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Review

Something about a Railbound Forging Manipulator

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Abstract: Heavy payload forging manipulators are mainly characterized by large load output and large capacitive load input. The relationships between outputs and inputs have greatly influenced the control and reliability. 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 greater precision and stability. They have been called the rail-bound forging manipulators. In this paper, one presents the general aspects of a rail-bound forging manipulator, like geometry, structure, general kinematics and forces of the main mechanism from such manipulator. The kinematic scheme shows a typical forging manipulator, with the basic motions in operation process: Walking, the motion of the tong and buffering. The lifting mechanism consists of several parts including linkages, hydraulic drives and motion pairs. An idea of establishing the incidence relationship between output characteristics and actuator inputs is proposed. Self-forging systems have the ability to achieve an open, fast, direct forging of products that are often heavy and heavy but also bulky. Open forging productivity is generally very high, it is determined not only by the capacity of forging press but obviously dynamic handling by forging manipulator. The most prominent and qualitative forging machines are the DANGO and DIENENTHAL series, equipped with high dynamic devices and specially designed to operate on heavy forging presses. They ensure the reliability and repeatability of all forging cycles. Even a modernization of existing forging machines with D&D machines will improve the capacity and quality of these facilities. D&D handlers allow to forge nearly clean shapes and guarantee superior surface qualities, thus saving energy, improving production and saving costs during the machining of parts. Savings due to shorter process times and reduction of reheating cycles result in shorter recovery time.

Keywords: Robots, Mechatronic Systems, Structure, Machines, Kinematics, Forging Manipulator, Heavy Payload, Lifting Mechanism, Rail-Bound Manipulator

Introduction

Such large gauge systems are currently used for hot forging materials in order to prepare them so that all intrinsic qualities grow. In order to have better stability, these monsters generally fit their own train, which also provides them with an extra balance. However, they can also be constructively found as independent forging manipulators, not just as rail bound forging manipulators.

Self-forging systems have the ability to achieve an open, fast, direct forging of products that are often heavy and heavy but also bulky. Open forging productivity is generally very high, it is determined not only by the capacity of forging press but obviously dynamic handling by forging manipulator.

The most prominent and qualitative forging machines are the DANGO and DIENENTHAL series, equipped with high dynamic devices and specially designed to operate on heavy forging presses. They ensure the reliability and repeatability of all forging cycles. Even a modernization of existing forging machines with D&D machines will improve the capacity and quality of these facilities.

D&D handlers allow to forge nearly clean shapes and guarantee superior surface qualities, thus saving energy, improving production and saving costs during the machining of parts. Savings due to shorter process times and reduction of reheating cycles result in shorter recovery time.

A 500kN shelf handle is designed to support the pliers with a variety of actions that keep pace with precision speeds and pressures such as forging in the forging area of the presses.

LS Heavy Industry Engineering Co., Ltd. Forging machines for railways are important equipment that determines the production capacity of forging presses openly dies by their high dynamics in forged iron handling. The forces are guided precisely and repeatedly and positioned in all forging cycles under the hydraulic unit and electronic control.

The integrated pillow frame is designed to absorb the eccentric energy generated in the forging process. It can better protect the manipulator itself by ensuring a long life.

500kN open rail manipulator is designed to support clamps that are fastened with their pliers, with a variety of actions to keep up with speed and precision pressures, such as forging in the forging area of the presses.

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For special alloy materials, they require a rapid forging process, to be completed in a narrow temperature range and it is recommended to use the two-handed handle with the press. The solution is used in the high-speed rail system.

Pressing and handling measures are integrated and controlled by an operator in a central impulse. Integrated with the press, the forged positioning by the horizontal forward and backward movement, which rotates in the forging area, synchronizes with the press parts.

Transport capacity: 30kN/60kN · m-1000kN/2500kN · m

Movement and commands to these mammoths are slow and difficult, which requires much automation to help the manipulator in conducting various operations, especially to achieve the necessary precision.

Orders can be made from the vehicle giant or from a central panel installed in the hall of the enterprise where the manipulator is used.A railbound forging manipulator is presented in the Fig. 1.

The kinematic chain plan (the kinematic diagram) of the main mechanism, which fall within a single plane or in one or more of the other plane parallel to each other, is presented in the Fig. 2 (Gao *et al*., 2010; Ge and Gao, 2012; Li and Liu, 2010; Yan *et al*., 2009; Zhao *et al*., 2010; Petrescu and Petrescu, 2015a,b,d; Aversa *et al*., 2017b).

