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Design of fitness multi station FMS-TD 01 Part II Geometric research of module "Leg Press"

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Abstract
In this papers proposed e classic algorithm for geometric study of a for articulated quadrilateral linkage mechanism with the pulley system. Studied is the functional relationship between height of lifting weights and moving incoming link. The proposed data conducted simulation study reporting the gear ratio and function of the position of the mechanism. The theoretical experiment is realized in an environment of software Matlab, design on a Top Solid' Design, model of "Leg Press".

Keywords: Multi Gym Equipment, Fitness Multi Station, Leg Press, Geometrically research, Articulated Quadrilateral, Matlab

1. Introduction
The geometrical analysis of the mechanisms is directed towards the study of the movements, as a function of the structure and geometry of the individual component units. Solve tasks related to determining the trajectories of the characteristic points of the units, their location and spatial orientation. Geometrical researches are realized independently in time and are not correlated with him. Functional dependence, according the change in position of the actuator relative introduced in primary generalized coordinates, presents a function of relocation. Consistent and differentiated initial parameter formed its first and second derivative - the first and second gear functions [1, 2, 5].
The aim of this papers is to determine the relationship between the height of lifting weights and moving incoming unit, i.e. the function of the situation - $S_{out.}(S_{in.})$ [3], about on "Leg Press" of Fitness Multi Station FMS-TD 01.

2. Geometrically research
2.1 Kinematic diagram
The geometrical analysis was performed on the element shown in Figure 1. It consists of the following major elements:

Results and Discussion
The dairy owners of the Puducherry region have their own feed formulation for their dairy cows. Majority of them feed their animals with dry fodder and concentrate due to non-availability of green fodder in this area.

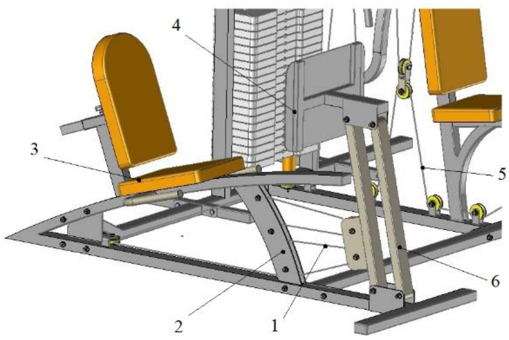

Fig 1: Modul ″Leg Press″
1. Ropes, 2. Frame, 3. Seat, 4. Pusher, 5. Pulley system, 6. Articulated quadrilateral

Fig 2 shows a kinematic diagram of the module. It consists of a articulated quadrilateral linkage mechanism with the pulley system.
The leverage mechanism is articulated quadrilateral OABC with dimensions OA=CB and OC=AB, hence the closed contour OABC is shaped like a parallelogram. Typical for him is that units 2 and 4 perform the same rotary movements, but unit 3 - makes plain translation, i.e. all points of him moving in the same way, have the same trajectories equal speeds and accelerations.
Pulley system is constituted by rolls 5, 6, 7 and 8 with equal radii r_p and rope 9. Rollers 8 and 6 have moveable axes of rotation, fixed to the member 2 of the articulated quadrilateral. Rollers 5 and 7 are with fixed axis of rotation.

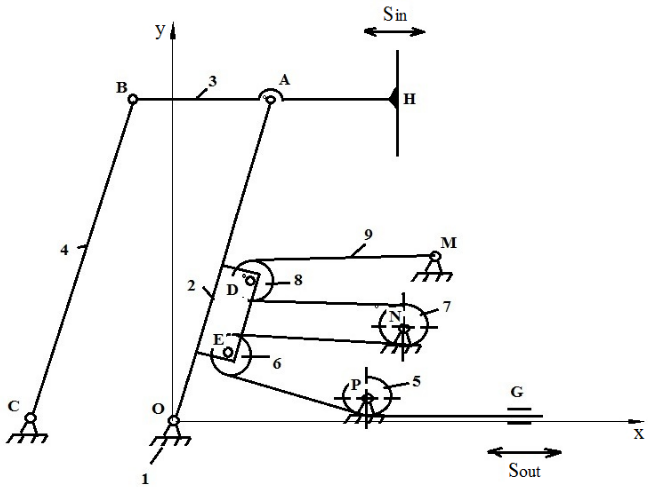

Fig 2: Kinematic diagram of modul "Leg Press"

2.2 Geometrical model of articulated quadrilateral
Geometric research of the module is done by the method of closed vector contours [3,4,6]. The Fig. 3 shows the vector outline of articulated quadrilateral.

