SYNTHESIS OF RIGID MEMORY FOR A PICK-AND-PLACE MANIPULATOR OF PARTS AND PALLETS, USED IN THE AGRICULTURAL MACHINE BUILDING INDUSTRY

SINTEZA MEMORIEI RIGIDE PENTRU UN MANIPULATOR DE TRANSFER PIESE, SEMIFABRICATE SAU PALETE, UTILIZAT ÎN INDUSTRIA CONSTRUCTOARE DE MAŞINI AGRICOLE

VICTOR MOISE, BARBU GRECU, GHEORGHE VOICU, IULIAN TABĂRĂ

University POLITEHNICA of Bucharest, Romania

Abstract: *There are situations, in the case of transfer of parts, blanks or pallets from a working place to another one, in the horizontal plan, when is necessary a little displacement on the vertical direction at the beginning and the end of the stroke, to avoid the damage of the manipulator or even the parts. In the paper, the synthesis of the rigid memory of a pick-and-place manipulator of parts or pallets is done, so that to ensure the grippers displacement under the given lows*

Rezumat: *În cazul transferului pieselor, semifabricatelor sau paletelor de la un post de lucru la altul, în plan orizontal, sunt situații când este necesară o mică deplasare pe verticală la începutul şi la sfârşitul cursei, pentru a nu deteriora manipulatorul sau chiar piesele. În lucrare se face sinteza memoriei rigide a unui manipulator pentru transfer piese sau palete, astfel încât mecanismele de prehensiune să se deplaseze după anumite legi de mişcare impuse.*

Key words: *manipulator, pick-and-place of parts, transmission functions, rigid memory*
Cuvinte cheie*: manipulator, transfer piese, funcții de transmitere, memorie rigidă*

INTRODUCTION

In the industry are to be seen different situations in which the pick-and-place of parts, blanks and pallets between the working places, is done by require to certain conditions imposed by the technological process. In the figure 1 is presented such an example: the manipulator must pick the part from a working place I, to displace it on horizontal direction with the pitch p_v and to pick it to working place II. In the same time, the part from the working place II is displaced to the working place III. As it is to be observed in the figure, in the first phase the parts have to be displaced on vertical direction, it follows the displacement on horizontal direction between the working places, after that the parts are descended with the same distance. Such a pick-and-place mechanism is presented in the paper [7], but without accomplish of the cams synthesis that impress such a movement.

The paper propose, to fulfil the synthesis of the rigid memories of the cams of a manipulator so that to achieve the already mentioned conditions.

The kinematics scheme of the pick-and-place mechanism is presented in figure 2; from an electric motor, by using a driving belt transmission, it is received the movement from the shaft I, and from this, with the help of the gears 1, 2 and 3, it is transmitted to the shaft III.

By using the screw-gearing, the translation motion of assembly *A* is carried out. In the same time the rotation movement from the grooved shaft I is transmitted to the gears 7 and 8 via the gears 4 and 5, worm gear 5', 6 and gear 6'. From the gears 7 and 8 are rigidly linked two arms to which is articulated the element 12, of whose extremities there are the grippers 13 and 13'. The centres of joints *U* and *V* are described the elongated cycloids as a result of the rotation motion of the gears 7 and 8, as well as the translation movement of the assembly *A*, if the conditions are fulfilled:

$$KU = LV > r_7 = r_8 \ ; \ r_7 \frac{z_4 z_{5'} z_{6'}}{z_5 z_6 z_7} = \frac{p}{2\pi} \frac{z_1}{z_3}, \qquad (1)$$

where: r_7 is the division radius of gear 7 (toothing with no addendum modification) and *p* is the pitch of the pitch of motion screw III.

