



MALTESE MECHANISM WITH NONLINEAR CHANNELS

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Abstract: Subject of the article is a study of the Maltese kinematics mechanism with nonlinear channels. Maltese mechanism is attached to base for research slosh open containers. It is a numerical experiment to show the impact of the additional angle of stay α_o and the radius of curvature ρ of the Maltese on the acceleration mechanism.

Keywords: Maltese mechanism, Kinematics of Maltese mechanism

I. Introduction

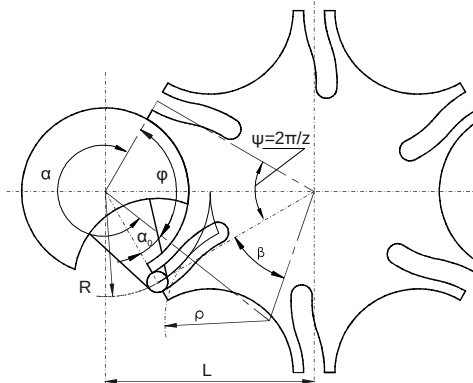
Interrupted movement in installation for research splashing of open containers is made with Maltese mechanism (MM) with straight radial canals [Marchev 2008, 2010] Maltese mechanism is characterized by simple construction, small size and relatively not great weight, but does not allow randomly to choose the ratio between the periods of motion and rest of the leading unit and brings some limitations in constructing cyclogram of the set, which in turn leads to a reduced productivity, and sometimes appears as an obstacle to the introduction of new progressive technological processes [Bass, 1980].

This paper presents studies of Maltese mechanism enabling increased productivity and reduced inertial loads in nodes with intermittent motion. In the setting for the study of splashing of open containers the stepping drive carried out by Maltese mechanism with straight channels is replaced by nonlinear whose profile is composed of two arcs of circles which curvature is different not only by size but also by character. (Figure 1).

II. KINEMATIC RELATIONS OF MM WITH NONLINEAR CHANNELS

On the basis of the closed contour vector [Penev,2009] when examining the mechanism (Figure 1) are obtained the following relationships:

Figure 1 Maltese mechanism with nonlinear channels



a) Function of the position of the mechanism

$$(1) \quad \psi = \operatorname{atg} \frac{\lambda \sin \varphi}{1 - \lambda \cos \varphi} + a \cos \frac{p - \lambda \cos \varphi}{\sigma \sqrt{1 + \lambda^2 - 2\lambda \cos \varphi}} - \frac{\pi}{Z} + \beta,$$

b) First transfer function - an analogue of the angular velocity of the Maltese Cross (MC)

$$(2) \quad k_{\omega} = \frac{d\psi}{d\varphi} = \frac{\lambda \sin \varphi}{\omega} \left(\frac{\cos \varphi - \lambda}{\sin \varphi} + \frac{x - \omega / \sigma}{\sqrt{\omega - x^2}} \right),$$

c) Second transmission function (an analogue of angular acceleration of the MC)

$$(3) \quad k_{\varepsilon} = \frac{d^2\psi}{d\varphi^2} = \frac{\lambda^2 \sin^2 \varphi}{\omega^2} \cdot \left[\frac{\lambda^2 - 1}{\lambda \cdot \sin \varphi} + \frac{\omega / \sigma - 2x}{\sqrt{\omega - x^2}} + \frac{\omega(x - \omega / \sigma)}{\sqrt{(x - \omega / \sigma)^3}} \left(\frac{\omega - x^2}{\lambda \cdot \sin \varphi \cdot \sigma} + \frac{x}{\sigma} - 1 \right) \right],$$

d) Angle of transmission of the movement

$$(4) \quad \gamma = \arctg \frac{\sigma \sqrt{\omega - x^2}}{\omega - x\sigma},$$

e) Coefficient of dynamic power

$$(5) \quad k_N = k_{\omega} \cdot k_{\varepsilon},$$

f) Non dimensional positional coefficients (invariants) of angular velocity, angular acceleration and dynamic power

$$(6) \quad q_{\omega} = U \cdot k_{\omega},$$

$$(7) \quad q_{\varepsilon} = \frac{2\pi}{z} U^2 \cdot k_{\varepsilon},$$

$$(8) \quad q_N = \frac{2\pi}{z} U^3 \cdot k_N,$$

g) Variable parameters depending on the wheelbase of MM - L, the number of channels - z, the angle of the extra stay - α_o and radiuses of curvature of the conjugated profiles - R and ρ :