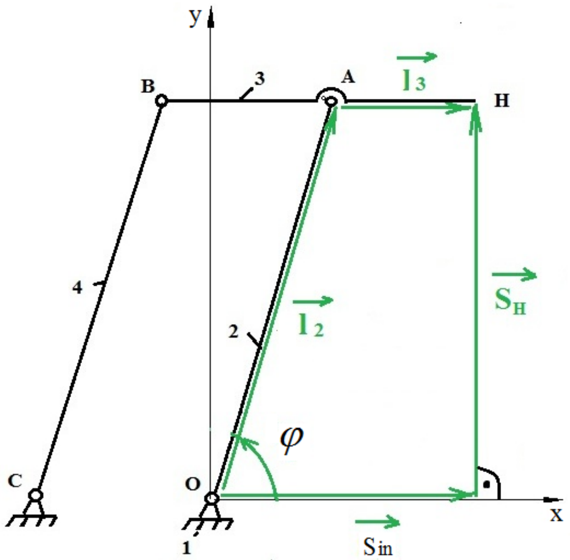

Fig 3: Closed vector contours of articulated quadrilateral from modul "Leg Press"

With $\vec{l}_i$ are mean vectors of constant size and with variable vectors $\vec{S}_{...}$. The equation of the contour has the form:

$$\vec{l}_2 + \vec{l}_3 = \vec{S}_{in.} + \vec{S}_H \quad (1)$$

where: l2 and l3 are lengths of units OA and AH;
SH – vertical movement of p.H on the Ox axis from a coordinate system Oxy;
Sin – horizontal displacement of p.H about Oy.
Equation (1) defines fully and uniquely position of the parallelogram. To solve design is done on the axes of the coordinate system Oxy. Considering that $\vec{l}_3$ | |Ox; $\vec{S}_{in}$ z Ox and $\vec{S}_{in} \perp$ Oy, is obtained:

$$l_2 \cos\varphi + l_3 = S_{in}$$
$$l_2 \sin\varphi = S_H \quad (2)$$

here φ is the angle between the vector $\vec{l}_2$ and the axis Ox.
The mechanism is driven by moving of p.H, hence the unknown values in (2) are φ and S_H, S_{in} is set as a function of the type:

$$S_{in} = S_0 - f(t)[m] \quad (3)$$

For the angle of rotation of the unit 2 is obtained:

$$\arccos\varphi = \frac{S_{in.} - l_3}{l_2} \quad [rad] \quad (4)$$

2.3 Geometrical model of Pulley System
Fig. 4 shows the vector contours that define the position of the units of the pulley system.

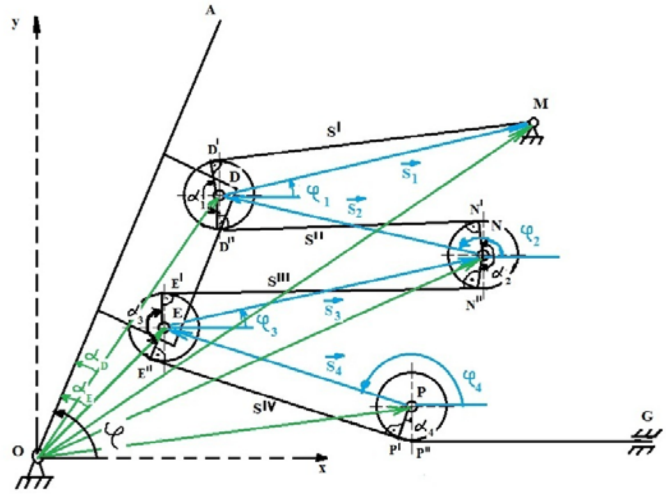

Fig 4: Vector contours that define the position of the units of the pulley system

With $\vec{S}_i$ (i=1÷4) depicts the vectors between the centers of the rollers and the support M having variable length. Are in force the following equations:

$$\vec{S}_1 = \overrightarrow{OM} - \overrightarrow{OD}$$
$$\vec{S}_2 = \overrightarrow{OD} - \overrightarrow{ON}$$
$$\vec{S}_3 = \overrightarrow{ON} - \overrightarrow{OE}$$
$$\vec{S}_4 = \overrightarrow{OE} - \overrightarrow{OP} \quad (5)$$

Equations (5) designed the axes of the coordinate system Oxy (Figure 4)

$$\begin{vmatrix} S_1\cos\varphi_1 = x_M - x_D \\ S_1\sin\varphi_1 = y_M - y_D \end{vmatrix} \Rightarrow \quad \tan\varphi_1 = \frac{y_M - y_D}{x_M - x_D}, \quad S_1^{\,2} = (x_M - x_D)^2 + (y_M - y_D)^2 \quad (6)$$

$$\begin{vmatrix} S_2\cos\varphi_2 = x_D - x_N \\ S_2\sin\varphi_2 = y_D - y_N \end{vmatrix} \Rightarrow \quad \tan\varphi_2 = \frac{y_D - y_N}{x_D - x_N}, \quad S_2^{\,2} = (x_D - x_N)^2 + (y_D - y_N)^2 \quad (7)$$