Fig. 1: Photo of a railbound forging manipulator

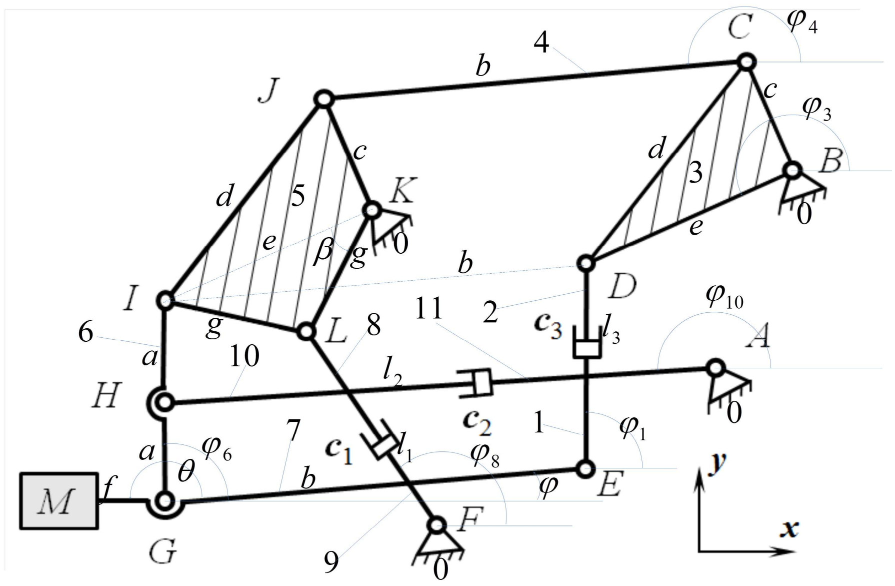

Fig. 2: Cinematic schema of a forging manipulator main mechanism

The mechanisms of this kind have spread rapidly in all areas of the grove, being extremely precious for metalworking where large materials of considerable size are used, which must be handled, gripped, transported, raised, rotated, pressed, forged, including when incandescent, so these machines are perfectly adapted to these difficult and otherwise dangerous operations for humans.

It can be talked about here by manipulating robots or self-employed robots with a large gauge (Rulkov *et al*., 2016; Agarwala, 2016; Babayemi, 2016; Gusti and Semin, 2016; Mohamed *et al*., 2016; Wessels and Raad, 2016; Maraveas *et al*., 2015; Khalil, 2015; Rhode-Barbarigos *et al*., 2015; Takeuchi *et al*., 2015; Li *et al*., 2015; Vernardos and Gantes, 2015; Bourahla and Blakeborough, 2015; Stavridou *et al*., 2015; Ong *et al*., 2015; Dixit and Pal, 2015; Rajput *et al*., 2016; Rea and Ottaviano, 2016; Zurfi and Zhang, 2016a-b; Zheng and Li, 2016; Buonomano *et al*., 2016a-b; Faizal *et al*., 2016; Cataldo, 2006; Ascione *et al*., 2016; Elmeddahi *et al*., 2016; Calise *et al*., 2016; Morse *et al*., 2016; Abouobaida, 2016; Rohit and Dixit, 2016; Kazakov *et al*., 2016; Alwetaishi, 2016; Riccio *et al*., 2016a-b; Iqbal, 2016; Hasan and El-Naas, 2016; Al-Hasan and Al-Ghamdi, 2016; Jiang *et al*., 2016; Sepúlveda, 2016; Martins *et al*., 2016; Pisello *et al*., 2016; Jarahi, 2016; Mondal *et al*., 2016; Mansour, 2016; Al Qadi *et al*., 2016b; Campo *et al*., 2016; Samantaray *et al*., 2016; Malomar *et al*., 2016; Rich and Badar, 2016; Hirun, 2016; Bucinell, 2016; Nabilou, 2016b; Barone *et al*., 2016; Chisari and Bedon, 2016; Bedon and Louter, 2016; Santos and Bedon, 2016; Minghini *et al*., 2016; Bedon, 2016; Jafari *et al*., 2016; Chiozzi *et al*., 2016; Orlando and Benvenuti, 2016; Wang and Yagi, 2016; Obaiys *et al*., 2016; Ahmed *et al*., 2016; Jauhari *et al*., 2016; Syahrullah and Sinaga, 2016; Shanmugam, 2016; Jaber and Bicker, 2016; Wang *et al*., 2016; Moubarek and Gharsallah, 2016; Amani, 2016; Shruti, 2016; Pérez-de León *et al*., 2016; Mohseni and Tsavdaridis, 2016; Abu-Lebdeh *et al*., 2016; Serebrennikov *et al*., 2016; Budak *et al*., 2016; Augustine *et al*., 2016; Jarahi and Seifilaleh, 2016; Nabilou, 2016a; You *et al*., 2016; Al Qadi *et al*., 2016a; Rama *et al*., 2016; Sallami *et al*., 2016; Huang *et al*., 2016; Ali *et al*., 2016; Kamble and Kumar, 2016; Saikia and Karak, 2016; Zeferino *et al*., 2016; Pravettoni *et al*., 2016; Bedon and Amadio, 2016; Chen and Xu, 2016; Mavukkandy *et al*., 2016; Gruener, 2006; Yeargin *et al*., 2016; Madani and Dababneh, 2016; Alhasanat *et al*., 2016; Elliott *et al*., 2016; Suarez *et al*., 2016; Kuli *et al*., 2016; Waters *et al*., 2016; Montgomery *et al*., 2016; Lamarre *et al*., 2016; Daud *et al*., 2008; Taher *et al*., 2008; Zulkifli *et al*., 2008; Pourmahmoud, 