$$(9) \quad U = \frac{z}{2} \left(1 - \frac{\alpha_o}{\pi} \right) - 1,$$

$$(10) \quad p = \frac{1 + \lambda^2 + \sigma^2 - \tau^2}{2},$$

$$(11) \quad \sigma = \sqrt{1 + (\tau + \lambda)[\tau + \lambda - 2 \cdot \sin(\pi/z + \alpha_o)]},$$

$$(12) \quad \beta = \arcsin \left[\frac{\tau + \lambda}{\sigma} \cos \left(\frac{\pi}{z} + \alpha_o \right) \right],$$

$$(13) \quad \lambda = \frac{R}{L} = \sin \frac{\pi}{z},$$

$$(14) \quad \tau = \frac{\rho}{L}.$$

For lack of hard hit in any direction of movement of the MC the angle for an additional stay is expected to be chosen in the range:

$$(15) \quad 0 \leq \alpha_o \leq \pi(4/9 - 1/z)[1].$$

For the convenience of calculations in terms of (1) to (4) are introduced additional indications

$$(16) \quad \omega = 1 + \lambda^2 - 2 \cdot \lambda \cdot \cos \varphi,$$

$$(17) \quad x = \frac{p - \lambda \cos \varphi}{\sigma}.$$

When considering movement of the MM in the initial region of movement where the radius of the channel is equal to the radius of the leading bend, the expressions of (1) to (4) reach the type:

$$(18) \quad \psi = 2 \cdot \arctg \frac{\lambda \sin \varphi}{1 - \lambda \cos \varphi},$$

$$(19) \quad k_{\omega} = \frac{2 \cdot \lambda}{\omega^2} (\cos \varphi - \lambda) \sin \varphi,$$

$$(20) \quad k_{\varepsilon} = \frac{2 \cdot \lambda}{\omega^2} (\lambda^2 - 1) \sin \varphi,$$

$$(21) \quad \gamma = \arctg \frac{\sin \varphi}{\lambda - \cos \varphi}.$$

3. NUMERICAL EXPERIMENT

In numerical experiments was used a model shown in Figure 1 with the following parameters: R = 50 mm; L = 100 mm z = 6. Variables to be tested are: the additional stay angle of the MM - α_o and the ratio of radius of the

curvature ρ to the wheelbase L (14) - $\tau(\rho)$. Primary unit is rotated at an angle of 120° completely down to the uppermost position for an interval of 0.5 sec.

3.1. Study the effect of the additional angle of stay

To study the impact of the additional stay angle (α_0) is made in numerical simulation value $\tau = 1$ and the angle $\alpha_0 = 5, 10, 15^\circ$ and 20° , the channels of the MC to occupy positions according Figure 2.

Figure 2 Modification of the channels of the Maltese Cross at $\tau = 1$ and the values of the additional stay angle $\alpha_0 = 5^\circ, 10^\circ, 15^\circ$ and 20°

