Romanian Journal of Petroleum & Gas Technology
Vol. V (LXXVI) • No. 2/2024

RESEARCH CONCERNING THE POSITIONAL ANALYSIS OF A FOURTH CLASS MECHANISM

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DOI: 10.51865/JPGT.2024.02.14

ABSTRACT

It is well known that with the increase in the class of mechanisms, the complexity of their analysis methods also increases accordingly. This is especially the case for mechanisms of class greater than four that contain kinematic groups whose structure includes deformable contours. The usefulness of these mechanisms is also given by their versatility due to the multiple configurations they can have during the kinematic work cycles. The present paper proposes a method for the positional analysis of a complex mechanism of the fourth class. First, the component independent contours of the mechanism are identified using the graph associated with it. Then, the system of equations containing the position parameters of the mechanism is established by projecting the associated vector contours on the axes of a conveniently chosen coordinate system. Solving the system of equations was done numerically, using the *fsolve* module included in the Maple program. The results obtained from solving the system of equations allowed the development of a functioning simulator of the analyzed mechanism. Finally, the variation curves of the position parameters on a kinematic cycle of operation are presented.

Keywords: mechanism, versatility, kinematic groups, associated graph, position parameters

INTRODUCTION

The analysis of mechanisms with a view to their optimal design represents one of the fundamental directions of study in the theory of machines and mechanisms [1-10]. Starting from the structural approach based on the theory of kinematic groups, it is known that with the increase in the class of mechanisms, the complexity of their analysis methods increases accordingly [11-23]. This happens especially in the case of mechanisms of class greater than four that contain kinematic groups whose structure includes deformable contours, the usefulness of these mechanisms being also given by their versatility due to the multiple configurations they can have during the kinematic work cycles.

The scope of the present paper is to develop a method for the positional analysis of a complex mechanism of the fourth class, little addressed in specialized literature. First, the component independent contours of the mechanism are identified using the graph associated with it. The system of equations containing the position parameters of the mechanism is established by projecting the associated vector contours on the axes of a conveniently chosen coordinate system. Solving the system of equations was done numerically, using the *fsolve* module included in the Maple program [24-26]. The results obtained from solving the system of equations allowed the development of a functioning simulator of the analyzed mechanism, which can be considered as a novelty aspect in the addressed field.

THEORETICAL CONSIDERATIONS AND RESULTS OF THE SIMULATIONS

Figure 1 shows a mechanism in the structure of which there is a kinematic group of the fourth class, which consists of kinematic elements 2, 3, 4 and 5. The graph associated with this mechanism is presented in Figure 2. The number of independent contours that make up the structure of the mechanism is determined with the relation [1]:

$$N_c = l - p + 1 \tag{1}$$

where N_c represents the number of independent contours, l is the number of sides of the graph and p is the number of its poles.

In the case of the analyzed mechanism $l = 7$ and $p = 6$, so it results $N_c = 2$. The two independent contours are: *0-1-2-3-5-0* and *0-1-2-4-5-0*.