2008; Pannirselvam *et al*., 2008; Ng *et al*., 2008; El-Tous, 2008; Akhesmeh *et al*., 2008; Nachiengtai *et al*., 2008; Moezi *et al*., 2008; Boucetta, 2008; Darabi *et al*., 2008; Semin and Bakar, 2008; Al-Abbas, 2009; Abdullah *et al*., 2009; Abu-Ein, 2009; Opafunso *et al*., 2009; Semin *et al*., 2009a-c; Zulkifli *et al*., 2009; Marzuki *et al*., 2015; Bier and Mostafavi, 2015; Momta *et al*., 2015; Farokhi and Gordini, 2015; Khalifa *et al*., 2015; Yang and Lin, 2015; Chang *et al*., 2015; Demetriou *et al*., 2015; Rajupillai *et al*., 2015; Sylvester *et al*., 2015; Ab-Rahman *et al*., 2009; Abdullah and Halim, 2009; Zotos and Costopoulos, 2009; Feraga *et al*., 2009; Bakar *et al*., 2009; Cardu *et al*., 2009; Bolonkin, 2009a-b; Nandhakumar *et al*., 2009; Odeh *et al*., 2009; Lubis *et al*., 2009; Fathallah and Bakar, 2009; Marghany and Hashim, 2009; Kwon *et al*., 2010; Aly and Abuelnasr, 2010; Farahani *et al*., 2010; Ahmed *et al*., 2010; Kunanoppadon, 2010; Helmy and El-Taweel, 2010; Qutbodin, 2010; Pattanasethanon, 2010; Fen *et al*., 2011; Thongwan *et al*., 2011; Theansuwan and Triratanasirichai, 2011; Al Smadi, 2011; Tourab *et al*., 2011; Raptis *et al*., 2011; Momani *et al*., 2011; Ismail *et al*., 2011; Anizan *et al*., 2011; Tsolakis and Raptis, 2011; Abdullah *et al*., 2011; Kechiche *et al*., 2011; Ho *et al*., 2011; Rajbhandari *et al*., 2011; Aleksic and Lovric, 2011; Kaewnai and Wongwises, 2011; Idarwazeh, 2011; Ebrahim *et al*., 2012; Abdelkrim *et al*., 2012; Mohan *et al*., 2012; Abam *et al*., 2012; Hassan *et al*., 2012; Jalil and Sampe, 2013; Jaoude and El-Tawil, 2013; Ali and Shumaker, 2013; Zhao, 2013; El-Labban *et al*., 2013; Djalel *et al*., 2013; Nahas and Kozaitis, 2013; Petrescu and Petrescu, 2014a-i; 2015a-e; 2016a-d; Fu *et al*., 2015; Al-Nasra *et al*., 2015; Amer *et al*., 2015; Sylvester *et al*., 2015b; Kumar *et al*., 2015; Gupta *et al*., 2015; Stavridou *et al*., 2015b; Casadei, 2015; Ge and Xu, 2015; Moretti, 2015; Wang *et al*., 2015; Antonescu and Petrescu, 1985; 1989; Antonescu *et al*., 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001; Aversa *et al*., 2017a; 2017b; 2017c; 2017d; 2017e; 2016a; 2016b; 2016c; 2016d; 2016e; 2016f; 2016g; 2016h; 2016i; 2016j; 2016k; 2016l; 2016m; 2016n; 2016o; Cao *et al*., 2013; Dong *et al*., 2013; Comanescu, 2010; Franklin, 1930; He *et al*., 2013; Lee, 2013; Lin *et al*., 2013; Liu *et al*., 2013; Padula and Perdereau, 2013; Perumaal and Jawahar, 2013; Petrescu, 2011; 2015a; 2015b; Petrescu and Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e; 2011a; 2011b; 2012a; 2012b; 2013a; 2013b; 2013c; 2013d; 2013e; 2016a; 2016b; 2016c; Petrescu *et al*., 2009; 2016; 2017a; 2017b; 2017c; 2017d; 2017e; 2017f; 2017g; 2017h; 2017i; 2017j; 2017k; 2017l; 2017m; 2017n; 2017o; 2017p; 2017q; 2017r; 2017s; 2017t; 2017u; 2017v; 2017w; 2017x; 2017y; 2017z; 2017aa; 2017ab; 2017ac; 2017ad; 2017ae; 2018a; 2018b; 2018c; 2018d; 2018e; 2018f; 2018g; 2018h; 2018i; 2018j; 2018k; 2018l; 2018m; 2018n).

