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REPRESENTATION OF LAWS OF MOVEMENT FOR THE CAM-FOLLOWER MECHANISM

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Abstract: *In this paper we will present the operating regime of the rotation cam-follower mechanism. With the help of a complex computational program developed in LabVIEW, data related to the motion laws corresponding to the mechanism will be displayed, times and speeds will be accurately calculated, and the ideal cam image will also be projected, according to the data originally entered. The program can successfully simulate several combinations of motion laws, such as linear-linear law, linear-parabolic law, linear-cosinusoidal law etc.*

Keywords: *Mechanism, cam, laws of motion, follower, graphic representations;*

1. INTRODUCTION

The pursuit of high productivity in industry is the essential force driving investigations to improve mechanisms. High-speed, high-precision automatic machines are becoming increasingly important. Effective mechanism design methods are required in order to develop superior machines [1].
Cam-follower mechanisms are found in almost all mechanical devices and machines (i.e., agriculture, transportation equipment, textiles, packaging, machine tools, printing presses, automobile internal combustion engines, and more recently in micromachines such as microelectromechanical systems) [2].
To begin with, we shall define the concept of the cam-follower mechanism [3].
Cam-follower mechanisms are mechanisms in which the movement is transmitted from the leading element to the driven one without intermediate elements, through direct contact.
This mechanism can also be designated as upper coupling, because of the rotating movement between the cam and the follower.
The cam mechanisms convert a rotating, uniform motion into an irregular or linear alternating rotary motion.
The cam mechanisms are widely spread in the mechanical engineering design, as the cam profile can have almost any shape, depending on the motion law desired for the follower to pursue.
Figure 1 shows the simplest cam mechanism.

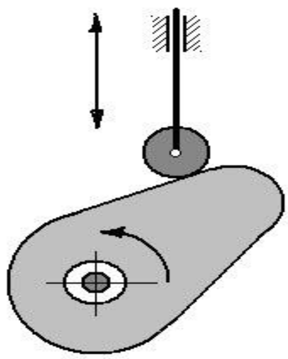

Figure 1. Cam-follower mechanism

Cam-follower mechanisms have a number of pros and cons.

Although these mechanisms possess a relatively complicated technology, they are simple mechanisms with a low gauge and generally have an elementary design.
It is known that because they have a small contact surface, this can lead to a high degree of tear and wear, but there is also a risk that the mechanism would get stuck if its design was inadequately made.
Depending on its destination, the cam-follower mechanisms can be found in various forms [4].
According to the shape of the follower, the cam- follower mechanisms may be: punctiform, circular, rectilinear.
According to another ranking made considering the movement of the follower, we can distinguish between a follower in translational movement, a follower in rotating movement, and a follower in rotating traslatory shift.
With regard to the cam, depending on its movement, we can distinguish different types of cams: cams in rotating motion, in translation motion, in rotating traslatory shift.
By the position of the cam profile:
- exterior – the working profile is located on the outer side of the cam;
- interior – the working profile is located on the inner side of the cam in the form of grooves;
By the shape of the followers:
- angular follower – the cam and the follower have contact in one single point;
- Roller followers – the contact between cam and follower is a line;
By the position of the follower in relation to the cam:
- axial-centric follower mechanisms;
- disengaged-eccentric follower mechanisms;
The present paper aims to describe the operating mode of the cam-follower mechanism, to reproduce graphics for each movement, to calculate the respective times and speeds and to display the ideal cam with the imposed R0 range.

2. MOVEMENT LAWS USED IN PRACTICE

2.1 Linear movement law

The law of linear motion is performed at a constant speed, as can be seen in Figure 2.
The movement graph in the linear motion law is continuous, but has angular points when passing from one phase to the other.