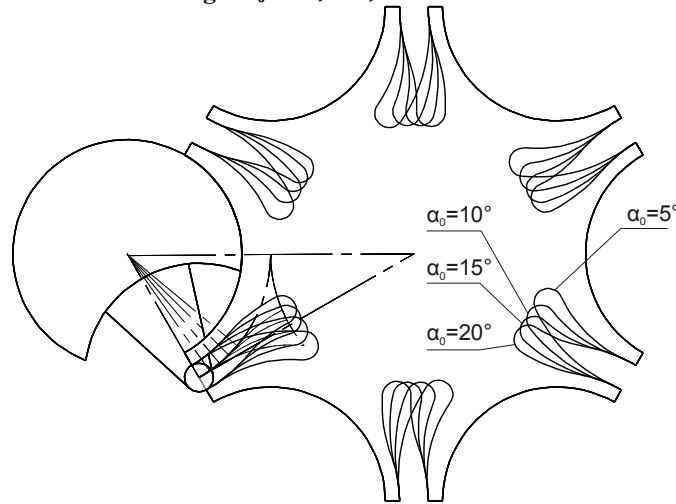
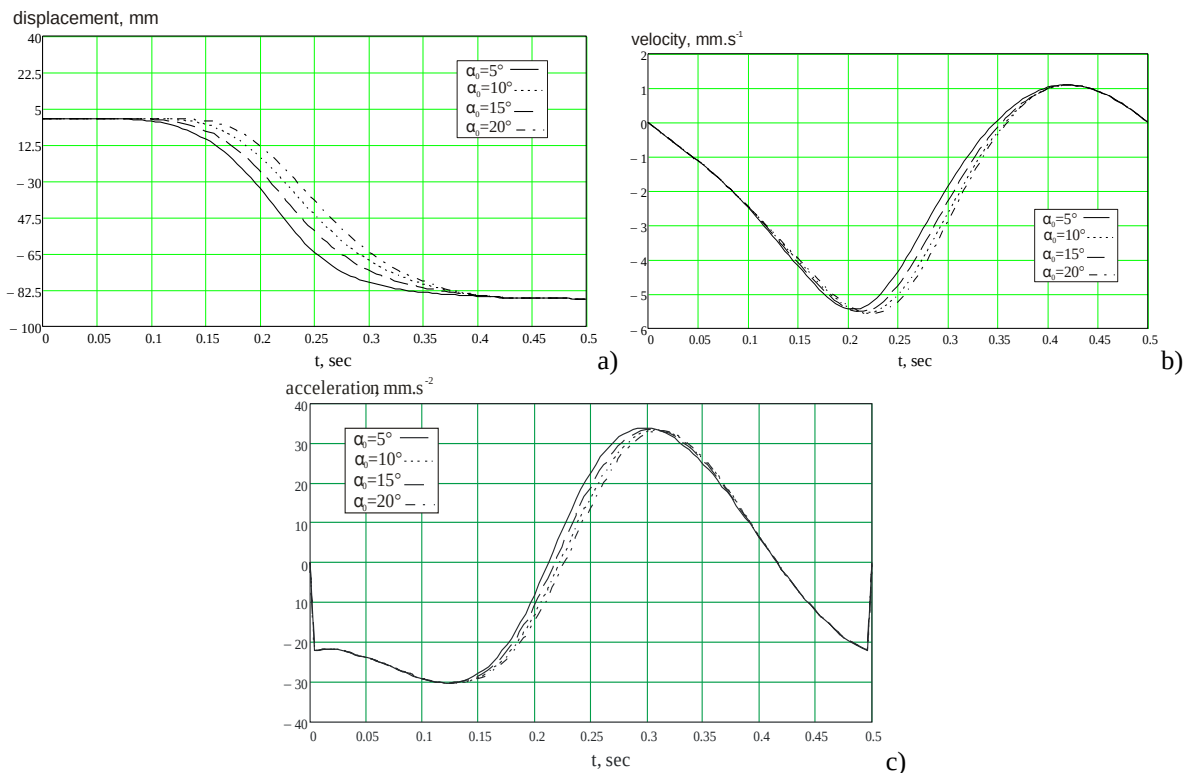


Figure 3 Modification of movement (A), the velocity (b) and acceleration (c) of the MC when $\tau = 1$ and the value of extra stay angle $\alpha_0 = 5^\circ, 10^\circ, 15^\circ$ and 20° in function of time



Reported are maximum acceleration values (Table 1), from where it is seen that their deviation is insignificant values ($\sim 3\%$).

Table 1 Maximum acceleration of the MC

α_0 , deg	Max. accelerations, mm.s ⁻²
5	33.888
10	33.568
15	33.326
20	33.132

3.2. Study of the influence of $\tau(\rho)$

Changing channels of the MC at various $\tau(\rho)$ is shown in Figure 4. The study was performed for different values of the stat angle α_0 at a constant $\tau(\rho)$. The results of numerical experiment for the maximum acceleration of the MC are shown in Table. 2 and displayed in Figure 5

Table 2: Change in max. acceleration of MC at different $\tau(\rho)$ and α_0

$\tau(\rho)$	Additional stay angle α_0			
	5	10	15	20
1	33.888	33.568	33.326	33.132
$\frac{1}{2}$	33.607	33.383	33.213	33.083
$\frac{1}{3}$	33.528	33.338	33.167	33.063
$\frac{1}{4}$	33.482	33.313	33.149	33.052
$\frac{1}{8}$	33.482	33.313	33.149	33.052
0	33.367	33.224	33.109	33.017