Materials and Methods

Mechanism Structure

Then can be determined easily and the structural schema (Fig. 3).

The structural formula can be determined from the structural diagram (relationship 1) (Gao *et al*., 2010; Ge and Gao, 2012; Li and Liu, 2010; Yan *et al*., 2009; Zhao *et al*., 2010; Petrescu and Petrescu, 2015a,b,d; Aversa *et al*., 2017b):

$$EF(0) + DM1(1,2,7) + DM0(3,4) + DM1(5,8,9) + DM1(6,10,11) \quad (1)$$

It is obtained: three motor dyads, one classic dyad and a fundamental item 0 [1-5].

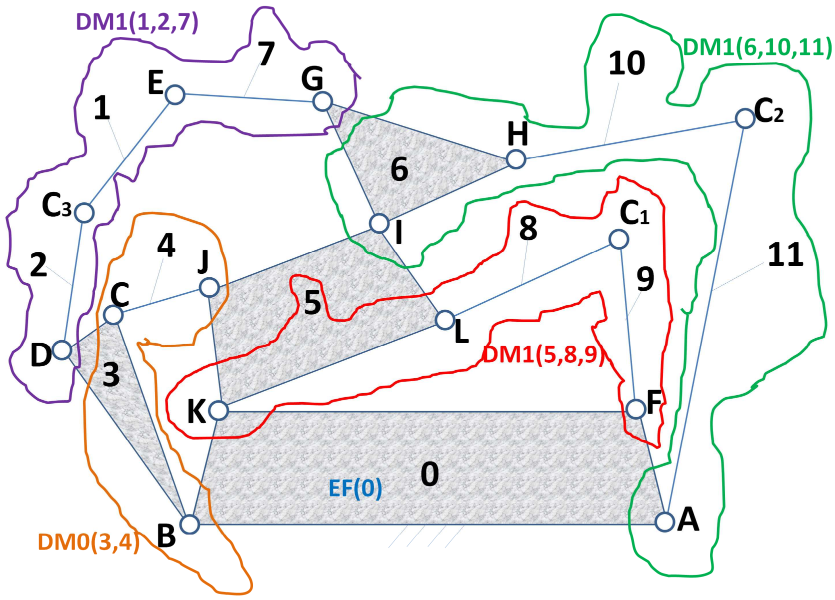

Fig. 3: Structural schema of a forging manipulator main mechanism

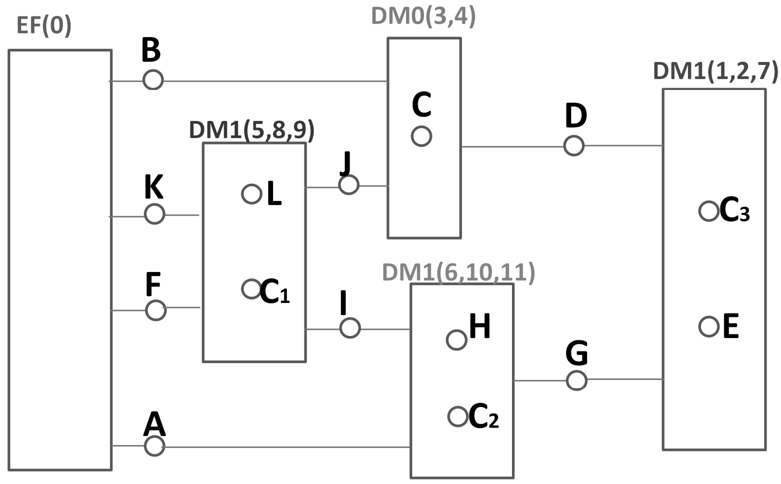

Fig. 4: Wiring diagram of a forging manipulator main mechanism

The mobility of the mechanism is determined with the formula (2) (Gao *et al*., 2010; Ge and Gao, 2012; Li and Liu, 2010; Yan *et al*., 2009; Zhao *et al*., 2010; Petrescu and Petrescu, 2015a; 2015b; 2015d; Aversa *et al*., 2017b):

$$M_3 = 3m - 2C_5 - C_4 = 3\cdot 11 - 2\cdot 15 - 0 = 33 - 30 = 3 \quad (2)$$

It follows three degrees of freedom corresponding to the three actuators (motors) linear.

The wiring diagram can be determined now using the structural formula (Fig. 4).

Mechanism Kinematics

Permanently one knows the constant lengths (a-g) and the coordinates (x_B, y_B, x_A, y_A, x_K, y_K, x_F, y_F) and the φ angle who must to be maintained constant [1-5].

In direct kinematics one knows l_1, l_2 and must be determined: Intermediary (with systems I, II, III) l_3, φ_1, φ_3, φ_6, φ_8, φ_{10} and finaly (with system IV) x_M, y_M [1-5].

In inverse kinematics one knows x_M, y_M and must be determined φ_1, φ_3, φ_6, φ_8, φ_{10}, l_1, l_2, l_3 with systems I, II, III, IV.

It takes four independent vector contours (KLFK, KIGEDB, AHIK, AHGM) and one can write the below systems (I, II, III, IV):

$$\begin{cases}(x_K - x_F) + g\cdot\cos(\varphi_3+\beta) = l_1\cdot\cos\varphi_8\\(y_K - y_F) + g\cdot\sin(\varphi_3+\beta) = l_1\cdot\sin\varphi_8\end{cases} \quad (I)$$

$$\begin{cases}x_K + b\cdot\cos\varphi + l_3\cdot\cos\varphi_1 = 2a\cdot\cos\varphi_6\\y_K + b\cdot\sin\varphi + l_3\cdot\sin\varphi_1 = 2a\cdot\sin\varphi_6\end{cases} \quad (II)$$

$$\begin{cases}(x_A - x_K) + l_2\cdot\cos\varphi_{10} + a\cdot\cos\varphi_6 = e\cdot\cos\varphi_3\\(y_A - y_K) + l_2\cdot\sin\varphi_{10} + a\cdot\sin\varphi_6 = e\cdot\sin\varphi_3\end{cases} \quad (III)$$

$$\begin{cases}(x_A - x_M) + l_3\cdot\cos\varphi_{10} + f\cdot\cos(\varphi+\theta) = a\cdot\cos\varphi_6\\(y_A - y_M) + l_3\cdot\sin\varphi_{10} + f\cdot\sin(\varphi+\theta) = a\cdot\sin\varphi_6\end{cases} \quad (IV)$$

Inverse Kinematics Relationships Computing

Then can be determined easily the parameters φ_1, φ_3, φ_6, φ_8, φ_{10}, l_1, l_2, l_3 solving the four systems I, II, III, IV. Following relationships are obtained (systems 3 and 4) (Gao *et al*., 2010; Ge and Gao, 2012; Li and Liu, 2010; Yan *et al*., 2009; Zhao *et al*., 2010; Petrescu and Petrescu, 2015a; 2015b; 2015d; Aversa *et al*., 2017b).