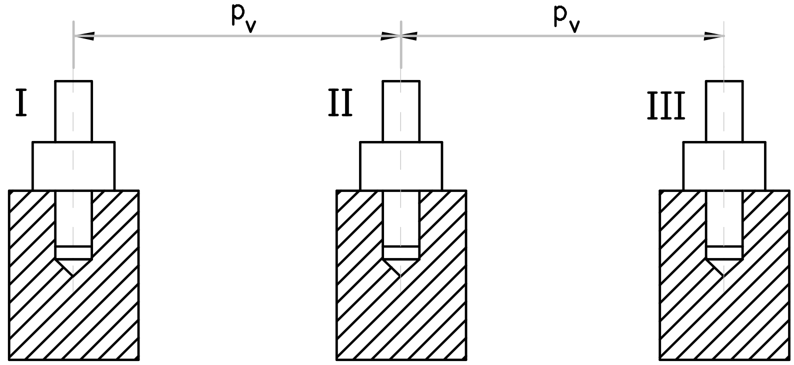

Figure 1. The positioning of working places

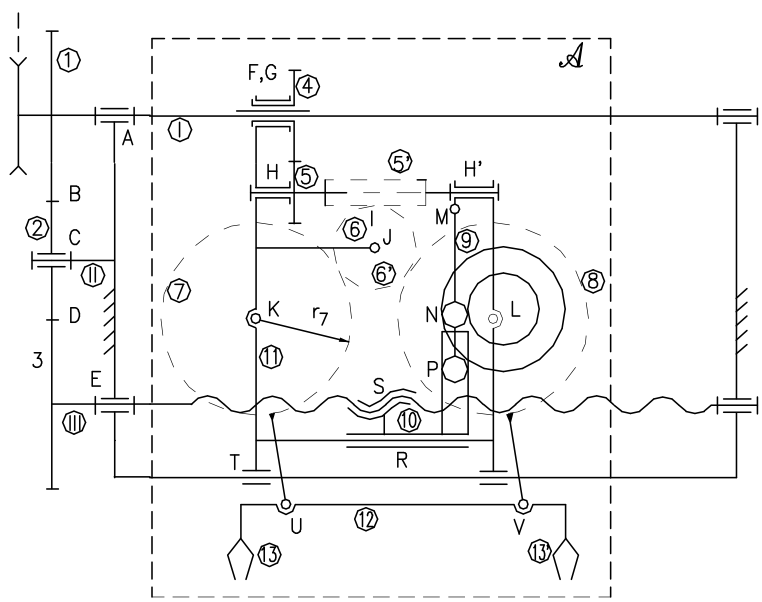

Figure 2. The positioning of working places

The points *U* and *V* describing elongated cycloids (fig. 3, curve A), the parts are not displaced on vertical at the beginning and the ending of the stroke, which can lead to the deterioration of the manipulator if the parts are seated in holes or in places which require a little displacement on vertical at the heads of the stroke. Therefore it must be introduced a supplementary mechanism which has to conduct to displacement of the parts on vertical at the extremities of the stroke.

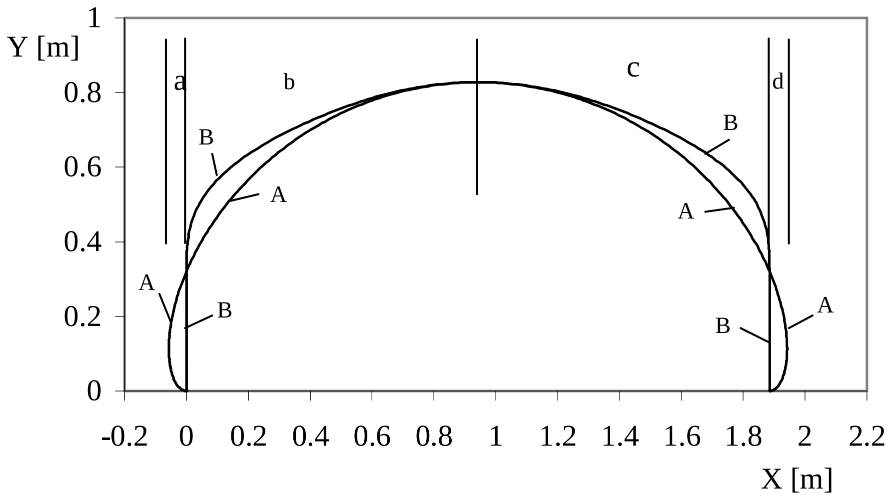

Figure 3. The diagrams of displacement of points *U* and *V*:
curve A, displacement without cam; curve B, displacement with cam

