SOME OPTIMIZATION POSSIBILITIES REGARDING THE KINEMATICS OF THE GENEVA MECHANISMS

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INTRODUCTION

A number of different mechanisms can be used to convert the uniform rotary motion into intermittent rotary motion. The simplest of these mechanisms is the Geneva mechanism. The major disadvantage of the conventional Geneva mechanism is that the output motion starts and ends with nonzero values of acceleration. This problem limits the usefulness of the Geneva mechanism to low speed applications. In order to eliminate the shock of loading caused by these nonzero initial and final accelerations, two directions can be considered in the existent literature:

- transforming the straight radial slots into curved slots;
- using an intermediary mechanism to rotate non-uniformly the driving pin.

1.GENEVA MECHANISM WITH CURVED SLOTS

Based upon the geometry and the kinematics of the Geneva mechanism with curved slotted wheel, studied by R.G. Fenton in [2], this paper presents the main characteristics of this mechanism.

1.1. Modeling parameters

The following parameters are used to characterize the Geneva mechanism with curved slots (see Figure 1):

N – number of slots in the wheel;

θ_0 – the half angle between the axes of symmetry of any two consecutive slots, $\theta_0 = 180/N$;

$\varphi_1^{(0)}$ - the initial position angle of the crank, $\varphi_1^0 \in [110^o, 160^o]$;

φ_1 - the current position angle of the crank;

$\varphi_2^{(0)}$ - the initial position angle of the wheel;

φ_2 - the current position angle of the wheel;

α_0 – the supplement of the initial position angle of the crank, freely selected by the designer, within certain practical limits, $\alpha_0 = 180^o - \varphi_1^0$;

t_m – the motion time of Geneva wheel at a full rotation of the driving crank;

t_p – the pause time of Geneva wheel at a full rotation of the driving crank;

σ - the indexing ratio, $\sigma = t_p/t_m$, or if the angular velocity is constant, the indexing ratio can be also expressed as $\sigma = (180 - \alpha_0)/\alpha_0$;

L – the distance between the driving crank and the wheel axis, O_1O_2;

R – the driving crank radius, O_2P;

R_d – the wheel radius;

$\Delta\theta_0$ – one half of the offset between the entry point, A, and the exit point, C, of the slot.

1.2. Aspects concerning the geometry and the kinematics

The geometry of the curved slotted Geneva mechanism was studied by Fenton in [2]. In order to define this mechanism, it is necessary to impose the fulfillment of the geometrical conditions by the displacement function, as it follows:

$$\begin{aligned} &\varphi_2(\varphi_1)\Big|_{\kappa_1=\varphi_1^0} = \varphi_2^0; \\ &\varphi_2(\varphi_1)\Big|_{\kappa_1=\varphi_1^0+2\alpha_0} = \varphi_2^0 - 2\theta_0 \end{aligned} \tag{1}$$

and the kinematical conditions:

$$\left.\frac{d\varphi_2}{dt}\right|_{t=0} = 0; \left.\frac{d\varphi_2}{dt}\right|_{t=t_m} = 0; \tag{2}$$

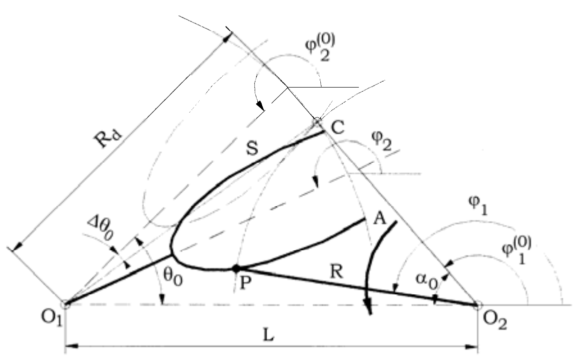

Figure 1. Fenton’s Geneva Mechanism

$$\left.\frac{d^2\varphi_2}{dt^2}\right|_{t=0} = 0; \left.\frac{d^2\varphi_2}{dt^2}\right|_{t=t_m} = 0. \quad (3)$$

To diminish the acting shocks of the mechanism, it is recommended that the maximum acceleration value to be as small as possible. In (1), the most representative displacement functions are studied. In Table 1, the corresponding maximum acceleration values for each studied displacement function is presented, considering the same configuration for the Geneva mechanism. All the mentioned displacement functions fulfill the imposed geometrical and kinematical conditions (1) and (2). After analyzing these maximum acceleration values, it can be concluded that the modified trapezoidal displacement function ensures the lowest acceleration peak.