$$\begin{cases}\cos\varphi_6 = \dfrac{A_1\cdot A_2 \mp A_3\cdot\sqrt{A_2^2+A_3^2-A_1^2}}{A_2^2+A_3^2}\\ \Rightarrow \varphi_6 = \arccos(\cos\varphi_6);\, l_2 = -A_4 \mp \sqrt{A_4^2+e^2}\\ A_0 = 4a^2 + (x_K + b\cos\varphi)^2 + (y_K + b\sin\varphi)^2\\ -4a\left[(x_K+b\cos\varphi)\cos\varphi_6 + (y_K + b\sin\varphi)\sin\varphi_6\right]\\ l_3 = \sqrt{A_0}\begin{cases}\cos\varphi_1 = \dfrac{2a\cdot\cos\varphi_6 - x_K - b\cdot\cos\varphi}{l_3}\\ \sin\varphi_1 = \dfrac{2a\cdot\sin\varphi_6 - y_K - b\cdot\sin\varphi}{l_3}\end{cases}\\ \Rightarrow \varphi_1 = sign(\sin\varphi_1)\cdot\arccos(\cos\varphi_1)\\ \begin{cases}\cos\varphi_{10} = \dfrac{a\cdot\cos\varphi_6 - f\cdot\cos(\varphi+\theta) + x_M - x_A}{l_3}\\ \sin\varphi_{10} = \dfrac{a\cdot\sin\varphi_6 - f\cdot\sin(\varphi+\theta) + y_M - y_A}{l_3}\end{cases}\\ \Rightarrow \varphi_{10} = sign(\sin\varphi_{10})\cdot\arccos(\cos\varphi_{10})\end{cases} \quad (3)$$

$$\begin{cases} \begin{cases} \cos\varphi_3 = \dfrac{x_A - x_K + l_2\cdot\cos\varphi_{10} + a\cdot\cos\varphi_6}{e} \\ \sin\varphi_3 = \dfrac{y_A - y_K + l_2\cdot\sin\varphi_{10} + a\cdot\sin\varphi_6}{e} \end{cases} \\ \Rightarrow \varphi_3 = sign(\sin\varphi_3)\cdot\arccos(\cos\varphi_3) \\ l_1 = \sqrt{\left[x_K - x_F + g\cos(\varphi_3+\beta)\right]^2 + \left[y_K - y_F + g\sin(\varphi_3+\beta)\right]^2} \\ \begin{cases} \cos\varphi_8 = \dfrac{x_K - x_F + g\cdot\cos(\varphi_3+\beta)}{l_1} \\ \sin\varphi_8 = \dfrac{y_K - y_F + g\cdot\sin(\varphi_3+\beta)}{l_1} \end{cases} \\ \Rightarrow \varphi_8 = sign(\sin\varphi_8)\cdot\arccos(\cos\varphi_8) \\ A_1 = 3a^2 + (x_K + b\cdot\cos\varphi)^2 + (y_K + b\cdot\sin\varphi)^2 - \\ \left[x_M - x_A - f\cdot\cos(\varphi+\theta)\right]^2 - \left[y_M - y_A - f\cdot\sin(\varphi+\theta)\right]^2 \\ A_2 = 4a\cdot(x_K + b\cdot\cos\varphi) + 2a\cdot\left[x_M - x_A - f\cdot\cos(\varphi+\theta)\right] \\ A_3 = 4a\cdot(y_K + b\cdot\sin\varphi) + 2a\cdot\left[y_M - y_A - f\cdot\sin(\varphi+\theta)\right] \\ A_4 = \cos\varphi_{10}\cdot(a\cdot\cos\varphi_6 + x_A - x_K) + \sin\varphi_{10}\cdot(a\cdot\sin\varphi_6 + y_A - y_K) \end{cases} \quad (4)$$

Results

Determining Driving forces of the Main Mechanism

In step 1 (starting from system 5) it calculated the all external forces from the mechanism (The inertia forces, gravitational forces and the force of the weight of the cast part):

$$\begin{cases} \begin{cases} F_{G_1}^{ix} = -m_{12}\cdot\ddot{x}_{G_1} \\ F_{G_1}^{iy} = -m_{12}\cdot\ddot{y}_{G_1} - m_{12}\cdot g \\ M_1^i = -J_{G_1}\cdot\ddot{\varphi}_1 \end{cases} & \begin{cases} F_{G_3}^{ix} = -m_3\cdot\ddot{x}_{G_3} \\ F_{G_3}^{iy} = -m_3\cdot\ddot{y}_{G_3} - m_3\cdot g \\ M_3^i = -J_{G_3}\cdot\ddot{\varphi}_3 \end{cases} \\ \begin{cases} F_{G_6}^{ix} = -m_6\cdot\ddot{x}_{G_6} = -m_6\cdot\ddot{x}_H \\ F_{G_6}^{iy} = -m_6\cdot\ddot{y}_H - m_6\cdot g \\ M_6^i = -J_H\cdot\ddot{\varphi}_6 \end{cases} & \begin{cases} F_{G_4}^{ix} = -m_4\cdot\ddot{x}_{G_4} \\ F_{G_4}^{iy} = -m_4\cdot\ddot{y}_{G_4} - m_4\cdot g \\ M_4^i = -J_{G_4}\cdot\ddot{\varphi}_4 = 0 \end{cases} \\ \begin{cases} F_{G_5}^{ix} = -m_5\cdot\ddot{x}_{G_5} \\ F_{G_5}^{iy} = -m_5\cdot\ddot{y}_{G_5} - m_5\cdot g \\ M_5^i = -J_{G_5}\cdot\ddot{\varphi}_3 \end{cases} & \begin{cases} F_{G_7}^{ix} = -m_7\cdot\ddot{x}_{G_7} \\ F_{G_7}^{iy} = -m_7\cdot\ddot{y}_{G_7} - m_7\cdot g \\ M_7^i = -J_{G_7}\cdot\ddot{\varphi} \end{cases} \\ \begin{cases} F_M^{ix} = -M\cdot\ddot{x}_M \\ F_M^{iy} = -M\cdot\ddot{y}_M - M\cdot g \\ M_M^i = -J_M\cdot\ddot{\varphi} \end{cases} & \begin{cases} F_{G_8}^{ix} = -m_{89}\cdot\ddot{x}_{G_8} \\ F_{G_8}^{iy} = -m_{89}\cdot\ddot{y}_{G_8} - m_{89}\cdot g \\ M_8^i = -J_{G_8}\cdot\ddot{\varphi}_8 \end{cases} \\ \begin{cases} F_{G_{10}}^{ix} = -m_{10,11}\cdot\ddot{x}_{G_{10}} \\ F_{G_{10}}^{iy} = -m_{10,11}\cdot\ddot{y}_{G_{10}} - m_{10,11}\cdot g \\ M_{10}^i = -J_{G_{10,11}}\cdot\ddot{\varphi}_{10} \end{cases} & \end{cases} \quad (5)$$

Is then calculated all the forces from couplers. In the end we can determine and (three) driving forces [1-5]. In Fig. 5 can be monitored engine element c1 composed of kinematic elements 8-9.