MATERIALS AND METHOD

By introducing of the cam mechanism from Figure 4.*a*, it is carried out the displacement of points U and V according to the curve B. (fig. 4). In the figure 4.*b* is presented the structural scheme and in the figure 4.*c* the block scheme of the mechanism. From the figure 4.*a*, it is observed, that by taking the element 10 as element of reference, the mechanism contains an active structural group with inferior and superior pairs having the motor pair in L.

Through the agency of the cam mechanism it is constrained that assembly A to displace regarding the basis with a greater speed then that of the slide 10 on the zones *a* and *c* (fig. 3) and with a smaller speed on the zones *b* and *d*.

If it is discomposed the displacement of point *V* on horizontal and on vertical it is determined the fact that the transmitting function, adequate to the displacement on vertical is that given by the equation of elongated cycloid, $Y = LV\,(1 - \cos(\theta))$, namely the two curves A and B have the same ordinate for a certain rotation angle of the gear 8. The displacement on horizontal, in the case of the elongated cycloid, is given by the relation $X = r_8\,\theta - LV \sin\theta$, where $\theta = |\theta_8|$, $\theta \in [0, 2\pi]$ (see figure 7).

The diagrams of the transmitting functions of order I and II of the point *V*, corresponding to axis *OX*, in the case of the elongated cycloid, are presented in figure 5; it is observed the facts that at the heads of the interval the transmitting function of order I takes negative values which can lead at the deterioration of the manipulator. In figure 5, there have been done the notation:

$$XD = \frac{dX}{d\theta}\ ,\ XDD = \frac{d^2 X}{d\theta^2}.$$

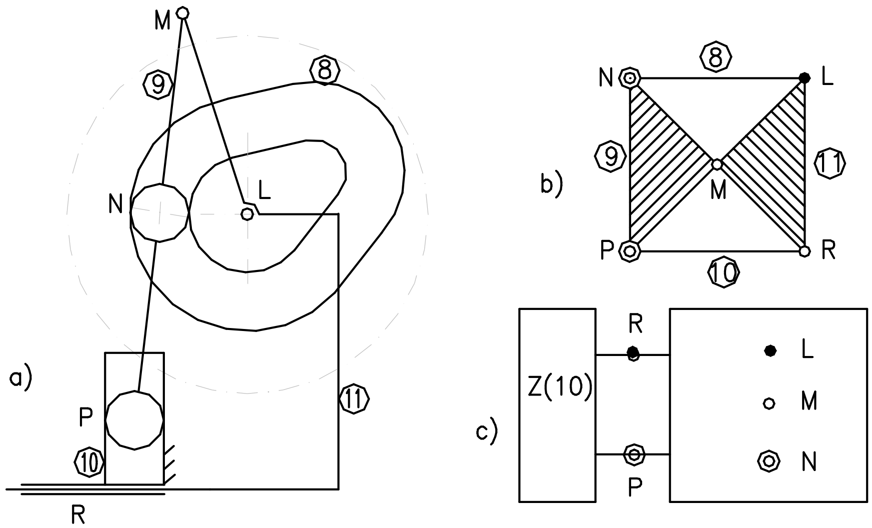

Figure 4. The kinematics scheme of the cam mechanism, from the composition of the manipulator