Table 1. Displacement functions.

The displacement functions	$\left.\frac{d^2\varphi}{dt^2}\right\|_{max}$
Cycloidal	$\pi\frac{\theta_0}{\alpha_0^2}$
Modified trapezoidal	$2{,}444\frac{\theta_0}{\alpha_0^2}$
Modified sine	$2{,}764\frac{\theta_0}{\alpha_0^2}$
Polynomial 3-4-5	$2{,}886\frac{\theta_0}{\alpha_0^2}$
Polynomial 4-5-6-7	$3{,}756\frac{\theta_0}{\alpha_0^2}$

By changing the slot shape from a straight radial line to a curved line, a Geneva mechanism with improved kinematical characteristics is obtained.

1.3. The "Y" type Geneva mechanism

Analyzing the Fenton's Geneva mechanism, it can be seen that the pressure angle reaches the value of 90^o [1], fact that renders the transmitted force, zero.

The "Y" type Geneva mechanism represents a hybrid mechanism between the conventional Geneva mechanism and the Fenton's one, This new mechanism was designed with aim to extend the optimization criteria, considering, also, the minimizing of the pressure angle, in order to improve the force transmitting properties of the mechanism.

According to Figure 2, the supplementary modeling parameters are (the previous presented remain available):

$\varphi_1^{(1)}$ - the position angle of the driving crank at the entrance of the linear zone of the slot;

$\varphi_2^{(1)}$.- the position angle of the wheel, when the driving crank enters the linear zone of the slot.

The proposed Geneva mechanism is named of type "Y" according to the shape of the slot in the wheel. The characteristic profile of the slot is represented by the line ABB'BA (see Figure2). Three zones characterize this profile:

AB – curvilinear zone of the slot, on which the driving pin enters the slot (Figure 2, a);

BB'B – radial linear zone of the slot, similar to the conventional mechanism, which corresponds to the middle of the motion period (Figure 2, b);

BC - curvilinear zone of the slot, on which the driving pin leaves the slot.

These three zones of the slot are imposed by the optimization criteria, as it follows:

- the kinematical optimization criteria (zero values for acceleration at the beginning and at the end of the Geneva wheel motion) fulfilled by adopting the curvilinear zones of the slot. These slot zones will be modeled by 5th degree polynomial displacement functions;

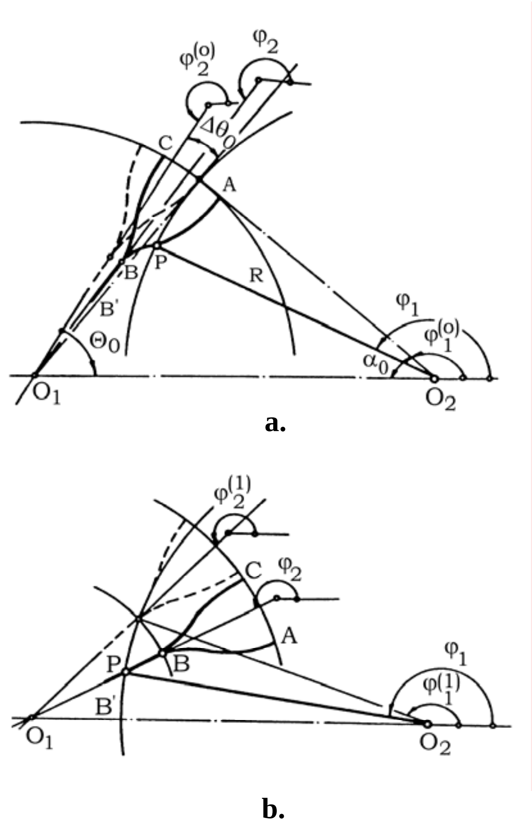

Figure 2. "Y" Geneva mechanism.

