MULTIPARAMETRIC SYNTHESIS THE MANIPULATOR OF THE SCRAPER OF THE PRESS MANURE REMOVAL

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ABSTRACT *This paper presents the results of solving the following problem of multiparametric synthesis: determine 4 parameters of the manipulator of the scraper of a press manure removal and find out their values that the manipulator takes the prescribed positions and has equal angular velocities at the beginning and ending its turning. Solution of this multiparametric synthesis problem is based on the methods of the Machine and Mechanism Theory. The results of this paper can be useful for the designers of manipulators for press manure removals.*

Keywords*: agriculture, machinery, manure, technology, simulation, computer graphics, Mathcad, synthesis, manipulator.*

Introduction

There are exists different manure removal systems, which are intend to remove manure from a cowshed and store it into a dung pit. One of them is the press manure removal that is intended to remove manure from a cowshed and store it by pressing through a manure pipe into a heap of muck. Fig. 1 shows a principal scheme of a manure press removal.

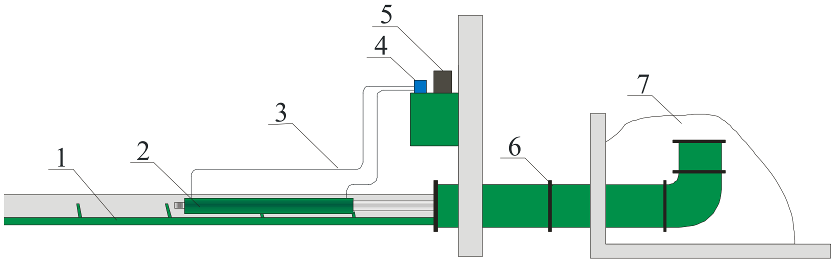


Figure 1. A principal scheme of the press manure removal. 1 – one-sided scraper; 2 – hydraulic cylinder; 3 – oil pipe; 4 – valve; 5 – electric engine; 6 – manure pipe; 7 – heap of muck

The principle of work of the press manure removal in Fig. 1 is the following. The manure scraper, driven by a hydraulic cylinder 2, transports the portions of manure to the manure pipe and presses these by the first manipulator of the manure scraper through the pipe 6 into a heap of muck 7. After the working stroke the valve 4 changes the direction of flow of oil in the oil pipes 3 and the scraper moves back to the initial position. By repeating this working cycle a large heap of muck will be structured. Press manure removal is economical and environmentally sound. A press manure removal can be in use in a small farm with 20 – 50 cows (Fig. 1).

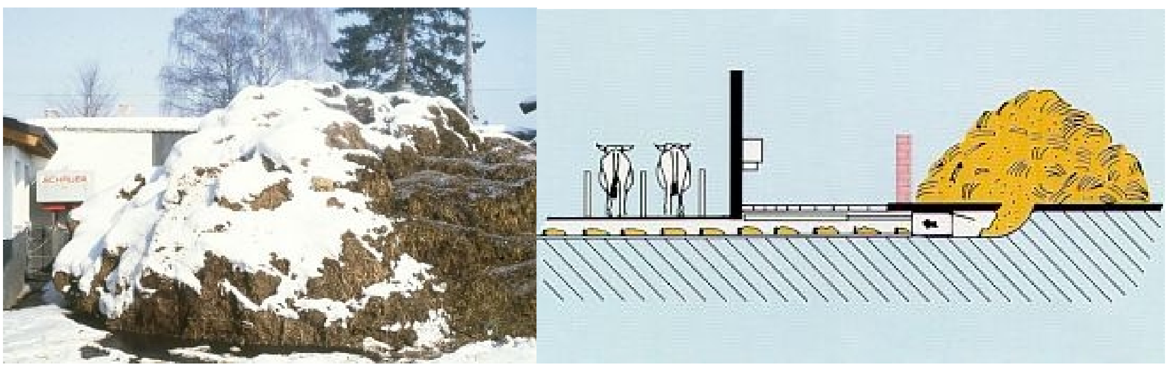


Figure 2. A press manure removal of a small farm by Schauer (2001)

The manure scraper in Fig 3 is used as the working tool of the manure press removal in Fig. 1. A principal scheme of a one-sided manure scraper in the working stroke (a) and in the return stroke (b) is shown in Fig. 3, where the working vanes of the scraper have vertical axes of rotation.