Figure 4 Amendment of the channels of the Maltese cross at different values of τ

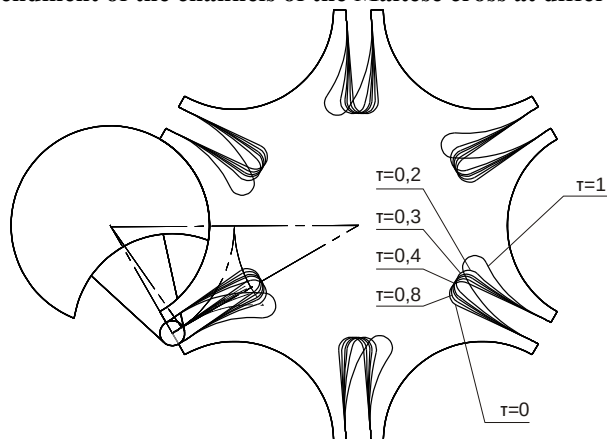
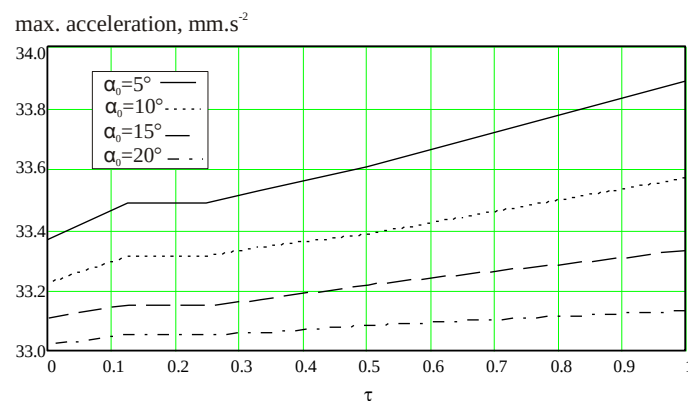


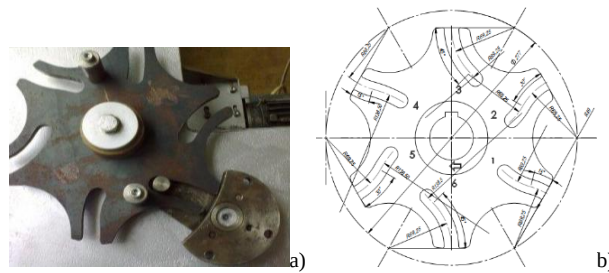
Figure 5. Modification of the maximum acceleration of MC at different α_0 in changing $\tau(\rho)$.



5. Experimental determination the mechanical characteristics of the nonlinear MM

To conduct the nature experiment is made real Maltese cross shown in Figure 6. Each channel has a different geometry, as shown in Table 3.

**Figure 6. Maltese cross with nonlinear channels:
a) real model; b) drawing of the module.**



To conduct experimental research used the wiring diagram shown in Figure 7. Was used accelerometer type KS50 company Metra Mess-und Frequenztechnik (with resonant frequency > 30kHz), placed directly on the Maltese Cross. Through the ADC converts the signal into digital form and then tared.

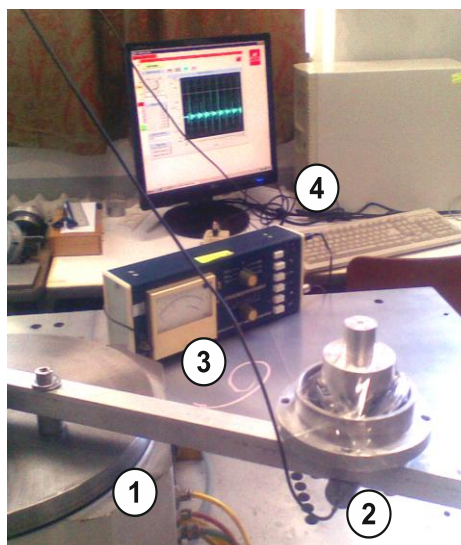
Table 3. Geometric parameters of the MM with nonlinear channels.

№ of channel	α	R, mm	ρ , mm
1	15°	69,25	69,25
2	30°	69,25	69,25
3	45°	69,25	69,25
4	15°	69,25	138,5
5	30°	69,25	138,5
6	45°	69,25	138,5

The experiment was conducted three times, each trial begins with the establishment of the Maltese cross from channel 1. The resulting signal is divided in one rotation of the knee, depending on the direction of rotation of the input unit of the Maltese mechanism (see Figure 8).

Figure 7. General view of the installation

1 -Vibrostand EET 101 - RFT, 2 - Sensor KS50 - MMF 3 - Amplifier R0B0JR0H 00 042, 4 - PC ADC ME 2000i Meilhouse Electronics.