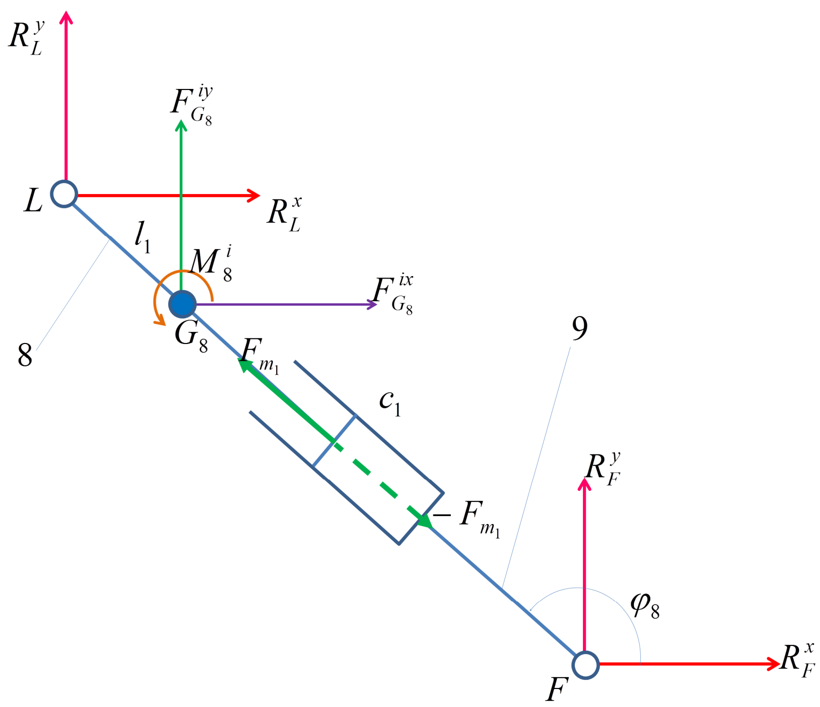

Fig. 5: Kinematics schema of the motor mechanism c_1

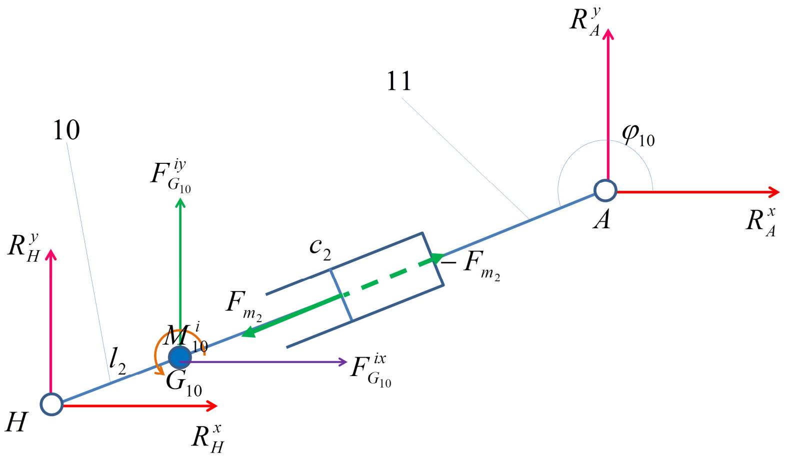

Fig. 6: Kinematics schema of the motor mechanism c_2

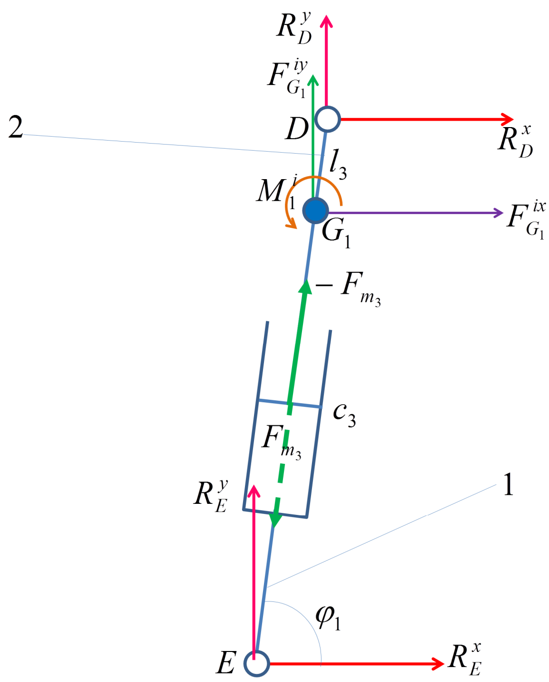

Fig. 7: Kinematics schema of the motor mechanism c_2

Determine motive power F_{m_1} with relations of the system 6; being two relations of calculation may be carried out a check:

$$\begin{cases} \sum F_x^{(8)} = 0 \Rightarrow F_{m_1} \cdot \cos\varphi_8 + F_{G_8}^{ix} + R_L^x = 0 \Rightarrow F_{m_1} = \dfrac{-F_{G_8}^{ix} - R_L^x}{\cos\varphi_8} \\ \sum F_y^{(8)} = 0 \Rightarrow F_{m_1} \cdot \sin\varphi_8 + F_{G_8}^{iy} + R_L^y = 0 \Rightarrow F_{m_1} = \dfrac{-F_{G_8}^{iy} - R_L^y}{\sin\varphi_8} \end{cases} \quad (6)$$