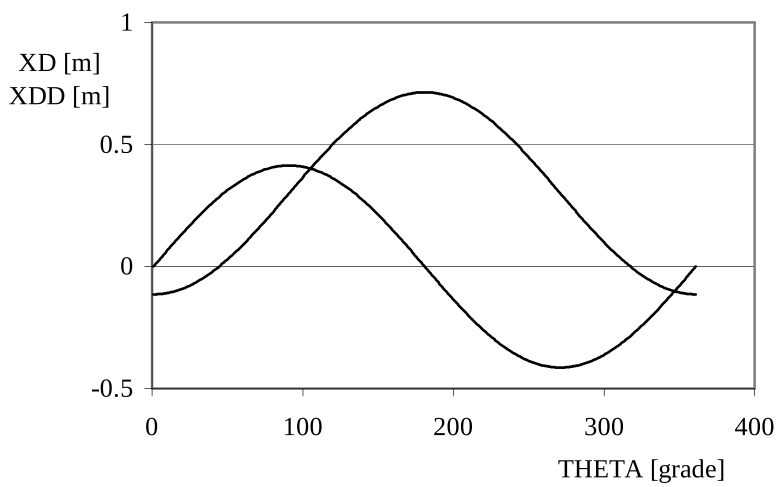

Figure 5. The transmitting function of order I and II, of the horizontal component of the elongated cycloid described by the point *U*, in the case of run without cam

In the case of curve B from figure 3, is proposed that the transmitting function corresponding to the displacement on horizontal to be chosen so that at the heads of the stroke don't be shocks, the displacement on horizontal to increase till a certain value from where to stand constant on the greatest part of the stroke, and then to get back to zero. This thing can be accomplished by connecting the different functions convenient selected. For example the coupling of two sinusoidal transmitting functions with a linear transmitting function (fig. 6), namely the uniform motion-deceleration ([4], pages 87-88). In figure 6 there have been made the notation:

$$XVD = \frac{\mathrm{d}(XV)}{\mathrm{d}\theta}\ ,\ XVDD = \frac{\mathrm{d}^2(XV)}{\mathrm{d}\theta^2}.$$

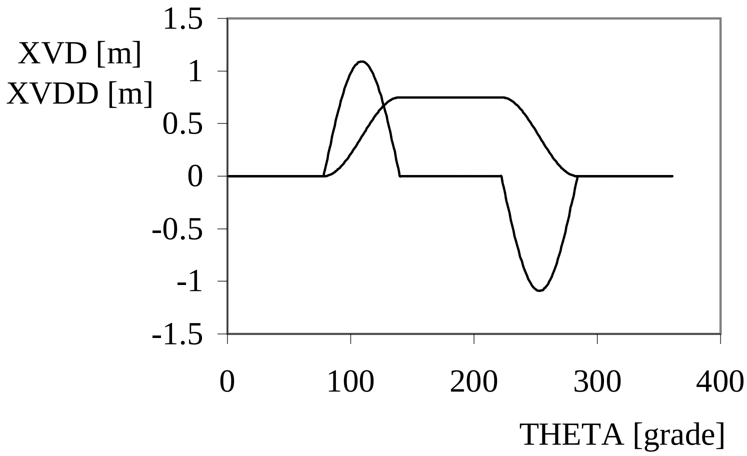

Figure 6. The transmitting function of order I and II,
for the displacement on horizontal of the points *U* and *V*

In the same scope there can be chosen the transmitting polynomial functions of superior order ([4], pp 89-93), which equal the work even more still then in the prior case.

For the determination of the cam profile there have to be known: the movement low of the cam, the movement low of the follower and the follower profile. With the end of convenient writing of the motion lows of the cam and follower there will be consider the following coordinates systems (fig. 7):

- XOY – fixed system of coordinates;
- $X_{10}P_{10}Y_{10}$ – system of coordinates attached to the element 10 (the slide);
- $X_{11}LY_{11}$ - system of coordinates attached to the element 11, with the origin in the revolute pair L;
- x_8Ly_8 - system of coordinates attached to the element 8 (the cam), with the origin in the revolute pair L;
- x_9My_9 - - system of coordinates attached to the element 9 (the follower), with the origin in M.