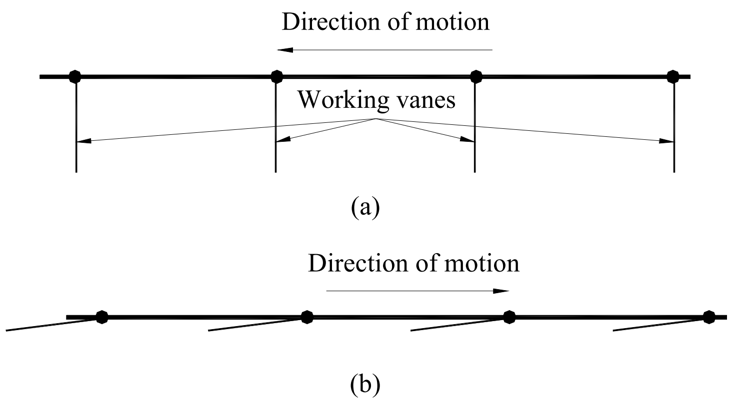


Figure 3. A principal scheme of a one-sided manure scraper in the working stroke (a) and in the return stroke (b)

The working vanes of the manure scraper in Fig. 3 are foursquare and can rotate freely around its vertical (or horizontal) axis under the resistance forces, applied to vane in the manure ply. Scrapers in Fig 3 are, for example, in the structure of press manure removals Paskervilleri 8000 (1997), and Schauer (2001). The disadvantage of the scraper in Fig. 3 is the lugging of manure by the manure scraper on its return stroke (Fig. 3b).

Merivirta Oy (1998) and Paskervilleri 4000 (1999) have used the forced driven system for rotation of the working vanes of the manure scraper. This system is complicated but guarantees the stable rotation of the working vanes from working position to the position of return stroke and opposite.

The scientific team, headed by V. Veinla, in Estonian University of Life Sciences have created novel manure scraper for press manure removal in which the first working vane (Fig. 4) was clamped to the forced driven manipulator.

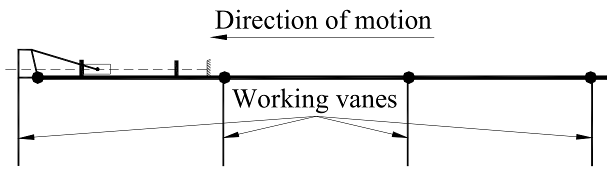


Figure 4. The scheme of a novel manure scraper according to the idea of V. Veinla

The structure of Scraper's manipulator in Fig. 4 is shown in Fig. 5.

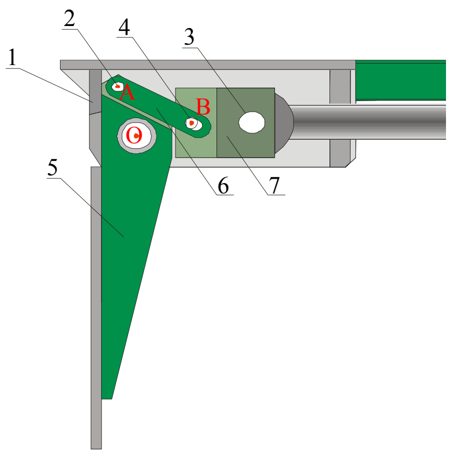


Figure 5. A scheme of a manipulator, created by V. Veinla 1 – case; 2, 3 – pivots; 4 – pivot with a large tolerance; 5 – rib with a vane, 6 – connecting plate; 7 – slider

Veinla, Leola (2001, 2003) have made experimentally thorough study the press manure removal in Fig.1 with manure scraper in Fig. 4. The purpose of their experimental study of the manure press removal was to measure the

- resistance force, applied to the working vane by manure in the manure pipe,
- pressure, applied to the walls of the manure pipe,
- pressure inside of the heap of muck,

and to study the dependence the height of the heap of muck on the resistance pressure of manure in the manure pipe. Fig. 6 shows the device for study the press manure removal experimentally.