In Fig. 6 can be monitored engine element c_2 composed of kinematic elements 10-11 and determine motive power F_{m_2} with relations of the system 7 (Gao *et al*., 2010; Ge and Gao, 2012; Li and Liu, 2010; Yan *et al*., 2009; Zhao *et al*., 2010; Petrescu and Petrescu, 2015a,b,d; Aversa *et al*., 2017 b):

$$\begin{cases} \sum F_x^{(10)} = 0 \Rightarrow F_{m_2} \cdot \cos\varphi_{10} + F_{G_{10}}^{ix} \\ +R_H^x = 0 \Rightarrow F_{m_2} = \dfrac{-F_{G_{10}}^{ix} - R_H^x}{\cos\varphi_{10}} \\ \sum F_y^{(10)} = 0 \Rightarrow F_{m_2} \cdot \sin\varphi_{10} + F_{G_{10}}^{iy} \\ +R_H^y = 0 \Rightarrow F_{m_2} = \dfrac{-F_{G_{10}}^{iy} - R_H^y}{\sin\varphi_{10}} \end{cases} \quad (7)$$

In Fig. 7 can be monitored engine element c_3 composed of kinematic elements 1-2 and determine motive power F_{m_3} with relations of the system 8 (Gao *et al*., 2010; Ge and Gao, 2012; Li and Liu, 2010; Yan *et al*., 2009; Zhao *et al*., 2010; Petrescu and Petrescu, 2015a,b,d; Aversa *et al*., 2017b):

$$\begin{cases} \sum F_x^{(1)} = 0 \Rightarrow -F_{m_3} \cdot \cos\varphi_1 + F_{G_1}^{ix} + R_E^x = 0 \Rightarrow F_{m_3} = \dfrac{F_{G_1}^{ix} + R_E^x}{\cos\varphi_1} \\ \sum F_y^{(1)} = 0 \Rightarrow -F_{m_3} \cdot \sin\varphi_1 + F_{G_1}^{iy} + R_E^y = 0 \Rightarrow F_{m_3} = \dfrac{F_{G_1}^{iy} + R_E^y}{\sin\varphi_1} \end{cases} \quad (8)$$

Discussion

A 500kN shelf handle is designed to support the pliers with a variety of actions that keep pace with precision speeds and pressures such as forging in the forging area of the presses.

LS Heavy Industry Engineering Co., Ltd. Forging machines for railways are important equipment that determines the production capacity of forging presses openly dies by their high dynamics in forged iron handling. The forces are guided precisely and repeatedly and positioned in all forging cycles under the hydraulic unit and electronic control.

The integrated pillow frame is designed to absorb the eccentric energy generated in the forging process. It can better protect the manipulator itself by ensuring a long life.

A 500kN open rail manipulator is designed to support clamps that are fastened with their pliers, with a variety of actions to keep up with speed and precision pressures, such as forging in the forging area of the presses.

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For special alloy materials, they require a rapid forging process, to be completed in a narrow temperature range and it is recommended to use the two-handed handle with the press. The solution is used in the high-speed rail system (Fig. 8).

Pressing and handling measures are integrated and controlled by an operator in a central impulse. Integrated with the press, the forged positioning by the horizontal forward and backward movement, which rotates in the forging area, synchronizes with the press parts.

Transport capacity: 30kN/60kN · m - 1000kN/2500kN · m.

Servicing of hydraulic presses during forging operations by forging manipulators can lead to doubling the productivity of the forging machine (hydraulic press or hydraulic hammer).

Fig. 8: Heavy forging manipulator

This, especially when a certain degree of inter-conditioning of their movements with the basic equipment is achieved and even more so when their functional integration is achieved.

This integration is usually based on a programmable machine or a process calculator and modern instrumentation that is appropriate to automatic systems that can monitor, control and emit the command signals imposed by the system and close the loop reaction needed to adjust the functional parameters.

Of course, in order to operate in such working regimes, it is necessary for the forging manipulators, as well as the hydraulic press or forging hammer, to be able to achieve the corresponding dynamic responses, so that when lifting the ram on a race and then returning it to the level of the forgings, the manipulator executing the feed strokes, pivoting the pliers and lifting the necessary pliers required by the plastic deformation process by pressing, especially when working with a press, or with a forging hammer, with increasing work cadences. This required forging manipulators to have all the working mechanisms capable of performing. Therefore, in order to know in detail the dynamic responses of the working mechanisms of forging manipulators, it is necessary to investigate their dynamic behavior.

One of these mechanisms is the lifting/lowering mechanism of the clamp.

The hoisting and lowering mechanisms of the deflector manipulator clamp have specific design and action solutions based on electro-mechanical elements. They are generated by the large masses they have to raise during the forging operation, in accordance with the movements of the press or the hammer with which they work in tandem. In order to know the dynamic behavior of this mechanism, theoretical research was carried out. This research was based on the modern method of analysis and synthesis of components and systems by modeling and computer simulation of dynamic behavior. Modeling of the elements and systems of the displacement mechanism was carried out in several stages, as follows: Physical modeling; system modeling, mathematical modeling and computer modeling. Analysis and synthesis involve describing the dynamic behavior of the components of hydro-mechanical elements by mathematical modeling, in the form of systems of differential equations that best express the characteristics of the equivalent physical model, after which, on the basis of the inter conditions existing between the component elements, their synthesis is made.