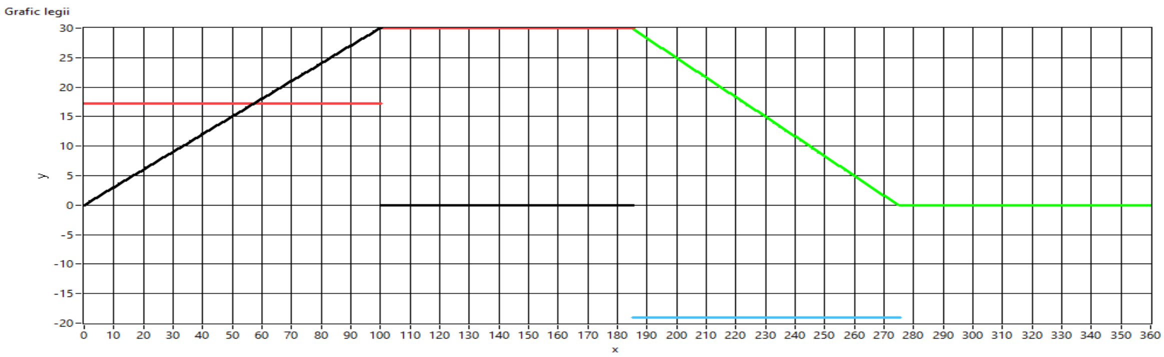

Figure 2. Linear law graph

Ascending formulas:

$$s = \frac{h}{\varphi_u} \cdot \varphi \; ; \tag{1}$$

$$s' = \frac{h}{\varphi_u} \, . \tag{2}$$

Descending formulas:

$$s = h - \frac{h}{\varphi_c} \cdot \varphi \; ; \tag{3}$$

$$s' = -\frac{h}{\varphi_c} \, , \tag{4}$$

where: s represents the time parameter, h is the follower's stroke, φ_u is the ascending angle, φ_c is the descending angle, and $\boldsymbol{s}'$ the time derivative, namely the speed.

The velocity chart shows discontinuities of type 1 (finite) at the same points in which the space had angular points.
The acceleration diagram shows discontinuities of type 2 (infinite) at the crossing points from one phase to the next.

2.2. Linear parabolic law

A disadvantage of using the parabolic law is that very strong shocks occur, which lead to compressions. As early as in the design stage, shock-proof connections are provided as shown in Figure 3.

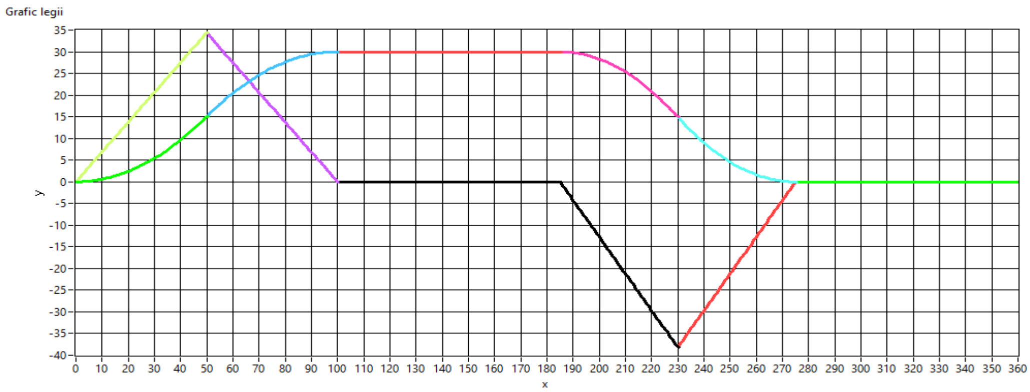

Figure 3. Parabolic law graph

Ascending formulas:

I.

$$s = \frac{2h}{\varphi_u^2} \cdot \varphi^2; \tag{5}$$

$$s' = \frac{4h}{\varphi_u^2} \cdot \varphi; \tag{6}$$

I'.

$$s = -\frac{2h}{\varphi_u^2} \cdot \varphi^2 + \frac{4h}{\varphi_u} \cdot \varphi - h; \tag{7}$$

$$s' = -\frac{4h}{\varphi_u^2} \cdot \varphi + \frac{4h}{\varphi_u}; \tag{8}$$

Descending formulas:

III.

