

SYNTHESIS OF A MECHANICAL SYSTEM FOR MICROCOMPUTER MAGNETIC TAPE STORAGE DEVICES

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1. Introduction

The microcomputer Magnetic Tape Storage Devices (MTSD) are designed for operation with two-roller 1/4" cartridges and are used for backing up magnetic disk storage devices [1]. They feature high longitudinal and transverse density of recording. The maximum capacity of a cartridge is from 45 to 520 M bytes. The reliability of the devices is increased by restricting human operator's access to the magnetic tape and using mechanisms that perform the functions of cartridge loading, magnetic head positioning, magnetic tape driving and ready condition indication. This highly increases the requirements to the mechanical system (MS).

This paper gives the scientific basis of the synthesis of MS of microcomputer MTSD in order to optimize the functions, interaction, dimensions and allocation of the individual mechanisms.

2. Mechanical system functions and structure

Two stable states of MS exist, corresponding to the ready condition for loading of the selected cartridge and read/write operating mode. These states correspond to the final positions of the movable links of the mechanisms that are connected in parallel and are driven by a common input. The driving power is provided by the operator when entering the cartridge and by a return spring when the cartridge is released. The motion cycle from the starting position to the final position is conveniently divided into separate tacts during which the condition of all links remains unchanged (motion is either present

or absent). Performance time of the same tact may be different depending on the operator's effort and mechanism parameters. Fig. 1 shows tact diagrams related to the common input link, driving roller abduction mechanism, magnetic head abduction mechanism and cartridge vertical restriction mechanism. Points 1 and 4 correspond to the two stable states of the input link and the mechanisms reach operating positions in point 3. The numbers of individual tacts correspond to the following successive states: MS non-operating state, cartridge loading by the operator, MS off-line operation, MS operating state, cartridge unloading by the operator and MS idle run.

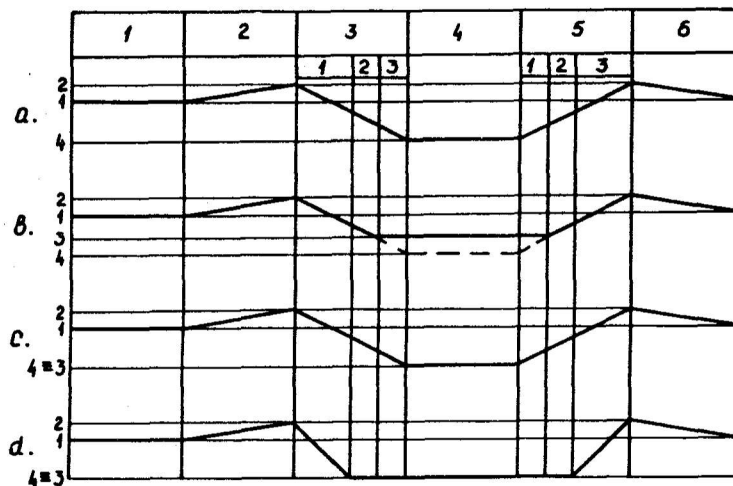


Fig. 1

In-building 10 mechanisms into the small space of a microcomputer MTSD and the special standard cartridge unit has imposed the common use of friction and cam mechanisms. When possible, linkages should be synthesized in order to decrease the effort required by the operator. A matrix method for the synthesis of linkages with tact diagrams has been proposed, as shown in Fig. 1. The common input is a slide. Its two stable states are determined by a mechanical T flip-flop and the magnetic head abduction mechanism.

3. Synthesis of a driving roller abduction offset crank-slider mechanism

The mechanism (Fig. 2) provides for a free transition of the cartridge in the beginning of its loading and a contact with the driving roller in the operating mode. In the tact diagram (Fig. 1b) the output link moves in tacts 3-1 and 3-2 and terminates

its motion before the input slide, in order to ensure the normal force on the driving roller. The linear motions σ_{12} and σ_{13} of the slide, its initial position $B_1(x_{B1} = e, y_{B1})$ and the angular motions Ψ_{12} and Ψ_{13} of the connecting rod OA are given.