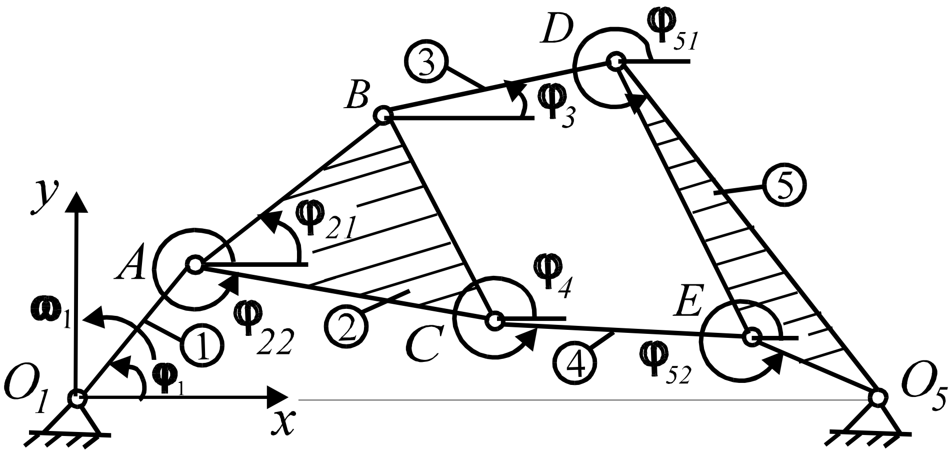

Figure 1. *Fourth class mechanism*

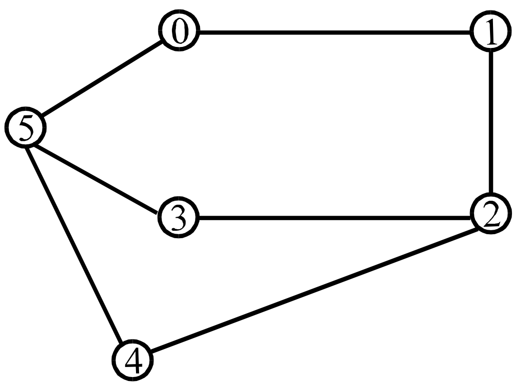

Figure 2. *The associated graph*

The method of independent and closed vector contours [3] has been applied for the positional analysis.

From the first independent contour *0-1-2-3-5-0* in the structure of the mechanism, the system of equations has been obtained:

$$\begin{cases} O_1A\cdot\cos\varphi_1 + AB\cdot\cos\varphi_{21} + BD\cdot\cos\varphi_3 + DO_5\cdot\cos\varphi_{51} - O_1O_5 = 0 \\ O_1A\cdot\sin\varphi_1 + AB\cdot\sin\varphi_{21} + BD\cdot\sin\varphi_3 + DO_5\cdot\sin\varphi_{51} = 0 \end{cases} \quad (2)$$

Analogously, from the second independent contour *0-1-2-4-5-0* results the system of equations:

$$\begin{cases} O_1A\cdot\cos\varphi_1 + AC\cdot\cos\varphi_{22} + CE\cdot\cos\varphi_4 + EO_5\cdot\cos\varphi_{52} - O_1O_5 = 0 \\ O_1A\cdot\sin\varphi_1 + AC\cdot\sin\varphi_{22} + CE\cdot\sin\varphi_4 + EO_5\cdot\sin\varphi_{52} = 0 \end{cases} \quad (3)$$

Between angles φ_{22} and φ_{21}, on the one hand, and angles φ_{52} and φ_{51}, on the other hand, there are the following relationships (Figure 1):

$$\begin{cases} 2\cdot\pi - \varphi_{22} = \angle BAC - \varphi_{21} \\ (2\cdot\pi - \varphi_{51}) - (2\cdot\pi - \varphi_{52}) = \angle DO_5E \end{cases} \quad (4)$$

Relations 2, 3 and 4 form a system of six equations with six unknowns, these being the angles: $\varphi_{21}, \varphi_{22}, \varphi_3, \varphi_4, \varphi_{51}$ and φ_{52}.

A simulator of the analyzed mechanism has been developed using Maple program. Solving the system of equations was done using the *fsolve* module included in the Maple program.

A series of simulation results have been obtained by considering the following dimensions for the links of the analyzed mechanism: $O_1A = 0.2\text{m}$, $AB = 0.4\text{m}$, $AC = 0.7\text{m}$, $BC = 0.5\text{m}$, $BD = 0.4\text{m}$, $CE = 0.45\text{m}$, $DE = 0.5\text{m}$, $O_5D = 0.7\text{m}$, $O_5E = 0.45\text{m}$, $O_1O_5 = 1.1\text{m}$.

In Figures 3÷8 are presented the variation curves on a kinematic cycle of the angles $\varphi_{21}, \varphi_{22}, \varphi_3, \varphi_4, \varphi_{51}$ and φ_{52}, for one of the possible working configurations of the analyzed mechanism.