$$s = h - \frac{2h}{\varphi_c^2} \cdot \varphi^2; \tag{9}$$

$$s' = -\frac{4h}{\varphi_c^2} \cdot \varphi; \tag{10}$$

III'.

$$s = \frac{2h}{\varphi_c^2} \cdot \varphi^2 - \frac{4h}{\varphi_c} \cdot \varphi + 2h; \tag{11}$$

$$s' = \frac{4h}{\varphi_c^2} \cdot \varphi - \frac{4h}{\varphi_c}; \tag{12}$$

2.3. Law of sinusoidal motion

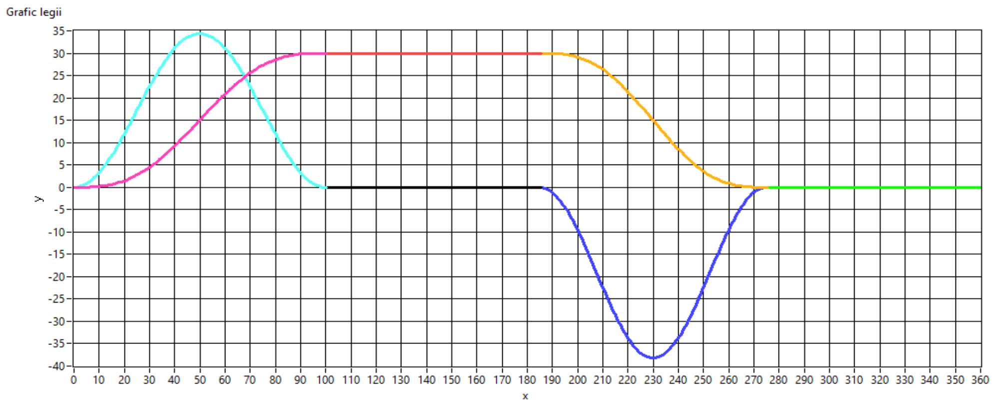

Figure 4. The sinusoidal law graph

Ascending formulas:

$$s = h\left(\frac{\varphi}{\varphi_u} - \frac{1}{2\pi}\cdot sin\frac{2\pi\varphi}{\varphi_u}\right); \tag{13}$$

$$s' = \frac{h}{\varphi_u}(1 - cos\frac{2\pi\varphi}{\varphi_u}); \tag{14}$$

Descending formulas:

$$s = h - h\left(\frac{\varphi}{\varphi_c} - \frac{1}{2\pi}\cdot sin\frac{2\pi\varphi}{\varphi_c}\right); \tag{15}$$

$$s' = -\frac{h}{\varphi_c}(1 - cos\frac{2\pi\varphi}{\varphi_c}; \tag{16}$$

All kinematic parameters of the law are continuous and only the acceleration has angular points at the ends of the ascending (or descending) lapse, which can be seen in Figure 4.
From a dynamic (vibrational) point of view, the sinusoidal law has its perks, because space and speed laws are continuous laws without angular points.
The acceleration law is continuous throughout the whole lapse, including the passage phases, but presents angular points at the crossing points from one phase to the next.
The small differences in the space diagrams and thus in the cam profiles can lead to high speed and especially acceleration values. That is why very precise machining is required for profile cams and the surfaces of the profiles have to be treated so that the wear and tear is reduced, thus large accelerations can be reached, the inertia forces increasing greatly.

2.4. Law of cosinusoidal motion

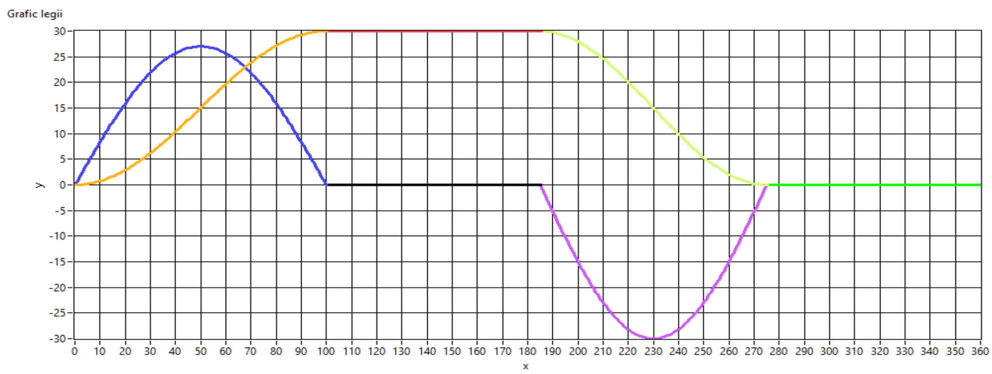

Figure 5. The cosinusoidal law graph

Ascending formulas:

$$s = \frac{h}{2}\left(1 - cos\frac{\pi\varphi}{\varphi_u}\right); \tag{17}$$

$$s' = \frac{\pi\varphi}{2\varphi_u} \cdot sin\,\frac{\pi\varphi}{\varphi_u}; \tag{18}$$

Descending formulas:

$$s = \frac{h}{2}(1 + cos\,\frac{\pi\varphi}{\varphi_c}); \tag{19}$$

$$s' = -\frac{\pi h}{2\varphi_c} \cdot sin\,\frac{\pi\varphi}{\varphi_c}; \tag{20}$$

As can be seen in Figure 5, the diagram that operates after such motion law has a continuous space diagram, a continuous velocity diagram, and the acceleration diagram has finite discontinuities, but less than the parabolic law.

It works better from the point of view of forces if the descent is also a cosine and if there is no higher downtime. As a drawback, we can say that in comparison to the linear law the maximum speed is higher.

3. PROGRAM DESCRIPTION

The program of the chosen theme was made in LabView, consisting of a front panel and a working diagram. The front panel is the user interface and displays graphs and values, and in the working diagram the calculations related to the realization of the program are to be found. Figure 6 presents the working diagram with the whole program.

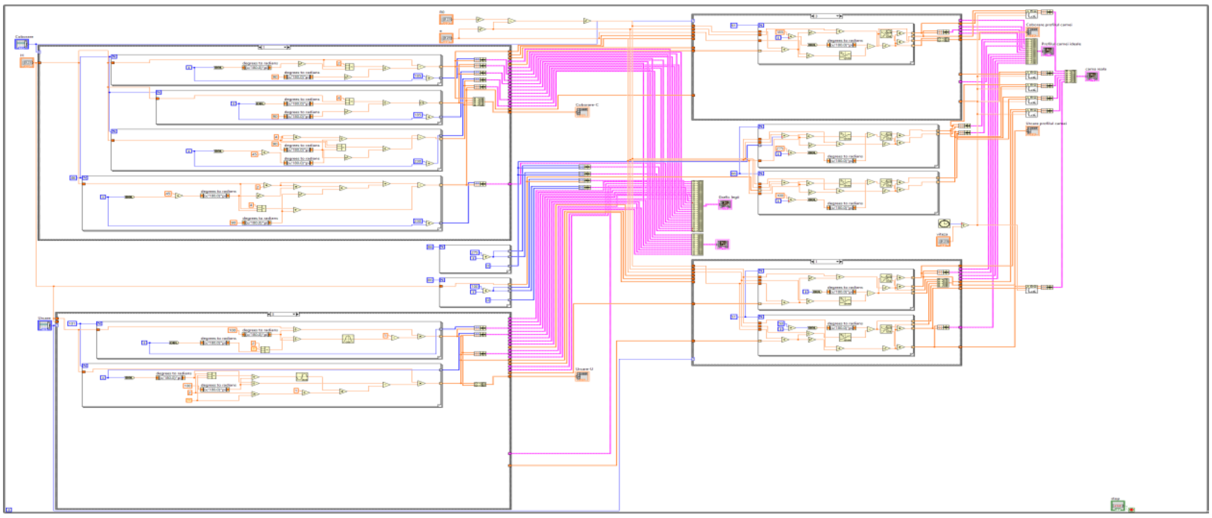

Figure 6. The program in the working diagram

At the top of the panel we come across a graph generator and in its immediate vicinity, the user can choose different functions, both ascending and descending, the graph being able to generate any combination of two functions, as can be seen in Figure 7 (sinusoidal, cosinusoidal, linear, parabolic).