Dynamic phenomena that take place in the work schedules of the actions hydro-mechanical, is a result of the interaction between the mechanical-hydraulic subsystem and the working process. That is why the theory of systems was approached as the theoretical basis of research development.

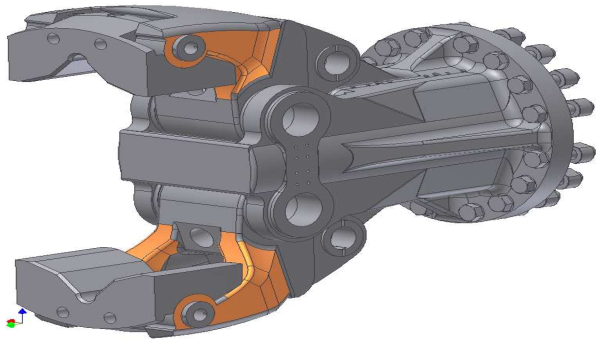

Fig. 9: End effector of a forging manipulator on rail

It is known that, in the systemic sense, hydro-mechanical drive systems are comprised from bipolar, quadripolar or six polar elements, characterized by inbound margins and specific outputs that bind and interact with each other. The system model, based on the physical model, was the basis for the mathematical model and it created the possibility of conceiving the simulation model. The computer simulation model of the dynamic behavior of the lifting/lowering mechanism allowed knowledge of the graphical evolution of the parameters of interest: Races, speeds, accelerations, moments, pressures, power, energy, etc. The article presents the results of the theoretical research on the dynamic behavior of the lifting and lowering mechanism from the recently designed forging manipulator.

The very large loads of the forging manipulator led to the use lifting and lowering electro-hydro-mechanical clamp mechanisms based on linear hydraulic motors which, by means of an articulated bar mechanism, perform the force and the required lifting/lowering of the hot semi-finished products.

Elaborate the physical model of the lifting mechanism lowering pliers (Fig. 9).

In order to elaborate the physical model of the claw-lowering mechanism, the hydromechanical actuation scheme, which mentions the physical dimensions involved in carrying out the lifting-lowering process of the semi-fabric caught in the manipulator clamps, was started.

The main physical elements involved in the lift-down movement clergy and the physical dimensions involved in the process are the following:

- The electric drive motor M, characterized by a moment factor K ME, a supply voltage U, an absorbed current I, a moment of inertia J ME and an angular synchronous velocity s
- The GH hydraulic generator, characterized by a Qp cylinder, an angular velocity p, a Qa aspiration flow rate, a Qp effluent flow rate, a suction pressure pa and a discharge pressure pp
- The RU oil tank with a surface A RU, at the pressure p01 where the oil level h varies accordingly
- The SLP pressure limitation pump, characterized by the opening pressures p11 and p12
- The lift-down mechanism, consisting of a parallelogram (ABCD), with uneven sides b and c, with the variable diagonal materialized by the MHL linear hydraulic motor with the minimum length L min and the current length Lx

The parallelogram is suspended by means of some tensioners, the body of the weight clamp Gc, which requests the parallelogram (Dg + b) from the fixed joint A. The distance Dc is the proper clamp, where the hot semi-finished part of the length Ls which has the center of gravity at the distance Ls/2.

The current angle made by the horizontal bar with AC is the current angle between the side AB and MHL is. With respect to the horizontal position of the AC side, the clamps rise and fall by half of the hc stroke on the current stroke xc with the Vc speed and the accelerator. The weight of the moving parts of the casing and of the semi-product is thrown by the FR lifting force generated by the MHL.

Conclusion

Self-forging systems have the ability to achieve an open, fast, direct forging of products that are often heavy and heavy but also bulky. Open forging productivity is generally very high, it is determined not only by the capacity of forging press but obviously dynamic handling by forging manipulator.

The most prominent and qualitative forging machines are the DANGO and DIENENTHAL series, equipped with high dynamic devices and specially designed to operate on heavy forging presses. They ensure the reliability and repeatability of all forging cycles. Even a modernization of existing forging machines with D&D machines will improve the capacity and quality of these facilities.

D&D handlers allows to forge nearly clean shapes and guarantee superior surface qualities, thus saving energy, improving production and saving costs during the machining of parts. Savings due to shorter process times and reduction of reheating cycles result in shorter recovery time.

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Ethics

This article is original and contains unpublished material. Authors declare that are not ethical issues and no conflict of interest that may arise after the publication of this manuscript.

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Source of Figures

Petrescu and Petrescu, 2015a; 2015b; 2015d; Aversa *et al*., 2017b.

Nomenclature

c_1	lifting hydraulic cylinder
c_2	the buffer hydraulic cylinder
c_3	leaning hydraulic cylinder
l_1, l_2, l_3	variable lengths
A-L	linkages
A, B, K, F	fixed linkages
φ_1, φ_3, φ_6, φ_8, φ_{10}	variable angles
a-g	constant lengths
x_B, y_B, x_A, y_A, x_K, y_K, x_F, y_F	constant coordinates
β, θ, φ_4	constant angles
φ	an angle which must be maintained constant ($\varphi = \pi - \theta$) to keep permanently the segment GM horizontally
$F_{m_1}, F_{m_2}, F_{m_3}$	the driving forces of the mechanism.