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# ANALYSIS OF INFLUENCE OF PARAMETERS ON TRANSFER FUNCTIONS OF APERIODIC MECHANISMS

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**Abstract**. *Based on knowledge about the structural synthesis of the aperiodic mechanisms the equations of the transfer functions of different types of aperiodic mechanisms have been defined. These expressions are the complex functions of numerous parameters. The primary aim of this paper is to analyze the influence of the change of some parameters on the character of transfer functions of different types of aperiodic mechanisms. Specific attention is drawn to the analysis of the influence of these parameters upon the period of the motion, as one of the major parameters of choosing an aperiodic mechanism for the concrete process. The deviation analysis of different aperiodic transfer functions from nominal transfer functions is given, too.*

**Key words**: *Analysis, Mechanisms, Aperiodic mechanisms, Transfer function.*

## 1. INTRODUCTION

Basic mechanisms that are examined in the Theory of machines and mechanisms have periodic transfer functions. However, in many technological processes mechanisms whose transfer functions are not periodic but the mechanisms with grater or considerably grater periods of motions are required, depending on the requirements of the process. Therefore, aperiodic mechanisms were developed as a new group of mechanisms with the specific characteristics resulting from the conditions that had to be fulfilled according to the definition of an aperiodic transfer function. The transfer function whose period is as long in reference to the duration of the process so that the time of its execution is not repeated as much as the nature of the process requires, can be considered as an aperiodic transfer function.

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## 2. THE ANALYSIS OF APERIODIC MECHANISMS

Having relied on knowledge about the structural synthesis of the aperiodic mechanisms the equations of the transfer functions of different types of aperiodic mechanisms have been determined. They take into account structural restrictions that are defined by Grashof's criterion then the criterion of minimal allowed transfer angle and recommendations for ratios of lengths of mechanism links. On the bases of this obtained expressions are the complex functions of numerous parameters, such as structural: lengths of links, diameters of gears, eccentricity of a slider crank mechanism and so on, or miscellaneous like the transmission ratio of the driving angular velocities or similar. In this part of the paper the analysis of the characteristic aperiodic mechanisms that are obtained by different structural methods is done. The analysis means analyzing the influence of the change of some parameters on the character of transfer functions as the deviation of aperiodic mechanisms transfer functions from basic mechanisms nominal transfer functions. Specific attention is drawn to the analysis of the influence of these parameters upon the period of the motion, as one of the major parameters of choosing an aperiodic mechanism for the concrete process.

### 2.1 The analysis of extended aperiodic mechanisms

The first analysis that is done is carried out on a characteristic extended aperiodic mechanism whose kinematic scheme is shown in Fig. 1. In the base of this mechanism a slider crank mechanism is founded which is extended by another mechanism with a slider. It is done in order to achieve the changeable length of the crank 1. The part of the aperiodic transfer function which is realized by the slider crank mechanism with the changeable length of its frame represents the generator of the aperiodic transfer function. The another part represents the adapter of the aperiodic transfer function and in this extended aperiodic mechanism it is the slider crank mechanism with changeable length of the crank.

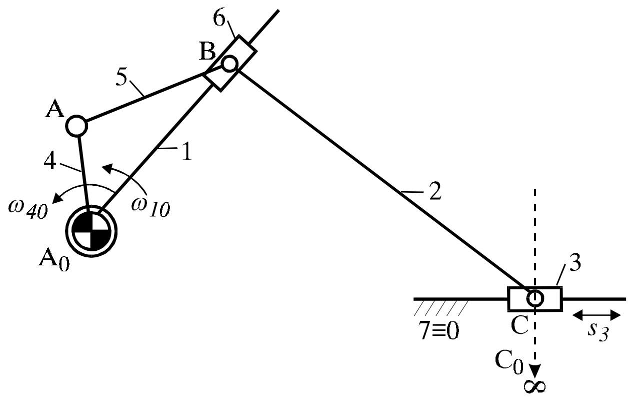


Fig. 1. Characteristic extended aperiodic mechanism

As it has been mentioned earlier the transfer function of a aperiodic mechanism depends on numerous parameters. The transfer function of the extended aperiodic mechanism from Fig. 1. represents complex dependence of the output coordinate $s_3$ not only upon the driving angle $\theta_{10}$ but upon the following parameters: the transmission ratio of the driving angular velocities $k$, the eccentricity of a slider crank mechanism $e$ and the lengths of links 2, 4 and 5. In accordance to the labels marked in Fig. 1. the transfer function of the extended aperiodic mechanism, in general case when an eccentricity of slider crank mechanism in the base exists, is described by the next dependence:

$$s_3 = f(\theta_{10}, k, e, l_2, l_4, l_5) .$$

According to the definition of the transfer function of an aperiodic mechanism it can be concluded that the period of a motion is one of the major parameters of choosing an aperiodic mechanism for the concrete process that requires aperiodic motion. Thus, in this type of aperiodic mechanisms there are two periods. The period of a total extended aperiodic mechanism $T$ that represents a number of cycles after which a motion of a total mechanism repeats itself and the period of perturbation $t$. Another period is in regard to the generator of the aperiodic transfer function and it can be determined as a number of cycles of a part of an aperiodic mechanism in the generator during the period of the motion of a total aperiodic mechanism. These periods are functions only of the parameter $k$, so they are:

$$T = f(k) \; ; \quad t = f(T, k)$$

On the bases of the realized analyses and conclusions and recommendations that have come from them it is possible to make a choice of an extended aperiodic mechanism which has the optimal values of the parameters for fulfilling a nominal transfer function for which the transfer function of a theoretical slider crank mechanism is adopted. In this way defined extended aperiodic mechanism must have a centric slider crank mechanism in its base. Also, for the length of the floating link 2 it is recommended to adopt the maximum possible length. For reducing changes in the transfer function of the generator of an extended aperiodic mechanism it is necessary to take the links 4 and 5 with minimum possible lengths. Of course that choosing these lengths of links is restricted by mentioned structural restrictions. Finally, for the value of the transmission ratio of the driving angular velocities $k$ it is needed to choose its value so that the period of perturbations $t$ has the value that is equal to one in keeping with the desired period $T$. In that case the motion of the driven element of an extended aperiodic mechanism is symmetrical towards a position of a equilibrium.

### 2.2. The analysis of led aperiodic mechanisms

The next analysis is realized on the characteristic led aperiodic mechanism whose kinematic scheme is given in Fig. 2.

This mechanism can be obtained by the method of leading if as the generator of the aperiodic transfer function there is a mechanism which is able to perform leading of a floating link joint of the driven slider crank mechanism on an open trajectory. That can be achieved if a differential mechanism or a planetary pair with the ratio of its diameters which is not a whole number is used as the generator of an aperiodic motion. The rest of a led aperiodic mechanism represents the adapter of the aperiodic transfer function and in this led aperiodic mechanism it is a slider crank mechanism whose the floating link joint

B has the trajectory that can be represented by its vector of position $\vec{r}_B$. The transfer function of the led aperiodic mechanism from Fig. 2. represents more complex dependence of the output coordinate $s_3$ also not only upon the driving angle $\theta_{10}$ but upon the next parameters: the transmission ratio of the driving angular velocities *k*, the eccentricity of a slider crank mechanism *e*, the length of link 2, the distance *h* between joints A and B and the radii of gears 4 and 5. In keeping with the labels designated in Fig. 2. the transfer function of the led aperiodic mechanism, in general case with an eccentricity of slider crank mechanism in the base, is described by the next function:

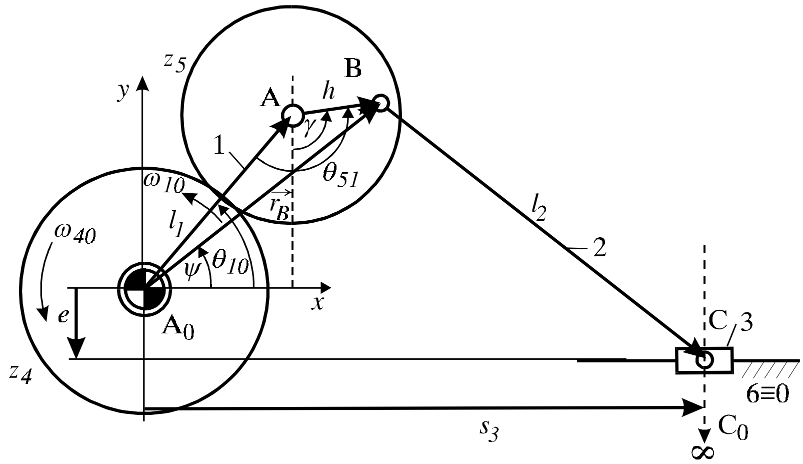


Fig. 2. Characteristic led aperiodic mechanism

$$s_3 = f(\theta_{10}, k, e, l_2, h, r_4, r_5) \; .$$

In this type of aperiodic mechanisms also there are two periods of a motion, the period of a total led aperiodic mechanism *T* and the period of perturbation *t*. However, in this case these periods are not only functions of the parameter *k*, but the transmission ratio of gears 4 and 5. Thus, they will be:

$$T = f(k, i_{54}) \; ; \quad t = f(T, k, i_{54})$$

Having relied on the analysis that had been done some conclusions and recommendations have been formed. These can be used to make a choice of a led aperiodic mechanism with the optimal values of the parameters for realizing a nominal transfer function for which the transfer function of a theoretical slider crank mechanism is adopted. In keeping with obtained recommendations a centric slider crank mechanism mast be taken in the adapter of the aperiodic transfer function. It is also recommended to adopt the maximum possible length of the floating link 2. For the purpose of reducing changes in the output coordinate of the generator of the aperiodic transfer function the distance h is needed to be as less as possible. Paying attention to structural restrictions when choosing values of these parameters is of particular importance. The last two parameters must be taken together into consideration, because of exerting their contemporary influence on the both periods. Because of that it is necessary to choose the values of the transmission ratios of the driving angular velocities *k* and the radii of gears 4 and 5 so that the period of perturbations *t* has the value that is equal to one in accordance to the required period *T*. It is very important to fulfill as only in that case the motion of the driven element of an led aperiodic mechanism is symmetrical towards a position of a equilibrium. These conclusions and recommendations are valid no matter which type of gearing in the generator of the aperiodic transfer function is used. It is possible because the type of gearing is taken into considerations by using proper sign of radii and transmission ratios of gears in the equations of the transfer functions of a led aperiodic mechanisms.

### 2.3. The analysis of combined aperiodic mechanisms

The analysis of the transfer function of a combined aperiodic mechanism is done on the epitome of this type of aperiodic mechanisms. This characteristic mechanism is obtained in the process of combining a five bar mechanism in the base with three geared differential mechanism of which the gear $z_1$ is fastened to the link 1. Its kinematic scheme is represented in Fig. 3. The function of the generator of the aperiodic motion is generated by a five bar mechanism with the fastened gear $z_1$, while a differential mechanism is used as the adapter of aperiodic transfer function. The third entity in its structure is a driven part.

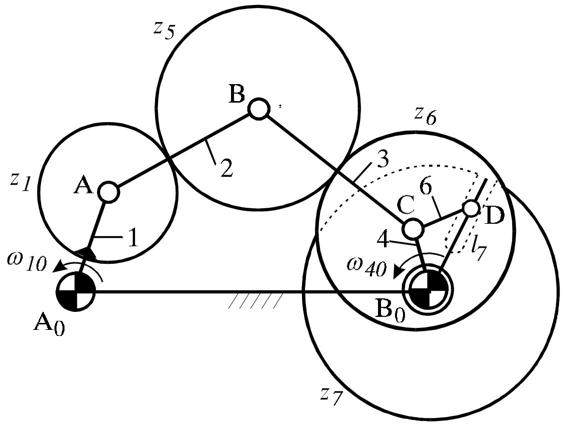


Fig. 3. Characteristic combined aperiodic mechanism

The transfer function of the combined aperiodic mechanism from Fig. 3. represents the most complex dependence of the output coordinate $\theta_{70}$ also not only upon the driving angle $\theta_{10}$ but upon the numerous parameters: the transmission ratio of the driving angular velocities *k*, the length of the fame, the lengths of links 1, 2, 3, 4, 6, and the radii of gears 1, 5 and 6. In agreement with the designates in Fig. 3. the transfer function of the combined aperiodic mechanism, can be represented by the next dependence:

$$\theta_{70} = f(\theta_{10}, k, l_0, l_1, l_2, l_3, l_4, l_6, r_1, r_5, r_6).$$