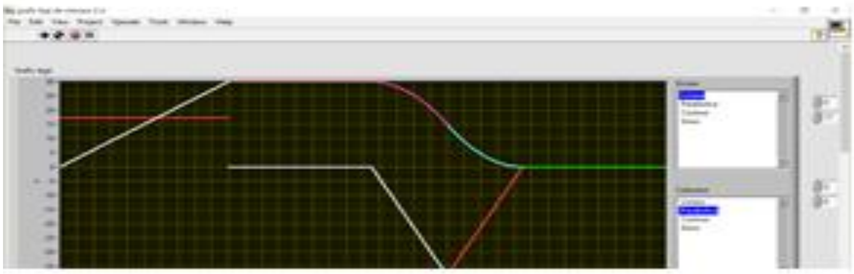

Figure 7. Graph generator

To generate this graph, it is necessary to enter a value corresponding to "h"' (the follower's stroke).

As output data, both the chart of the chosen law, ascending and descending, for time and speed, as well as the numerical values at any point in the generated graph, as in Figure 8, will be displayed.

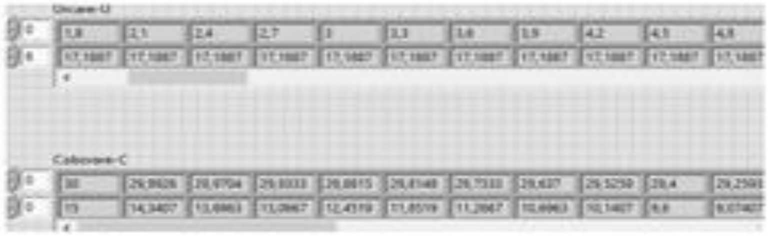

Figure 8. Ascending and descending values

The next step of the program in obtaining the real cam is the completion of the ideal cam through the graphic method. This method can be partially viewed in Figure 9.
With the help of previously obtained values, a series of points will be fixed by another graph generator, drawing two diagonals from the critical points R0 (minimum cam radius).

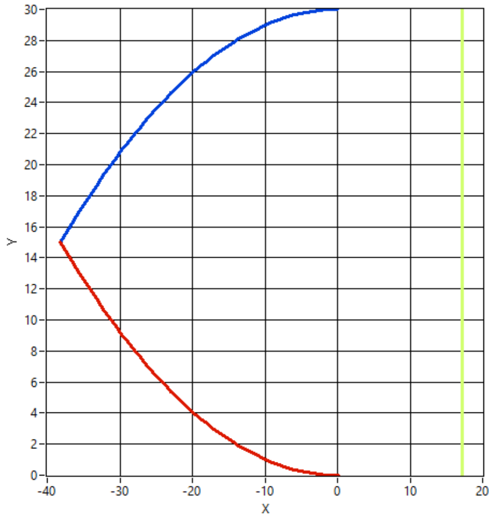

Figure 9. The graphic method

Next, with the value obtained for R0 and entering the value of eccentricity “e” in the program as input, we can see the ideal cam profile in Figure 10.