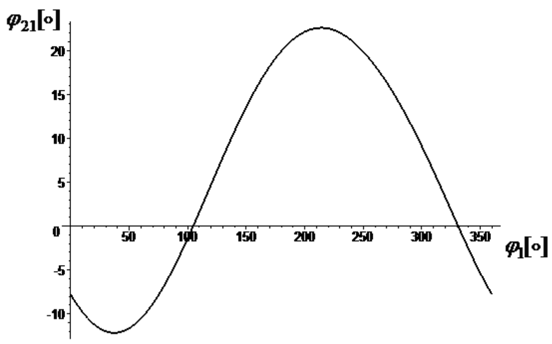

Figure 3. *The variation of the angle* φ_{21}

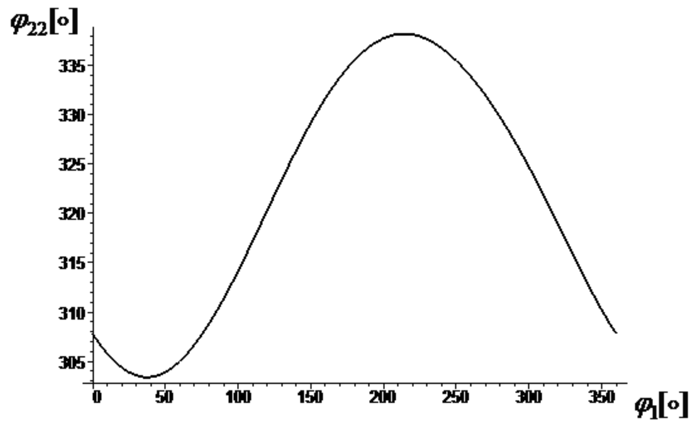

Figure 4. *The variation of the angle* φ_{22}

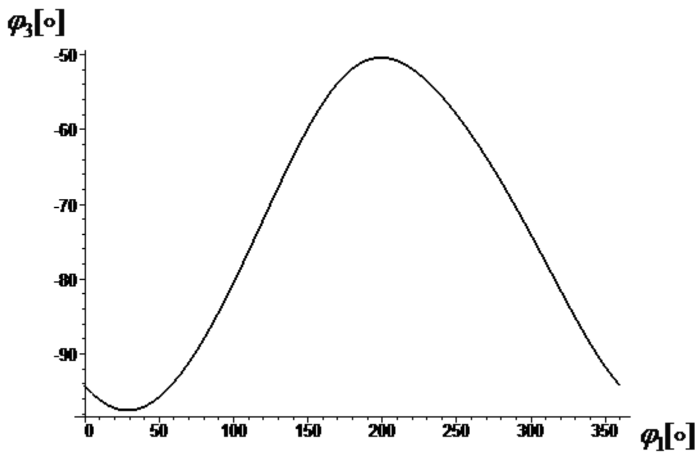

Figure 5. *The variation of the angle* φ_3

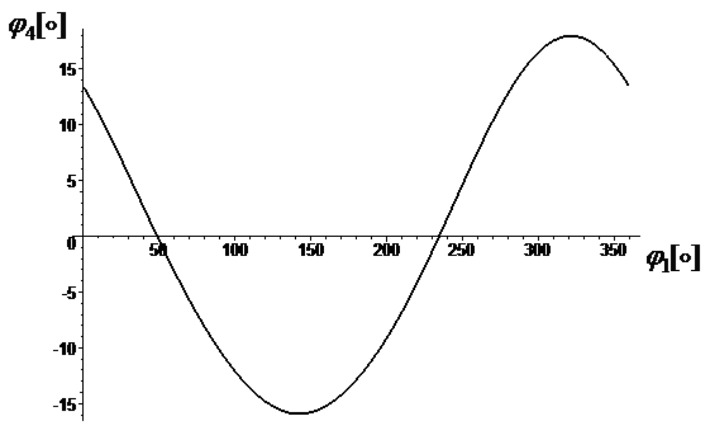

Figure 6. *The variation of the angle* φ_4

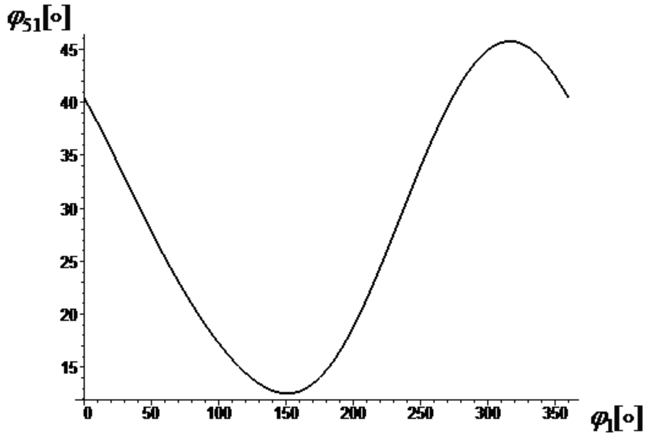

Figure 7. *The variation of the angle* φ_{51}

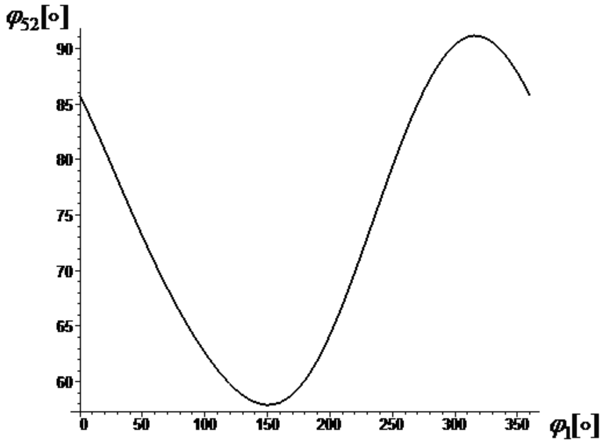