Figure 6. The device of the press manure removal, created for experiments by the idea of V. Veinla

To specify the parameters of the manipulator in Fig. 5 Heinloo, Leola, Veinla (2005) have developed the mathematical and virtual modeling based method for synthesis the virtual manipulator (Fig 8), created on the worksheet of the Computer Package Mathcad according to the scheme in Fig. 7. Heinloo, Leola, Veinla (2005) found out such length for link AO and for the x-co-ordinate δ of the pivot B (Fig. 7) that guarantee the position in Fig. 7 of the manipulator before it turning clockwise and the position in Fig. 8 after this turning.

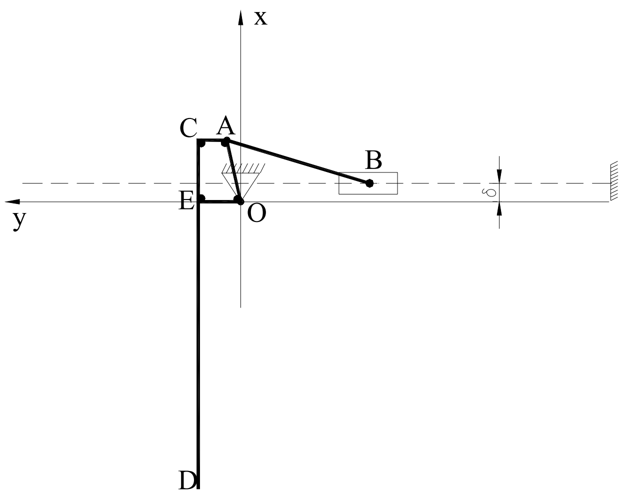


Figure 7. The computational scheme of the manipulator in Fig 4, O, A – pivots; B – pivot with a large tolerance; OACED – rigid link

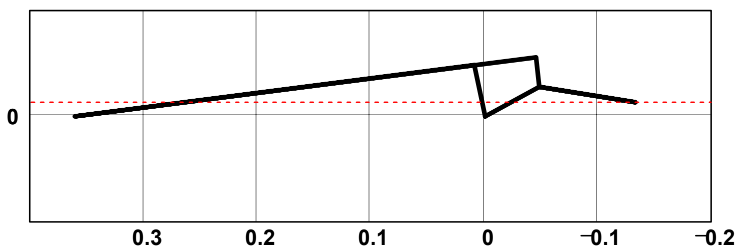


Figure 8. A virtual model of a manipulator in Fig. 5, composed on the Mathcad worksheet

This paper deals with the solving the following problem of multiparametric synthesis: Find out such lengths ρ_{AO}, ρ_{AB}, ρ_{OE} of the links AO, AB and the side OE of the link OACED and the x-co-ordinate δ of the pivot B (Fig. 7) that guarantee the optimal position in Fig. 7 before turning the link OACED clockwise and the position in Fig. 8 after this turning and satisfaction the condition of equality of the angular velocity of the link OACED at the positions in Fig. 7 and in Fig. 8.

Prescribed restrictions to the motion of the manipulator

Let us and suppose that the prescribed restrictions to the motion of the manipulator (Figs. 5, 7, 8) are:

- At the interval of the time $0 \le t \le t_0$, where $t_0 = L/v_r = 0.0263$ s ($L = 0.006$ m – tolerance caused free stroke of the slider B before moving the link OACED; $v_r = 0.2285$ m/s – velocity of the slider B in the moving to the negative direction of y-axis) the link OACED is immovable;
- At the interval of the time $t_0 \le t \le t_1$, where $t_1 = h/v_r = 0.3632$ s ($h = 0.0830$ m – full stroke of the slider B in the system Oxy) the link OACED turns around the pivot O clockwise from working position in Fig. 7 to the return position in Fig. 8;
- At the interval of the time $t_1 \le t \le t_2$, where the time $t_2 = 6$ s is given, the link OACED is traversing to the final position;
- At the interval of the time $t_2 \le t \le t_2 + t'_0$, where $t'_0 = L/v_l = 0.0431$ s ($v_l = 0.1393$ m/s – the velocity of the slider B in the moving to the positive direction of y-axis of the system Oxy), due to the tolerance at the pivot B the link OACED is immovable;
- At the interval of the time $t_2 + t'_0 \le t \le t_2 + t'_1$, where t'_1 is the local time, the link turns around the pivot O anticlockwise from position in Fig. 8 to the position in Fig. 7;
- At the interval of the time $t_2 + t'_1 \le t \le t_2 + t'_2$, where t'_2 is the local time the link is traversing and reaches the initial position at the moment $t = t_2 + t'_2$ of the time;
- slider B can move only along its track and the x-co-ordinate of the pivot B is fixed (Fig. 7)