$$\begin{vmatrix} S_3\cos\varphi_3 = x_N - x_E \\ S_3\sin\varphi_3 = y_N - y_E \end{vmatrix} \Rightarrow \quad \tan\varphi_3 = \frac{y_N - y_E}{x_N - x_E}, \quad S_3^{\,2} = (x_N - x_E)^2 + (y_N - y_E)^2 \quad (8)$$

$$\begin{vmatrix} S_4\cos\varphi_4 = x_E - x_D \\ S_4\sin\varphi_4 = y_E - y_D \end{vmatrix} \Rightarrow \quad \tan\varphi_4 = \frac{y_E - y_D}{x_E - x_D}, \quad S_4^{\,2} = (x_E - x_D)^2 + (y_E - y_D)^2 \quad (9)$$

where φi are corners that vectors (i = 1 ÷ 4) conclude with Ox axis. The coordinates of point M, N and P are constant structural dimensions (fig. 4). The coordinates of p.D and E are variables, defines the dependencies:

$$x_D = OD\cos(\varphi - \alpha_D)$$
$$y_D = OD\sin(\varphi - \alpha_D) \quad (10)$$

and

$$x_E = OE\cos(\varphi - \alpha_E)$$
$$y_E = OE\sin(\varphi - \alpha_E) \quad (11)$$

Where OD, OE, αD and αE are structural dimensions, respectively lengths and angles of unit 2 of the leverage mechanism (Fig. 4).

Therefore, after solving the equation (4) can determine the lengths and angles φ_i. With the help of these variables is the dependency for the determination of the length of the rope support from M to support G, namely:

$$l_в = l_в(t) = S' + r_P.\alpha_1 + S'' + r_P.\alpha_2 + S''' + r_P.\alpha_3 + S^{IV} + r_P.\alpha_4 + P''G \quad (12)$$

where P′′G is the structural size and other parameters are calculated by the following equations:

$$S' = \sqrt{S_1^{\,2} - r_p^{\,2}}, \quad S'' = \sqrt{S_2^{\,2} - 4r_p^{\,2}}, \quad S''' = \sqrt{S_3^{\,2} - 4r_p^{\,2}}, \quad S^{IV} = S_4,$$
$$\alpha_1 = \pi - \varphi_1 + \varphi_2 - \arctan\frac{S'}{r_p} - \arctan\frac{S''}{2r_p},$$
$$\alpha_2 = \pi + \varphi_2 - \varphi_3 - \arctan\frac{S''}{2r_p} - \arctan\frac{S'''}{2r_p},$$
$$\alpha_3 = \frac{\pi}{2} - \varphi_3 + \varphi_4 - \arctan\frac{S''}{2r_p},$$
$$\alpha_4 = \pi - \varphi_4. \quad (13)$$

Moving $S_{out.}$ expressed in:

$$S_{out.} = l_в - l_{в0} \quad (14)$$

where $l_{в0}$ is the length of the rope support from M to support G at the starting
moment, $l_{в0}$=const.

2.4 Theoretical experiment

In the aria of Matlab software is made numerical solution of (4) and (12) in the input data:

l_2=0,66m; l_3=0,135m; h_0=0,631m; x_P=0,422 m; y_P=0,01 m; x_N=0,493 m;
y_P=0,146 m; x_M=0,556 m; y_M=0,266 m; α_E=28,3°;α_D=16,93°; l_E=0,148m;
l_D=0,240m; r_p=0,04m; P''_G=0,800m; (15)

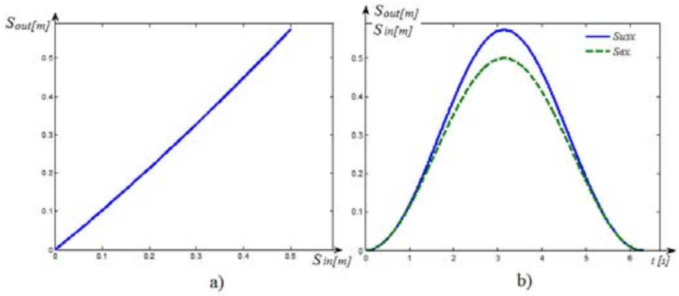

Fig 5: Function of the situation of modul ″Leg Press″

The law of motion of the input unit 3 is set by function:

$$S_{in.} = S_0 - \frac{H}{2} - \frac{H}{2}\sin\left(t - \frac{\pi}{2}\right)[m] \quad (16)$$

where H is the course of driving, it is assumed H=0,5m.
Fig.5a shows graphically dependence $S_{out}(S_{in})$. The functions S_{in} (t) and S_{out} (t) are shown in Fig. 5b. The simulations are for one cycle.

3. Conclusions

Created geometry model of module ″Leg Press″ allows determination the function of the position of the mechanism and its gear ratio. The results of the numerical solutions for input (15) show that this mechanism implements a transmission ratio $\frac{S_{in}}{S_{out}} = 0{,}87$.

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