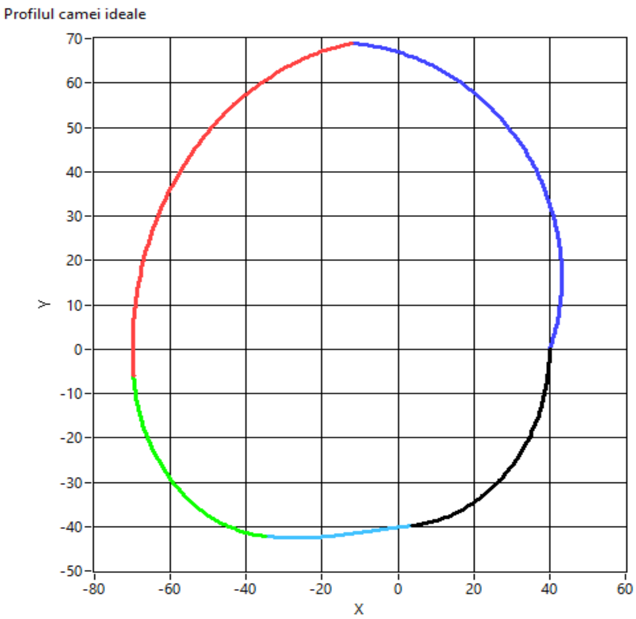

Figure 10. The ideal cam profile

As one can see in Figure 11, the ideal cam can be obtained as well as the values of the polar coordinates R and ß, as output data.

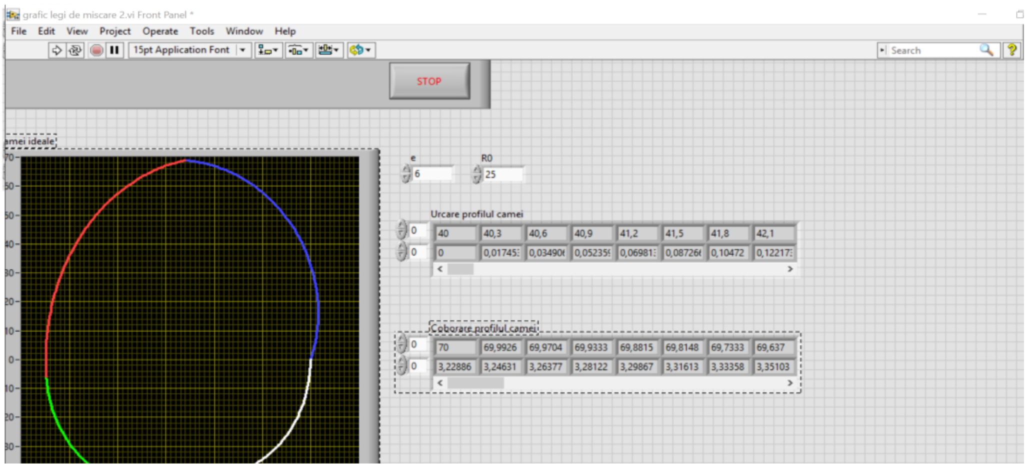

Figure 11. The polar coordinates

In order to avoid errors, but also to generate the ideal cam profile, one condition must be taken into account, i.e. R0 > e.
The last step performed by the program is to display the real cam, as can be seen in Figure 12. It can be presented also in rotation motion if the user enters a last input date, namely the cam rotation speed.

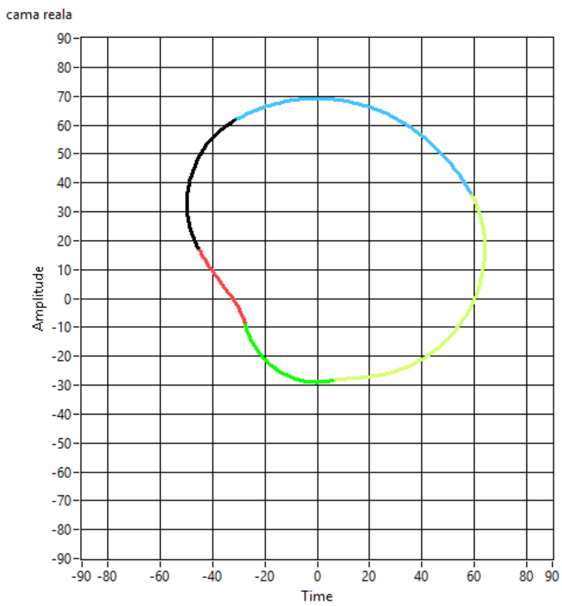

Figure 12. The real cam profile

4. CONCLUSIONS

In conclusion, one can observe the usefulness of realizing a calculation program of a rotating cam-translation follower mechanism.
Also, from the presentation of the program one can highlight the precision of the calculations made and the accuracy with which the graphs were made.
This way, with appropriate input data, real-time results can be obtained for almost any type of cam-follower mechanism.

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