$$x_B(t) = \delta \tag{1}$$

- the y-co-ordinate changes in the system Oxy according to the law

$$y_B(t) = y_{BO} - v_r(t - t_0), \; (t_1 \ge t \ge t_0 > 0), \tag{2}$$

when the slider B is moving in this system to the negative direction of y-axis and according to the law

$$y'_B(t') = y_B(t_1) + L + v_l(t' - t'_0), \; (t'_1 \ge t' \ge t'_0 > 0), \tag{3}$$

when the slider B is moving to the positive direction of y-axis. Here t – the current time; t' – the local current time, counted from reaching the link OACED the final position; $y_{B0} = 0.0550$ m – the fixed y–co-ordinate of the pivot B directly before moving the link OACED at the moment of the time t_0.

Basic equations

Co-ordinates of the points C, E, D and pivots A, B are determined in the local system of co-ordinates Oxy (Fig. 7) by the following system of equations:

$$x_A^2 + y_A^2 = \rho_{AO}^2, \; (x_A - \delta)^2 + [y_A - y_B(t)]^2 = \rho_{AB}^2,$$

$$(x_E - x_A)^2 + (y_E - y_A)^2 = \rho_{AE}^2, \; x_E^2 + y_E^2 = \rho_{OE}^2$$

$$x_C^2 + y_C^2 = \rho_{OC}^2, \; (x_C - x_E)^2 + (y_C - y_E)^2 = \rho_{EC}^2, \tag{4}$$

$$x_D = \frac{\rho_{DC}}{\rho_{EC}}\left[x_E + \left(\frac{\rho_{EC} - \rho_{DC}}{\rho_{DC}}\right)x_C\right], \; y_D = \frac{\rho_{DC}}{\rho_{EC}}\left[y_E + \left(\frac{\rho_{EC} - \rho_{DC}}{\rho_{DC}}\right)y_C\right].$$

A possible analytical solution of the system (1) had been derived by Leola, Veinla, Heinloo (2004).

By differentiation the system (4) by the time t one can found the following linear system of equations for determination the velocities v_{Ax}, v_{Ay}, v_{Cx}, v_{Cy}, v_{Ex}, v_{Ey}, v_{Dx}, v_{Dy}, of points C, E and D and pivots A and B.

$$x_A v_{Ax} + y_A v_{Ay} = 0\,,\; (x_A - \delta)v_{Ax} + [y_A - y_B(t)](v_{Ay} + v_r) = 0\,,$$

$$x_E v_{Ex} + y_E v_{Ey} = 0\,,\; (x_E - x_A)(v_{Ex} - v_{Ax}) + (y_E - y_A)(v_{Ey} - v_{Ay}) = 0\,,$$

$$x_C v_{Cx} + y_C v_{Cy} = 0\,,\; (x_C - x_E)(v_{Cx} - v_{Ex}) + (y_C - y_E)(v_{Cy} - v_{Ey}) = 0\,, \tag{5}$$

$$v_{Dx} = \frac{\rho_{DC}}{\rho_{EC}}\left[v_{Ex} + \left(\frac{\rho_{EC} - \rho_{DC}}{\rho_{DC}}\right)v_{Cx}\right],\; v_{Dy} = \frac{\rho_{DC}}{\rho_{EC}}\left[v_{Ey} + \left(\frac{\rho_{EC} - \rho_{DC}}{\rho_{DC}}\right)v_{Cy}\right].$$

Systems of equations (4) and (5) are valid in the case of motion of the slider B to the negative direction of y-axis of the local system Oxy (Fig. 6). To obtain the velocities of points C, E and D and pivots A and B in the case, when the slider B moves to the positive direction of y-axis of the local system Oxy one have to change in the systems (4) and (5) $y_B(t)$, determined by the formula (2), to $y'_B(t')$, determined by the formula (3), the local velocity v_r to the local velocity $-v_l$ and the time t to the local time t'.