Figure 8. *The variation of the angle* φ_{52}

Figures 9÷12 show the mechanism analyzed in different positions on a kinematic cycle obtained with the operating simulator for the considered work configuration.

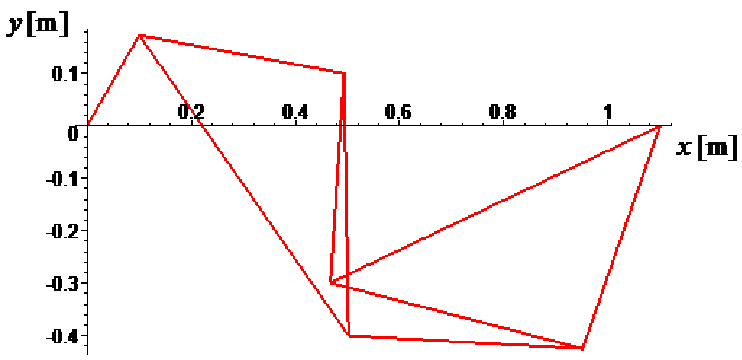

Figure 9. *The configuration of the analyzed mechanism when* $\varphi_1 = 60^\circ$

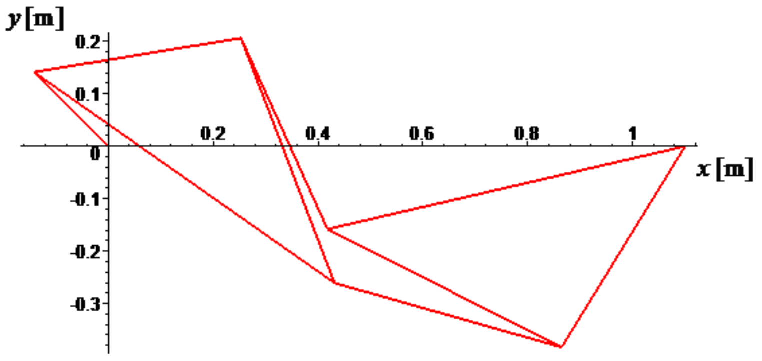

Figure 10. *The configuration of the analyzed mechanism when* $\varphi_1 = 135^\circ$