As in the previous types, this type of aperiodic mechanisms has also two periods of a motion, the period of a total combined aperiodic mechanism *T* and the period of perturbation *t*. In accordance with the mentioned complexity of the transfer function in this type of aperiodic mechanisms the periods are also very complex functions of the parameter *k* and the transmission ratio of links 1 and 6. These dependencies can be expressed as:

$$T = f(k, i_{61})\,;\; t = f(T, k, i_{61})$$

In the similar way based on the results of the analysis, some conclusions and recommendations have been founded, so it can be used to make a choice of a combined aperiodic mechanism with the optimal values of the parameters for realizing a nominal linear transfer function. Likewise, these conclusions and recommendations are valid no matter which types of gearing in the differential mechanism with three gears are used. It is possible because the types of gearing are taken into considerations by using proper sign of radii and transmission ratios of gears in the equations of the transfer functions of led aperiodic mechanisms. According to the realized analyses it can be concluded that the length of the frame does not affect the character of the aperiodic transfer function and for it any length can be adopted. Because of this the parameter $l_0$ is used as the main value to express length of the other links relatively. On order to achieve linear transfer functions it is useful to take minimal value for the length of the link 1. The remaining parameters must be taken together into consideration, because of exerting their contemporary influence both on the periods and the transfer function. Thus, as the result of the analysis of the contemporary influence of the lengths of the links 4 and 6 it is recommended to adopt the length of the link 4 as greater as possible according to the length of link 6. Finally, for the values of the transmission ratio of the driving angular velocities *k* and the transmission ratio of the links 1 and 6 it is needed to choose their values so that the period of perturbations *t* has the value that is equal to one in keeping with the desired period *T*. However, this is a necessary, but not a sufficient condition. In order to further approaching of the transfer function of a combined aperiodic mechanism to the nominal linear function it is needed to provide as less value of the transmission ratio of the links 5 and 6 as possible. This is to be done while the value of the parameter $i_{61}$ remains fixed by using proper values for parameters $l_2$, $l_3$, $r_1$, $r_5$ and $r_6$. These conclusions and recommendations are also valid for any types of gearing by using proper sign of radii and transmission ratios of pairs of gears in the equations of the transfer functions of a combined aperiodic mechanisms.

## 3. Conclusion

On the basis of the previous, as the conclusion of this paper the recommendations for choosing an aperiodic mechanism and its optimal structural and other parameters for the performance of demanded motion and necessary period of the motion are presented. For this purpose programs based on the mathematical models of different types of aperiodic mechanisms have been written in the software package MATLAB. The furthest intention will be to unite these programs into a unique one that would be able to use the defined recommendations and which would be able to give the best solutions for the demanded aperiodic motion.

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# ANALIZA UTICAJA PARAMETARA NA PRENOSNE FUNKCIJE APERIODIČNIH MEHANIZAMA


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*Na osnovu saznanja razvijenih u postupku strukturne sinteze aperiodičnih mehanizama definisane su jednačine prenosnih funkcija različitih tipova aperiodičnih mehanizama. Tako dobijeni izrazi predstavljaju složene funkcije velikog broja uticajnih parametara. Zbog toga je osnovni cilj ovog rada analiza specifičnih uticaja promene parametara na karakter prenosnih funkcija različitih tipova aperiodičnih mehanizama. Posebna pažnja je posvećena analizi uticaja parametara na veličinu periode prenosne funkcije, kao jednog od najuticajnijih parametara pri izboru aperiodičnog mehanizma za realizaciju kretanja koje zahteva konkretan tehnološki proces. Takođe je u radu data i analiza odstupanja prenosnih funkcija ralićitih aperiodičnih mehanizma od nominalnih prenosnih funkcija.*