The motion low of the cam is given by the coordinates *XL*, *YL*, of point *L*, and the angle θ_8 between the coordinates systems $X_{11}LY_{11}$, x_8Ly_8, as is shown in next relations:

$XL = XL0 + S + XV - X$; $YL = const1$; $\theta_8 = \theta_8(t)$, where S is the displacement given by the motion screw from the shaft III.

The movement low of the follower is given by the coordinates *XM*, *YM*, of the point ale *M*, and angle φ_9 between the coordinates systems $X_{11}LY_{11}$, x_9My_9 , as follows:

$XM = XL + LM\cos\beta$; $YM = YL + LM\sin\beta$;
$\varphi_9 = \varphi_9(t)$.

For the determination of the oscillation angle of the follower the relative motion between the elements 10 and 11 is considered. Thus, from the vectorial equation $\overline{OL} + \overline{LM} + \overline{MP} = \overline{OP}$, projected on coordinates axes XOY results two scalar equations:

$$\begin{aligned} XL + LM \cos\beta + MP \cos\varphi_9 &= XP10 + S10 \cos\varphi_{10}; \\ YL + LM \sin\beta + MP \sin\varphi_9 &= YP10 + S10 \sin\varphi_{10}, \end{aligned} \tag{2}$$

which form a non-linear system with the unknowns φ_9 and *S10* . This system is solved analytically (by discrimination of the solution) or by a numerically adequate method [1, 5], starting from an initial solution [1, 5].

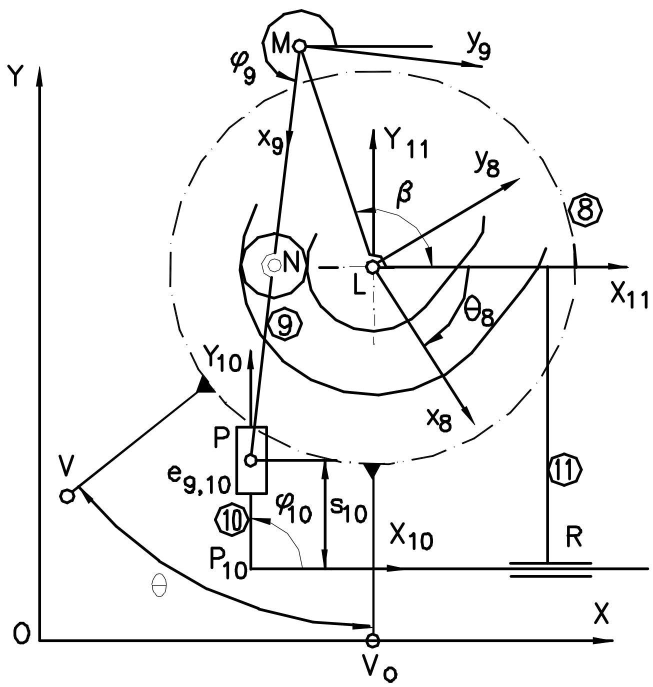

Figure 7. The emphasizing of the coordinates

The parametric equations of the two profiles of the cam, profiles that comes in contact with follower roll, have the expressions:

$$\begin{aligned} x_8 &= (XM - XL)\cos(\varphi_8) + (YM - YL)\sin(\varphi_8) + MN\cos(\varphi_9 - \varphi_8) \pm \\ &\pm \frac{r}{\sqrt{A^2 + B^2}}(A\cos(\varphi_9 - \varphi_8) - B\sin(\varphi_9 - \varphi_8)); \\ y_8 &= (XM - XL)\sin(\varphi_8) + (YM - YL)\cos(\varphi_8) + MN\sin(\varphi_9 - \varphi_8) \pm \\ &\pm \frac{r}{\sqrt{A^2 + B^2}}(A\sin(\varphi_9 - \varphi_8) + B\cos(\varphi_9 - \varphi_8)), \end{aligned} \tag{3}$$

where:

$$A = (XM - XL)\cos(\varphi_9)\varphi_8 + (YM - YL)\sin(\varphi_9)\varphi_8;$$
$$B = (XM - XL)\sin(\varphi_9)\varphi_8 + (YM - YL)\cos(\varphi_9)\varphi_8; \quad (4)$$

r - the radius of the follower roll.