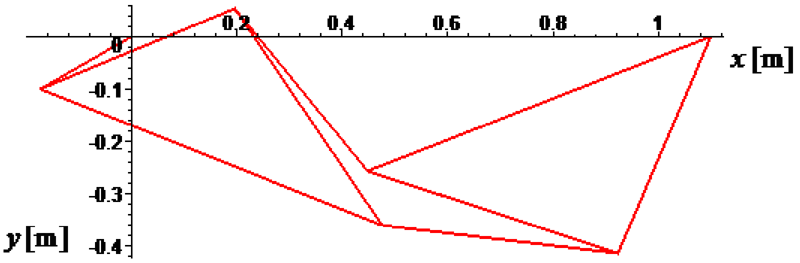

Figure 11. *The configuration of the analyzed mechanism when* $\varphi_1 = 210^\circ$

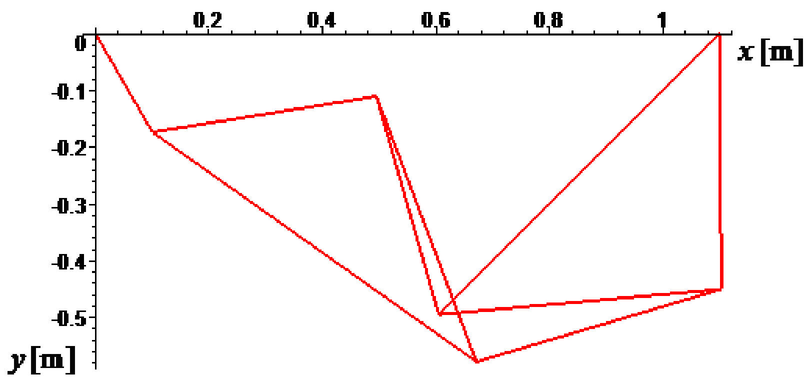

Figure 12. *The configuration of the analyzed mechanism when* $\varphi_1 = 300^\circ$

CONCLUSIONS

In the present paper has been proposed a method for the positional analysis of a complex mechanism of the fourth class. First, using the graph associated to the mechanism, its component independent contours have been identified. By projecting the two vector contours on the axes of a conveniently chosen coordinate system it has been obtained the system of equations containing the position parameters. Solving the system of equations was done numerically, using the *fsolve* module included in the Maple program. Then, the results obtained from solving the system of equations allowed the development of a functioning simulator of the analyzed mechanism using the facilities offered by Maple program. The variation curves of the position parameters on a kinematic cycle of operation that are presented at the end of the paper demonstrate through their continuity the good functioning of the analyzed mechanism. In the end, it can be concluded that the method presented in this paper offers a very effective solution for obtaining simulators of the functioning of complex mechanisms of higher classes.

REFERENCES

[1] Bădoiu D., Toma G., *Research on designing a multiloop planar linkage*, IOP Conference Series: Materials Science and Engineering, Volume 659, Issue 1, pp. 1-9, 2019;

[2] Bădoiu D., Toma G., *Analysis of the dynamic response of the mechanism of conventional sucker rod pumping units*, Revista de Chimie, Volume 71, Issue 1, pp. 395-399, 2020;

[3] Bădoiu D., *On the movement equation of the quadrilateral mechanism*, Buletinul Universităţii Petrol-Gaze din Ploieşti, Seria Tehnica, Vol. LXVII, No. 2, pp. 67-72, 2015;

[4] Bădoiu D., *On the calculus of the equilibrium moment for a mechanism with three independent contours*, Buletinul Universităţii Petrol-Gaze din Ploieşti, Seria Tehnica, Vol. LXVII, No. 1, pp. 99-104, 2015;

[5] Bădoiu D., *Research Concerning the Movement Equation of the Mechanism of the Conventional Sucker Rod Pumping Units*, Revista de Chimie, vol. 70, nr. 7, pp. 2477-2480, 2019;

[6] Vasilescu S., Bădoiu D., *Research Concerning the Variation of the Motor Moment in the Case of a Plane Mechanism*, Buletinul Universităţii Petrol-Gaze din Ploieşti, Seria Tehnica, Vol LXIII, No. 3, pp. 1-4, 2011;