- considering the qualities of the conventional Geneva mechanism regarding the efficiency of power transmission, reflected by zero values of the pressure angles, a straight radial zone of the slot replaces that curvilinear slot zone of the Fenton's mechanism, characterized by important values of the pressure angle.

Therefore, the displacement function of the proposed mechanism is a compound function with three different analytical expressions, corresponding to the three zones of the slot. This compound displacement function is presented in Table 2.

The values of the polynomial coefficients of the displacement function characteristic for the entering and leaving zones of the slot will be established by considering premises:

- the displacement, velocity and acceleration functions are continuous;
- the displacement, velocity and acceleration functions have to fulfill the geometrical and the kinematical conditions, modeled by the relations (1) and (2).

The "Y" type Geneva mechanism represents a generalization the different types of external Geneva mechanisms, being a hybrid solution between the conventional Geneva mechanism with straight radial slots and Fenton's mechanism with curvilinear slots.

Table 2. The displacement function for a "Y" type Geneva mechanism.

Slot zone	**Profile type**	φ_1	φ_2
AB	Curvilinear	$\varphi_1^{(0)}...\varphi_1^{(1)}$	$\varphi_2 = a_1\varphi_1^5 + a_2\varphi_1^4 + a_3\varphi_1^3 + a_4\varphi_1^2 + a_5\varphi_1 + a_6$
BB'B	Rectilinear	$\varphi_1^{(1)}...360^o - \varphi_1^{(1)}$	$\varphi_2 = \pi + atg\dfrac{\frac{R}{L}\sin\varphi_1}{1+\frac{R}{L}\cos\varphi_1}$
BC	Curvilinear	$360^o - \varphi_1^{(1)}...360^o - \varphi_1^{(0)}$	$\varphi_2 = b_1\varphi_1^5 + b_2\varphi_1^4 + b_3\varphi_1^3 + b_4\varphi_1^2 + b_5\varphi_1 + b_6$

2. GENEVA MECHANISM DRIVEN BY A CAM MECHANISM

The obtained advantages by using an appropriate intermediary driven mechanism, in order to rotate non-uniformly the driven crank of a conventional Geneva mechanism are:

- the nonzero acceleration values at the beginning and at the end of the motion of the Geneva wheel can be eliminated;
- the acceleration peak of the Geneva wheel is decreased in comparison with the Geneva wheel without driven mechanism;
- the dwell to motion time ratio can be freely selected by the designer, therefore the using flexibility of this mechanism is increased;
- the input and the output elements of the compound mechanism can be coaxial assembled.

2.1. Modeling parameters of the compound Geneva mechanism

The compound Geneva mechanism, studied in this chapter, is obtained by a serial connection of a conventional Geneva mechanism with an intermediary driven cam mechanism. The main geometrical modeling parameters are presented in Figure 3.

The supplementary notations are the following:

φ_{1a} - the current position angle of the driving cam;

$\varphi_{1a}^{(0)}$ - the position angle of the cam which corresponds to the entering of the pin in the slot of the Geneva wheel.