By differentiation on time t the equations $x_A(t) = \rho_{AO}\sin(\varphi)$, $y_A(t) = \rho_{AO}\cos(\varphi)$, where φ - is the angle between the positive direction of y-axis of the system and the link AO, and by simple transformations one can derive the following formula for determination of the angular velocity ω_{AO} of the link OACED

$$\omega_{AO} = -\frac{v_{Ay}}{x_A}\,. \tag{6}$$

Solution of the problem of synthesis

Let us consider the time t, the dimensions ρ_{AO}, ρ_{AB}, ρ_{OE} and the x-co-ordinate δ of the pivot B as variables. Then the coordinates x_A, y_A, x_C, y_C, x_E, y_E, x_D, y_D, the velocities v_{Ax}, v_{Ay}, v_{Cx}, v_{Cy}, v_{Ex}, v_{Ey}, v_{Dx}, v_{Dy} and the angular velocity ω_{AO} have to be considered as functions of t, δ, ρ_{AO}, ρ_{AB}, ρ_{OE}.

The synthesis problem of this paper needs to solve the following system of equations

$$\begin{gathered} x_D(t_1, \delta, \rho_{AO}, \rho_{AB}, \rho_{OE}) = 0\text{ m},\\ y_D(0s, \delta, \rho_{AO}, \rho_{AB}, \rho_{OE}) - y_C(0s, \delta, \rho_{AO}, \rho_{AB}, \rho_{OE}) = 0\text{ m},\\ \omega_{AO}(t_1, \delta, \rho_{AO}, \rho_{AB}) - \omega_{AO}(0s, \delta, \rho_{AO}, \rho_{AB}) = 0\frac{1}{s}. \end{gathered} \tag{7}$$

The lengths

$$\rho_{EC} = 0.0560\text{ m},\ \rho_{DC} = 0.4110\text{ m},\ \rho_{AE} = 0.0622\text{ m},\ \rho_{OC} = 0.0718\text{ m} \tag{8}$$

were considered as given. To solve the system of nonlinear equations (7) relative to parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} one has to give the initial values of these parameters. For initial values

$$\delta = 0.0200\text{ m},\ \rho_{AO} = 0.0500\text{ m},\ \rho_{AB} = 0.0900\text{ m},\ \rho_{OE} = 0.0500\text{ m}, \tag{9}$$

The correspondent values, found out by applying the solve block of the Computer Package Mathcad, are

$$\delta' = 0.0198\text{ m},\ \rho'_{AO} = 0.0604\text{ m},\ \rho'_{AB} = 0.0830\text{ m},\ \rho'_{OE} = 0.0493\text{ m}. \tag{10}$$

Fig. 9 shows the dependency of angular velocity ω_{AO} on time t, when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (9) (dotted line) and found out values (10) (solid line)

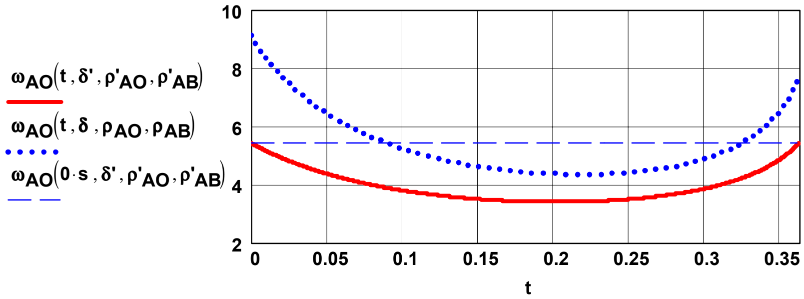


Figure 9. The dependency of angular velocity ω_{AO} on time t, when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (9) (dotted line) and found out values (10) (solid line)

Fig. 10 shows the positions of the link OACED at the moments of the times t_0 and t_1 (t'_0 and t'_1), when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (9).

