulator is vital because with the data obtained can properly size the mechanism.

On the other hand, dynamic study of the mechanism (LI, 2010) will be conducted with the help of knowledge forces acting on the mechanism (LIU, 2010).

In forging manipulators today one requires the use of very large weights and full automation of the process of forging, which involves knowing the forces of gravity that must be sustained, manipulated and forged.

Relationships presented can determine with a very high accuracy the forces which acting on the entire mechanism.

In the end we can determine and (three) driving forces. In Figure 9 can be monitored engine element c1 composed of kinematic elements 8-9. Determine motive power F_{m1} with relations of the system 14; being two relations of calculation may be carried out a check.

In Figure 10 can be monitored engine element c2 composed of kinematic elements 10-11, and determine motive power F_{m2} with the relations of the system 15.

In Figure 11 can be monitored engine element c3 composed of kinematic elements 1-2, and determine motive power F_{m3} with the relations of the system 16.

4. ETHICS

Author declares that are not ethical issues that may arise after the publication of this manuscript.

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