A system of two equations of geometric constraint is created:

$$(1) \quad (\vec{a}_j - \vec{b}_1)^T (\vec{a}_j - \vec{b}_1) = (\vec{a}_1 - \vec{b}_1)^T (\vec{a}_1 - \vec{b}_1); \quad j = 2, 3,$$

which reflects the preservation of the length AB of the coupler. The vectors $\vec{a}_j$ define the relative positions of the points A_j ($j = 2, 3$) in the slide plane. The vectors $\vec{a}_j = [U_{1j}^T] \vec{a}_1$ ($j = 2, 3$) are expressed by the vector $\vec{a}_1$ of the initial position A_1 of point A and the respective matrices for relative displacement

$$(2) \quad [U_{1j}^T] = \begin{bmatrix} \cos \Psi_{1j} & -\sin \Psi_{1j} & 0 \\ \sin \Psi_{1j} & \cos \Psi_{1j} & -\sigma_{1j} \\ 0 & 0 & 1 \end{bmatrix}, \quad j = 2, 3$$

and are substituted in (1). A system of two linear equations is resulting:

$$(3) \quad \begin{cases} ax_{A1} + by_{A1} = c \\ dx_{A1} + ey_{A1} = f \end{cases}$$

with coefficients

$$(4) \quad \begin{aligned} a &= 2[x_{B1}(1 - \cos \Psi_{12}) - (\sigma_{12} + y_{B1})\sin \Psi_{12}] \\ b &= 2[x_{B1}\sin \Psi_{12} + y_{B1} - (\sigma_{12} + y_{B1})\cos \Psi_{12}] \\ c &= -\sigma_{12}(\sigma_{12} + 2y_{B1}) \\ d &= 2[x_{B1}(1 - \cos \Psi_{13}) - (\sigma_{13} + y_{B1})\sin \Psi_{13}] \\ e &= 2[x_{B1}\sin \Psi_{13} + y_{B1} - (\sigma_{13} + y_{B1})\cos \Psi_{13}] \\ f &= -\sigma_{13}(\sigma_{13} + 2y_{B1}) \end{aligned}$$

and solution

$$(5) \quad x_{A1} = \frac{ce - bf}{ae - bd}; \quad y_{A1} = \frac{af - cd}{ae - bd}.$$

Example. Given $\sigma_{12} = -1.5$; $\sigma_{13} = 8.5$; $\Psi_{12} = 0.256^\circ$; $\Psi_{13} = 8.72^\circ$, $e = x_{B1} = 13.6$ and $y_{B1} = -15.2$, from (4) follows that $a = 0.149231$, $b = 3.121530$, $c = -47.85$, $d = 2.345925$, $e = -13.031207$ and $f = 186.15$, which, substituted in (5) determine $x_{A1} = -4.582652$ and $y_{A1} = -15.109936$. The connecting rod length is $OA =$

$\sqrt{x_{A1}^2 + y_{A1}^2} = 15.789581$ and the coupler length is $AB = \sqrt{(x_{A1} - x_{B1})^2 + (y_{A1} - y_{B1})^2} = 18.182875$.

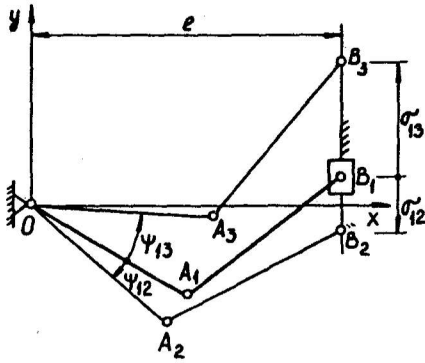


Fig. 2

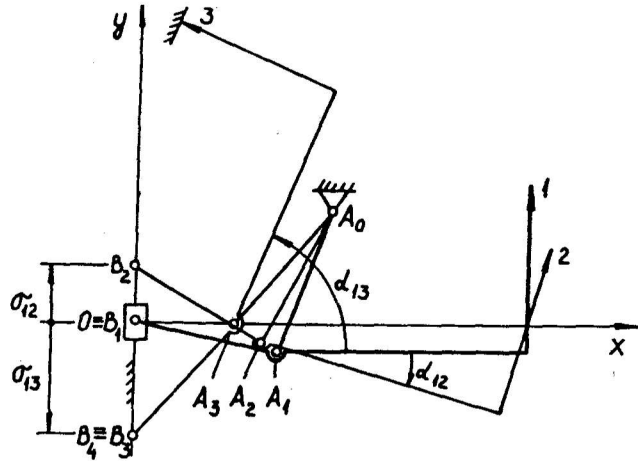


Fig. 3

4. Synthesis of a magnetic head abduction offset crank-slider mechanism

The mechanism (Fig. 3) provides for a free opening of the cartridge protective lid in the beginning of loading and the magnetic head positioning in operating position. The linear motions of the slide σ_{12} and σ_{13} (positions B_1 , B_2 and B_3 of a point of the coupler) and the angles of rotation σ_{12} and σ_{13} determined by the absolute positions of the coupler are given.