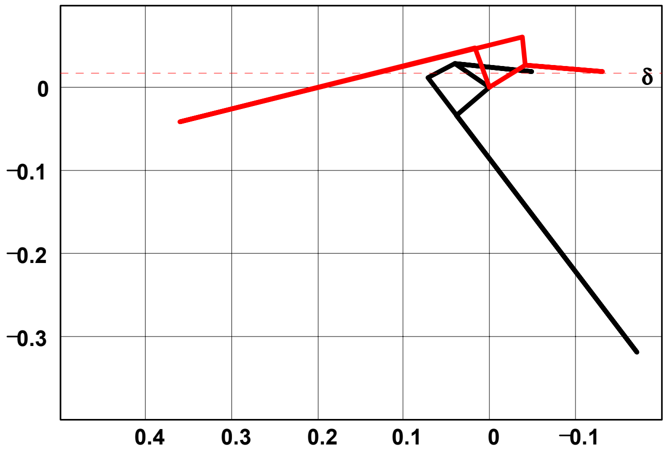
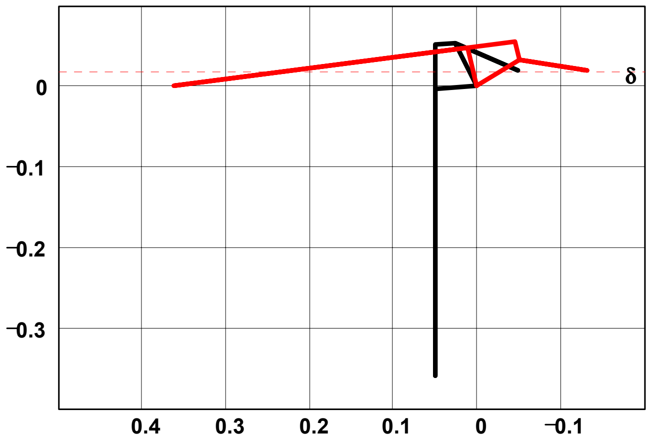


Figure 10. The positions of the link OACED at the moments of the times t_0 and t_1 (t'_0 and t'_1), when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (9)

Fig. 11 shows the positions of the link OACED at the moments of the times t_0 and t_1 (t'_0 and t'_1), when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the found out values (10).



(b)

Figure 11. The positions of the link OACED at the moments of the times t_0 and t_1 (t'_0 and t'_1), when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the found out values (10)

While the system (7) has 3 equations for determination of 4 parameters then its solution (10) is not unique. For initial values

$$\delta = 0.0100 \text{ m},\ \rho_{AO} = 0.0600 \text{ m},\ \rho_{AB} = 0.1000 \text{ m},\ \rho_{OE} = 0.0600 \text{ m} \tag{11}$$

the system (7) gives a correspondent solution

$$\delta' = 0.0101 \text{ m},\ \rho'_{AO} = 0.0583 \text{ m},\ \rho'_{AB} = 0.0834 \text{ m},\ \rho'_{OE} = 0.0479 \text{ m}. \tag{12}$$

Fig. 12 shows the dependency of angular velocity ω_{AO} on time t, when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (11) (dotted line) and found out values (10) (solid line)

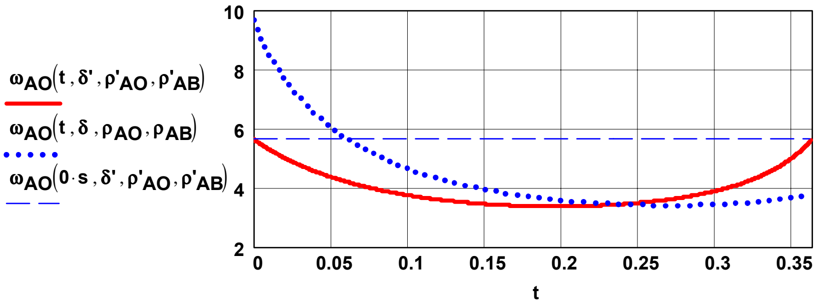


Figure 12. The dependency of angular velocity ω_{AO} on time t, when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (11) (dotted line) and found out values (12) (solid line)

Fig. 13 shows the positions of the link OACED at the moments of the times t_0 and t_1 (t'_0 and t'_1), when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (11).