[7] Tudor I., Rîpeanu R.G., Bădoiu D., *Device and simulator for testing pairs of materials used for joints design*, Proceedings of the 2nd International Conference on Manufacturing Engineering ICMEN and EUREKA Brokerage Event, pp. 417-423, Grecia, 2005;

[8] Posea N., *Calculul dinamic al structurilor*, Editura Tehnică, Bucureşti, 1991;

[9] Popovici Al., *Utilaj pentru exploatarea sondelor de petrol*, Editura Tehnică, Bucuresti, 1989;

[10] Jazar R.N., *Theory of Applied Robotics: Kinematics, Dynamics and Control (Second Edition)*, Springer, 2010;

[11] Dombre E., Khalil W., *Modelisation et commande des robots*, Ed. Hermes, Paris, 1988;

[12] Bădoiu D., Toma G., *Research concerning the predictive evaluation of the motor moment at the crankshaft of the conventional sucker rod pumping units*, Revista de Chimie, Volume 70, Issue 2, p. 378-381, 2019;

[13] Craig J.J., *Introduction to Robotics: Mechanics and Control (Third Edition)*, Pearson Prentice Hall, 2005;

[14] Bădoiu D.G., *Research Concerning the Use of Polynomial Functions in the Study of the Conventional Sucker Rod Pumping Units*, Revista de Chimie, vol. 70, nr. 4, pp. 1223-1227, 2019;

[15] Bădoiu D., *Research on establishing the differential model of the robotic mechanisms*, Romanian Journal of Petroleum & Gas Technology, Vol. III (LXXIV), No. 1, pp. 49-54, 2022;

[16] Badoiu D., *Research concerning the static balancing of a multiloop linkage*, Romanian Journal of Petroleum & Gas Technology, Vol. II (LXXIII), No. 1, 2021;

[17] Badoiu D., *On an Optimal Generation of the Trajectory in the Case of a Robotic Mechanism with Four Degrees of Freedom*, Buletinul Universităţii Petrol-Gaze din Ploieşti, Seria Tehnica, vol. LXIX, nr. 1, pp. 31-36, 2017;

[18] Bădoiu D., *On the Establishing and Solving of the Movement Equation in the Case of the Plane Mechanisms*, Buletinul Universităţii Petrol-Gaze din Ploieşti, Seria Tehnica, Vol LXVII, No. 3, pp. 87-93, 2015;

[19] Bădoiu D., *On the calculus of the equilibrium moment for a mechanism with three independent contours*, Buletinul Universităţii Petrol-Gaze din Ploieşti, Seria Tehnica, Vol. LXVII, No. 1, pp. 99-104, 2015;

[20] Sandor G. N., Erdman A. G., *Advanced Mechanism Design: Analysis and Synthesis (Volume 2)*, Prentice-Hall Inc., Englewood Cliffs, New Jersey, USA, 1984;

[21] Nikravesh P. E., *Computer-Aided Analysis of Mechanical Systems*, Prentice-Hall Inc., Englewood Cliffs, New Jersey, USA, 1988;

[22] Zhang C., Yang J., Chang Z., *Machinery dynamics*, Academic Press, 2022;

[23] Chapra, S.C., Canale, R.P., 2011. *Numerical Methods for Engineers*, vol. 2. Mcgraw-Hill, New York

[24] Monagan M. B., Geddes K.O., Heal K.M., Labahn G., Vorkoetter S.M., Mccarron J., Demarco P., *Maple Introductory Programming Guide*, Maplesoft, a division of Waterloo Maple Inc., 2005;

[25] Bădoiu D., *Analiza dinamica a mecanismelor si masinilor*, Editura Didactica si Pedagogica, Bucuresti, 2003;

[26] Bădoiu D., *Analiza structurală şi cinematică a mecanismelor*, Editura Tehnică, Bucureşti, 2001.

Received: October 2024; Revised: October 2024; Accepted: November 2024; Published: November 2024