2.2. Kinematical considerations regarding the compound Geneva mechanism

Considering that the displacement function of the intermediary driven mechanism is $\varphi_1 = \varphi_1(\varphi_{1a})$, depending on the chosen displacement function of the cam mechanism, and the displacement function for the conventional Geneva mechanism, imposed by the mechanism construction, $\varphi_2 = \varphi_2(\varphi_1)$, for the compound mechanism the displacement function becomes:

$$\boldsymbol{\varphi_2 = \varphi_2(\varphi_{1a})}. \tag{4}$$

After successive differentiation of the displacement function (4), the velocity and the acceleration of the mechanism are obtained, as it follows:

$$\frac{d\varphi_2}{d\varphi_{1a}} = \frac{\partial\varphi_2}{\partial\varphi_1}\frac{\partial\varphi_1}{\partial\varphi_{1a}}; \tag{5}$$

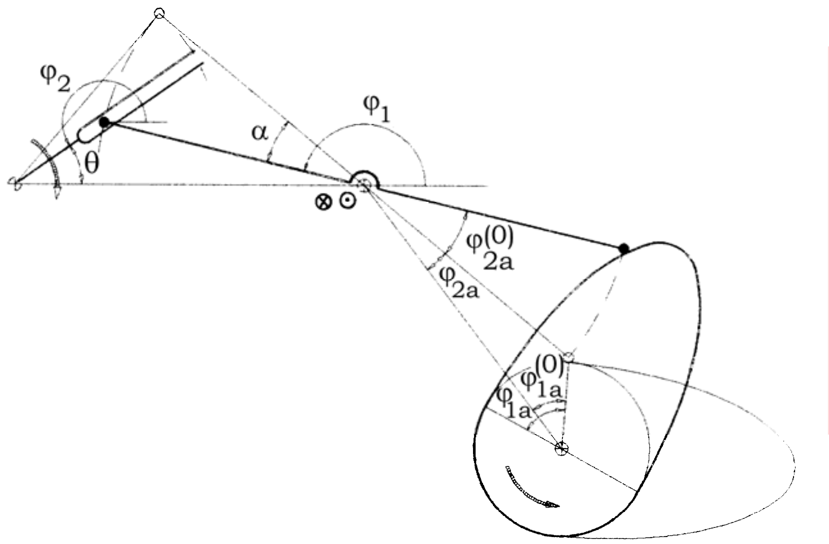

Figure 3. Geneva mechanism with driven cam mechanism.

$$\frac{d^2\varphi_2}{d\varphi_{1a}^2} = \frac{\partial^2\varphi_2}{\partial\varphi_1^2}\left(\frac{\partial\varphi_1}{\partial\varphi_{1a}}\right)^2 + \frac{\partial\varphi_2}{\partial\varphi_1}\frac{\partial^2\varphi_1}{\partial\varphi_{1a}^2}. \quad (6)$$

Considering the kinematical optimization criteria imposed to the compound mechanism (zero acceleration values at the beginning and at the end of the Geneva wheel motion), and after analyzing the relation (6), for the driven mechanism the following conditions are imposed:

$$\left.\frac{\partial\varphi_1}{\partial\varphi_{1a}}\right|_{\varphi_1=\frac{\pi}{2N}(N+2)} = 0\,; \left.\frac{\partial\varphi_1}{\partial\varphi_{1a}}\right|_{\varphi_1=\frac{\pi}{2N}(3N-2)} = 0\,. \quad (7)$$

The displacement function for the driven cam mechanism may be any of the displacement functions recommended in the literature, such as: the linear displacement function, the harmonic displacement function, the cycloidal displacement function etc. From all of these, considering in the same time the geometrical acting conditions and the kinematical criteria (7), the most appropriate are the cycloidal and the polynomial displacement functions.

3. CONCLUSIONS

All the proposed solutions, for improving the kinematical characteristics of the conventional Geneva mechanism, fulfill the imposed criterion to ensure zero acceleration values at the beginning and at the end of the Geneva wheel motion.

The “Y” type Geneva Mechanism represents a generalization of the different types of Geneva mechanisms with modified slots, rendering also a better transmission of the forces in the mechanism, due to optimum values for the pressure angle.

The compound Geneva mechanism driven by a cam mechanism doesn’t need a complex technology to obtain the wheel, as the other proposed solutions, ensuring in the same time the possibility of coaxial assembling for the input and output elements.

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Recomandat spre publicare: 10.09.2012