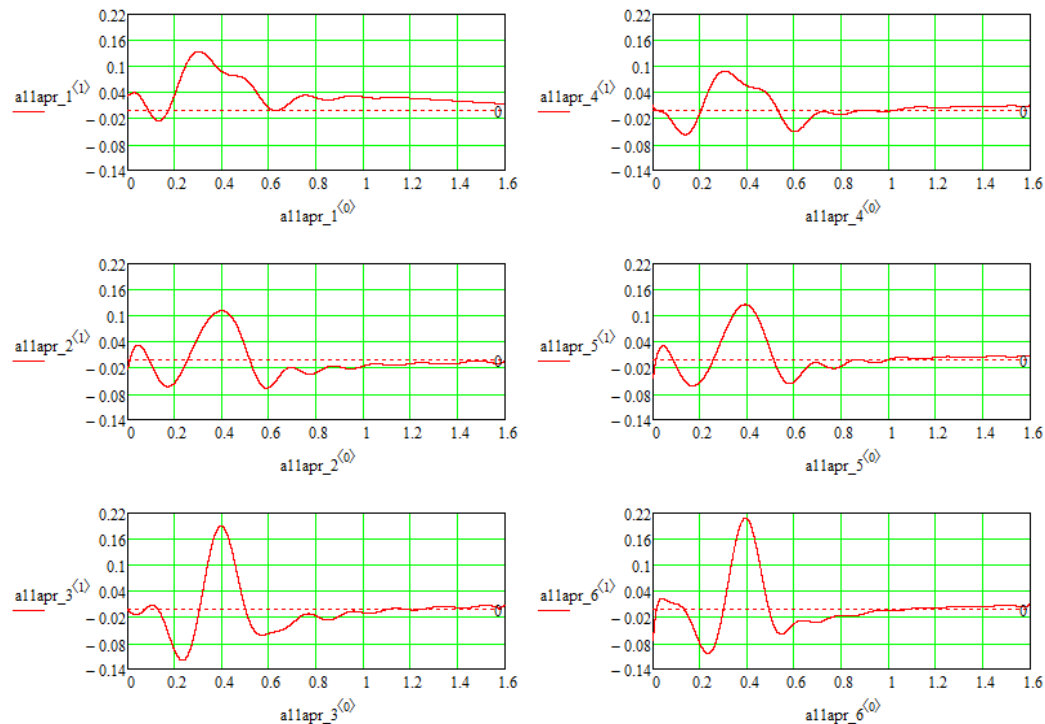


To smooth the data is selected spline LS B-Spline [TableCurve2D, 2006], wherein the minimization used the method of least squares. This method determines the function that corresponds to the data by minimizing the sum of squared residuals (difference of coordinates) between the data points and the curve. Following smoothing of the data representing the resulting curve of change in acceleration over time. Equations corresponding to the resulting curve is generated automatically and provide information about the reliability of each of them. Greatest similarity to afford application of Furies Series Polynomial 10x2 and having the form:

$$(22) \quad Acc = a + b.\cos(t) + c.\sin(t) + d.\cos(2t) + e.\sin(2t) + f.\cos(3t) + g.\sin(3t) + h.\cos(4t) + i.\sin(4t) + j.\cos(5t) + k.\sin(5t) + l.\cos(6t) + m.\sin(6t) + n.\cos(7t) + o.\sin(7t) + p.\cos(8t) + q.\sin(8t) + r.\cos(9t) + s.\sin(9t) + t.\cos(10t) + u.\sin(10t)$$

This sequence is applied to the data received for each of the channels, which are represented graphically in Figure 8.

Fig. 8. Graphical representation of equation (22).



The present studies lay the foundation for further optimization of the maximum acceleration of the Maltese mechanism with nonlinear channels by changing the geometry of the channels.

CONCLUSION

Equations are defined for accelerations of Maltese mechanisms with nonlinear channels experimentally.

Experimentally, are defined maximum acceleration amplitude of MM with nonlinear channels.

The present studies lay the foundation for further optimization of the maximum acceleration of the Maltese mechanism with nonlinear channels by changing the geometry of the channels.

REFERENCES

- [1] Marchev N. M. Penev (2008), "Setting for testing the behavior of a fluid in an open container during its motion in an arc. "IV International Conference "Mechanics and Machine Elements", 6-8 November 2008, Sofia, Bulgaria
- [2] Marchev N., M. Penev, N. Petkova, (2010) Setting for experimental studies on the behavior of the fluid driven by Maltese mechanism. "VI International Conference "Mechanics and Machine Elements", 4-6 November 2010, Sofia, Bulgaria, p 164-171.
- [3] Penev M., N. Marchev (2009), Research Maltese mechanism with nonlinear channels, International conference "General machine Design", pp. 143-146, ISSN 1313 - 9193, Русе, България, 15-16 октомври 2009.
- [4] Bass, R.L., Bowles, E.B. and Cox, P.A. (1980), "Liquid Dynamic Loads in LNG Cargo Tanks", SNAME Transactions, 88, pp. 103-126.
- [5] TableCurve2D, "Systat Software, Inc.," sited 20_02_06, <http://www.systat.com/downloads/?sec=d002>.