A system of two equations of geometric constraint is created

$$(6) \quad (\vec{a}_j - \vec{a}_0)^T (\vec{a}_j - \vec{a}_0) = (\vec{a}_1 - \vec{a}_0)^T (\vec{a}_1 - \vec{a}_0); \quad j = 2, 3,$$

obtained by the condition of constant length of the lever A_0A . The vectors $\vec{a}_j$ determine the positions of the points A_j ($j = 2, 3$); $\vec{a}_0$ determines the position of point A_0 and $\vec{a}_1$ determines the position of point A_1 . The vectors $\vec{a}_j = [U_{1j}] \vec{a}_1$ ($j = 2, 3$) are expressed by the respective coupler displacement matrices

$$(7) \quad [U_{1j}] = \begin{bmatrix} \cos \alpha_{1j} & -\sin \alpha_{1j} & x_{Bj} - x_{B1} \cos \alpha_{1j} + y_{B1} \sin \alpha_{1j} \\ \sin \alpha_{1j} & \cos \alpha_{1j} & y_{Bj} - x_{B1} \sin \alpha_{1j} - y_{B1} \cos \alpha_{1j} \\ 0 & 0 & 1 \end{bmatrix}, \quad (j = 2, 3)$$

Substituting in (6) and choosing the coordinates of point A_1 results in a system of equations similar to (3) with unknowns x_{A0} and y_{A0} in place of x_{A1} and y_{A1} . The coefficients are determined by the expressions:

$$\begin{aligned}
 a &= (x_{B1} - x_{A1})\cos \alpha_{12} - (y_{B1} - y_{A1})\sin \alpha_{12} + x_{A1} - x_{B2} \\
 b &= (y_{B1} - y_{A1})\cos \alpha_{12} + (x_{B1} - x_{A1})\sin \alpha_{12} + y_{A1} - y_{B2} \\
 c &= [(x_{B1} - x_{A1})y_{B2} - (y_{B1} - y_{A1})x_{B2}]\sin \alpha_{12} + [(x_{B1} - x_{A1})x_{B2} - \\
 &\quad (y_{B1} - y_{A1})y_{B2}]\cos \alpha_{12} - 0.5(x_{B1}^2 + y_{B1}^2 + x_{B2}^2 + y_{B2}^2) + x_{B1}x_{A1} + y_{B1}y_{A1} \\
 d &= (x_{B1} - x_{A1})\cos \alpha_{13} - (y_{B1} - y_{A1})\sin \alpha_{13} + x_{A1} - x_{B3} \\
 e &= (y_{B1} - y_{A1})\cos \alpha_{13} + (x_{B1} - x_{A1})\sin \alpha_{13} + y_{A1} - y_{B3} \\
 f &= [(x_{B1} - x_{A1})y_{B3} - (y_{B1} - y_{A1})x_{B3}]\sin \alpha_{13} + [(x_{B1} - x_{A1})x_{B3} - \\
 &\quad (y_{B1} - y_{A1})y_{B3}]\cos \alpha_{13} - 0.5(x_{B1}^2 + y_{B1}^2 + x_{B3}^2 + y_{B3}^2) + x_{B1}x_{A1} + y_{B1}y_{A1}
 \end{aligned}
 \tag{8}$$

and the solution of the system is similar to (5).