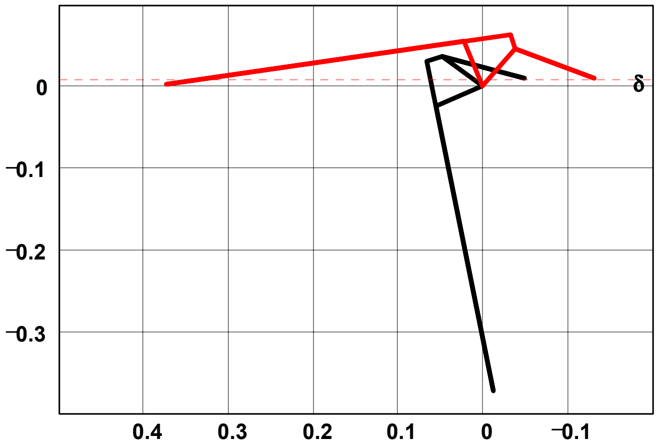


Figure 13. The positions of the link OACED at the moments of the times t_0 and t_1 (t'_0 and t'_1), when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (11)

Fig. 14 shows the positions of the link OACED at the moments of the times t_0 and t_1 (t'_0 and t'_1), when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the found out values (12).

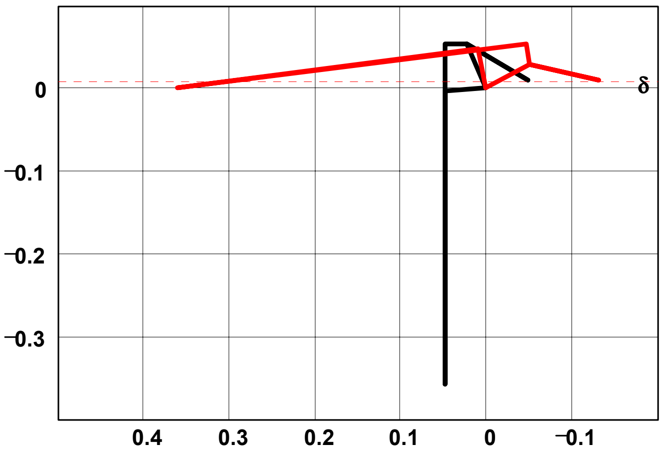


Figure 14. The positions of the link OACED at the moments of the times t_0 and t_1 (t'_0 and t'_1), when the parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} have the initial values (11)

It may happen that for some initial values of parameters δ, ρ_{AO}, ρ_{AB}, ρ_{OE} the system (7) have not any solution.

Motion of the link OACED at the interval $t_2 \geq t \geq t_2 + t'_2$ of the time t' can be studied analogically by Heinloo, Leola, Veinla (2005).

Conclusion

It is shown that the stated in this paper problem of multiparametric synthesis is solvable for the case of manipulator of the scraper of the press manure removal. It was convenient to compose special program for solution of the stated problem on the worksheet of the computer package Mathcad. This program allows easy to change given dimensions and conditions of synthesis of the manipulator and can be used in creation of press manure removals. The results of this paper confirm the world experience that the creation of virtual models of machine elements, their synthesis and simulation their motion might be more effective and precise than the creation of machine element only by experimentation. If possible, then it is reasonable to begin the creation real machine element after creation a virtual model, its synthesis and simulation its motion.

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References

Merivirta OY. Somero, 1998. POMO-Harrymatik Köysilannanpoistolaite.

Pellonpaja OY. Ylihärmä, 1997. PASKERVILLERI 8000. Gjutning-, montering-, anändnings- och serviceinstruktoner.

Pellonpaja OY. Ylihärmä, 1999. PASKERVILLERI 4000. Gjutning-, montering-, användnings- och serviceinstruktoner.

Schauer Maschinenfabrik Ges.m.b.H. & CoKG, 2001.

Veinla, V, Leola, T. 2001. The Research of Moving Resistance of the One-Side Scraper and Press Unit. Proc. Int. Conf. “Perspective Sustainable Technological Processes in Agricultural Engineering", Raudondvaris, 187-192.

Veinla, V, Leola T. 2003. The Research of Manure Pressing Equipment. Proc. Int. Conf. “Research for Rural Development”, Jelgava, 68 – 71.

Heinloo, M., Leola, T., Veinla, 2005 V. Synthesis of the Manipulator for the Scraper of a Press Manure Removal, CIGR Ejournal, vol. VII, 15 p.

Leola, T., Veinla, V., Heinloo, M. 2004. Selection of the Constructive Parameters For Working Tool of the Manure Pressurer, Proc. I-st Int. Conf. “Advanced Concepts in Mechanical Engineering”, Iasi, pp. 16 – 21.