RESULTS AND DISCUSSION

For $r_8 = 0.3$ m, $LV = 0.4138$ m it was obtained $\theta_{AB} = 77$ grade ($\theta_{AB} = 1{,}343904$ radiani) , angle for each the two curves A and B (fig. 3) are intersected, so for $\theta \in [0,\ \theta_{AB}]$, point V has speed zero, for $\theta \in [\theta_{AB}\ ,\ 2\pi - \theta_{AB}]$ displacement on axis OX is done after a transmitting function composed of three sectors namely: sinusoid – line - sinusoid (acceleration-uniform motion-deceleration), ([4], pp 87-88), and for $\theta \in [2\pi - \theta_{AB}\ ,\ 2\pi]$ point V has the speed is equal to zero. By considering the length of the follower $MN = 0.3$ m , the roll radius of the follower r = 0.026m, the distance between the joint of cam and joint and the joint of follower $LM = 0.36055$ m, the angle $X_{11}LM=\beta$ =2.15879 radians, as well as the angular speed of the cam $\varphi_8 = -1{,}6666\,s^{-1}$, there have resulted the two profiles of the cam (fig. 8), cam which is manufactured on gear 8, for control the manipulator so that the displacement to be done in the required conditions.

CONCLUSIONS

For the displacement of the parts and pallets between the working places there can be used diverse manipulators with rigid memory. Their synthesis can be accomplished by imposing different transmitting functions, so that the characteristic points U and V to be displaced on the trajectories imposed and in the required conditions.

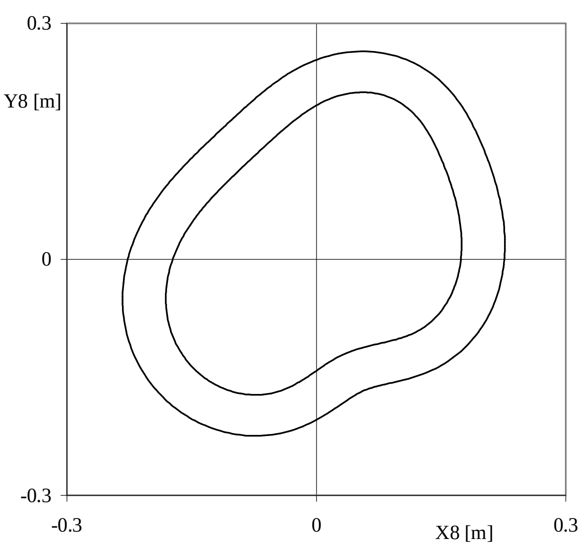

Figure 8. The emphasizing of the two profiles of the cam

REFERENCES

1. MOISE, V., MAICAN, E., MOISE, ŞT.I., Metode numerice. Editura Printech, Bucureşti, 2007.
2. MOISE, V., SIMIONESCU, I., ENE, M., NEACŞA, M., TABĂRĂ, I.A., Analiza mecanismelor aplicate. Editura Printech, Bucureşti, 2007.
3. PELECUDI, CHR., SAVA, I. - *Asupra analizei şi sintezei unitare a mecanismelor cu cuple superioare*, în Studii şi cercetări de Mecanică Aplicată, 3 tomul 22, 1966.
4. SIMIONESCU,I., MOISE, V., CIUPITU,L., STOENESCU, M. - *Indrumar de proiectare*. Universitatea POLITEHNICA Bucureşti, 1996.
5. SIMIONESCU,I., DRANGA,M., MOISE,V. - *Metode numerice*. Editura tehnică, Bucureşti,1995
6. SIMIONESCU,I., MOISE, V. - *Mecanisme*. Editura Tehnică, Bucureşti, 1999.
7. WORKPIECE TRANSFER MECHANISM - Brevet de invenție 4,496,280 , U.S., 1985.