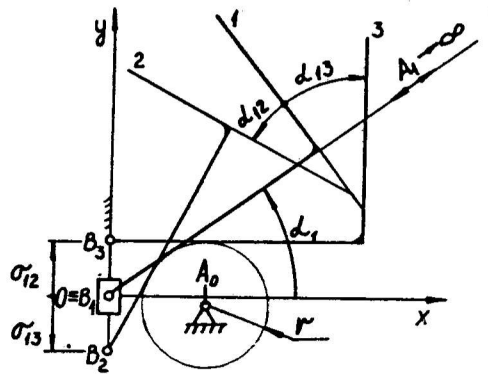


Fig. 4

Example. Given $\sigma_{12} = 1.5$; $\sigma_{13} = -8$; $\sigma_{12} = -4^\circ$ and $\alpha_{13} = 25.8^\circ$. A coordinate system Oxy is introduced with origin $O \equiv B_1$ and axis $y \equiv B_1B_3$. The coordinates of $B_1(0, 0)$, $B_2(0, 1.5)$ and $B_3(0, -8)$ are obtained. Point $A_1(17, -4)$ is chosen and from (8) follows that $a = 0.355314$, $b = -0.32511$, $c = 7.387335$, $d = -0.263963$, $e = 0.152509$ and $f = -5.220068$, which, substituted in (5) determine $x_{A0} = 18.036361$ and $y_{A0} = -3.010581$. The rotating lever length is $A_0A = \sqrt{(x_{A0} - x_{A1})^2 + (y_{A0} - y_{A1})^2} = 1.447521$, and the coupler length is $AB = \sqrt{(x_{A1}^2 + y_{A1}^2)} = 17.464249$.

5. Synthesis of a double slider PRPR cartridge vertical restriction mechanism

The mechanism (Fig. 4) provides for the free transition of the cartridge to the beginning of its loading and establishes a third supporting point for its fixing to the slide. In the tact diagram (Fig. 1d) the output link is moved at tact 3-1 and terminates its motion before the input slide in order to provide a travel for pressing the cartridge. In that case the point $A \rightarrow \infty$. In order to use the mathematical model of synthesis of crank-slider mechanism from Fig. 3, the coefficients of (8) are divided to y_{A1} and $\text{tg } \alpha_1 = -x_{A1}/y_{A1}$, $y_{A1} = \infty$ is substituted. The following is obtained:

$$\begin{aligned}
 a &= \text{tg } \alpha_1 (1 - \cos \alpha_{12}) - \sin \alpha_{12} \\
 b &= \cos \alpha_{12} - \text{tg } \alpha_1 \sin \alpha_{12} - 1 \\
 c &= (y_{B2} - x_{B2} \text{tg } \alpha_1) \cos \alpha_{12} - (x_{B2} + y_{B2} \text{tg } \alpha_1) \sin \alpha_{12} + x_{B1} \text{tg } \alpha_1 - y_{B1} \\
 d &= \text{tg } \alpha_1 (1 - \cos \alpha_{13}) - \sin \alpha_{13} \\
 e &= \cos \alpha_{13} - \text{tg } \alpha_1 \sin \alpha_{13} - 1 \\
 f &= (y_{B3} - x_{B3} \text{tg } \alpha_1) \cos \alpha_{13} - (x_{B3} + y_{B3} \text{tg } \alpha_1) \sin \alpha_{13} + x_{B1} \text{tg } \alpha_1 - y_{B1}
 \end{aligned}
 \tag{9}$$

and a solution similar to (5) with unknowns x_{A0} and y_{A0} , in place of x_{A1} and y_{A1} .

Example. Given $\sigma_{12} = -1.5$; $\sigma_{13} = 1.5$; $\sigma_{12} = 13.4^\circ$, $\alpha_{13} = -18.6^\circ$. A coordinate system Oxy is introduced with origin $O \equiv B_1$ and axis $y \equiv B_1 B_3$. The coordinates of $B_1(0, 0)$, $B_2(0, -1.5)$ and $B_3(0, 1.5)$ are obtained. The direction of the vanishing point A_1 is chosen by $\text{tg } \alpha = 0.336537$ and from (9) follows that $a = -0.222586$, $b = -0.105216$, $c = -1.342176$, $d = 0.336537$, $e = -0.159574$, $f = 0.916846$, which, substituted in (5) determine $x_{A0} = 4.379687$ and $y_{A0} = 3.491073$. The roller radius is $r = y_{A0} - y_{B3} = 1.991073$.

6. Conclusion

Tact diagrams have been composed for the three main, operating in parallel, mechanisms in microcomputer MTSD and methods of synthesis have been proposed. The known mathematical model [3] has been used for crank-slider mechanism synthesis. The model of crank-slider mechanism synthesis by three given absolute positions of the coupler has been deduced, selecting the coordinates of the movable hinge with the crank in first position. The model has been converted for double slider mechanism synthesis.

The proposed method of synthesis reduces the calculation procedures of determination of the main dimensions and allocation of mechanisms. Numerical solutions have been obtained for the three mechanisms. The comparison of the results obtained with those set in similar linkages allow to assert that here, optimal engineering solutions of MS of MTSD are reached, relatively fast and efficiently.

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