

## KINEMATICS ANALYSIS OF THE SIX MEMBER MECHANISM IN MSC ADAMS/VIEW

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**Abstract:** The aim of this article is to develop a functional model of six-member mechanism in ADAMS/View software and his following complete kinematics analysis. We analyze the movement of the members of the mechanism. Kinematics analysis was performed analytically and graphically. The mechanism has been also modeled and solution in the program MSC ADAMS/View. The next stage is the simulation with a set of different parameters to obtain its kinematics analysis. Finally the data gathered in this process is compared and evaluated. Finally, the work presents the results with graphical representation of parameters such as speed, distance and acceleration.

### 1 Introduction

In addressing the motion of machine parts, machines and equipment it is necessary first to create a kinematics model. Kinematics model of a device schematically captures all its properties which are essential in kinematical analysis i.e. individual members with dimensions, kinematics pairs, and so on. Conventional numerical solution uses vector calculus as the basic mathematical apparatus because the main kinematics variables are vector quantities. For analytical kinematics analysis of movement different coordinate systems may be used. According to the kind of movement we can choose the appropriate coordinate system for that model configuration thus simplifying the solution. Classical numerical solution of movement kinematics is often lengthy and difficult especially for complex kinematics models with different movements. To simplify and expedite the analysis a graphical solution may be used which is nowadays replaced with a solution using computer techniques using various software products. These software products ease the investigator's effort. Investigator enters the model configuration and the input data and the program calculates the required outputs. These data can be presented in a tabular form or the program draws graphical results. One of the software products suitable for kinematics analysis is MSC ADAMS/View program that allows to modeled kinematics chains and solve their motion [1-3].

### 2 MSC Adams main characteristic

MSC Adams (Automatic Dynamic Analysis of Mechanical Systems) is one of the most widely used multi-function computing software. It helps in simulations of mechanical systems consisting of rigid and flexible bodies connected by different types of kinematics links.

It allows creating dynamic, kinematics and static analysis of the proposed mechanical systems and helps to optimize and improve their properties. The aim of this article is to create a functional model crank rocker mechanism in ADAMS/View software and to make its complete kinematics analysis. The aim is to investigate the movement of individual members of the mechanism and its points.

### 3 Kinematics analysis of mechanism with vertical motion

Kinematical analysis of the mechanism means to solve kinematical variables of movement of the driven members with respect to the kinematics variables of movement of the driving members. Mechanism is a simple machine used to transform the rotational motion to linear translational motion and vice versa. Kinematical analysis is shown in six-member mechanism which is shown in Fig 1. We determine displacement, velocity, acceleration, angular displacement, angular velocity and angular acceleration of the members of this mechanism in program MSC Adams View.

Mechanism consists of a six links with width 20mm, depth 10mm and lengths:  $O_{21}A = 150$  mm,  $AB = 750$  mm,  $O_{21}O_{41} = 885$  mm,  $CD = 450$  mm and  $DE = 400$  mm. Driving link  $O_{21}A$  has a counterclockwise angular velocity  $\omega_{21} = 1$  (rad/s).

The point A of the member 2 crank moves in a circle with radius  $O_{21}A$  and point B of the member 4 also moves in circle with radius  $O_{41}B$ . The member 3 and 5 are performing planar motion, member 6 moves linear translational motion.

Our task is to determine angular displacement  $\varphi_{41}$ , angular velocity  $\omega_{41}$  and angular acceleration  $\alpha_{41}$  of the link  $O_{41}B$  graphically for the crank position indicated

and then to create a model of a mechanism in MSC Adams/View environment and determine displacement, velocity and acceleration of the member DE.

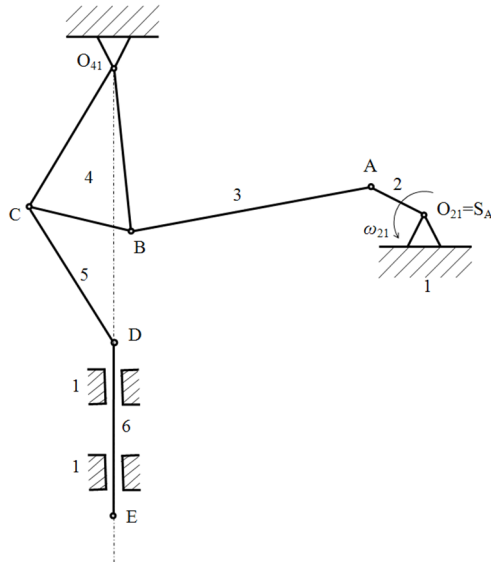


Figure 1 Mechanism with vertical motion

The crank  $O_{21}A$  rotates around point  $O_{21}$ , motion of the connecting member  $AB$  is a general planar motion and member  $O_{41}B$  rotates around point  $O_{41}$ . When we determine lengths of the members we indicate velocities of the points  $A$  and  $B$ . The angular velocity of the member 2 is  $\omega_{21}$ .

The velocity of points  $A$  and  $B$  can be obtained by using the rule of the viewing angles. Tangent of the angle  $\beta_{v21}$  under which we see the endpoints of velocities from the permanent center of rotation is proportional to the angular velocity of the rotating member. If we denote the angular velocity  $\omega_{21}$  of the member 2, then for the velocity  $v_A$  and acceleration  $a_{An}$  at point  $A$  shall apply [5, 6]:

$$v_A = \overline{O_{21}A} \cdot \omega_{21} \quad (1)$$

$$a_{An} = \frac{v_A^2}{\overline{O_{21}A}} \quad (2)$$

$$\operatorname{tg} \beta_{v21} = \frac{v_A}{\overline{O_{21}A}} = \dot{\varphi}_{21} = \omega_{21} \quad (3)$$

$$\beta_{v21} = \operatorname{arctg} \omega_{21} \quad (4)$$

The velocity  $v_A$  lies on the tangent of the trajectory of point  $A$ . The velocity vector at the point is shown in the Fig. 2. The velocity at the point  $B$  is given by the basic decomposition of the member 3:

$$\mathbf{v}_B = \mathbf{v}_A + \mathbf{v}_{BA} \quad (5)$$

In equation (5) we know the magnitude, direction and orientation of the velocity of vector  $\mathbf{v}_A$ . Point  $B$  is located on the member 3 and 4. The member 3 performs general

plane motion and the member 4 performs rotational motion around a fixed axis of rotation in  $O_{41}$ . Trajectory of the point  $B$  is circle with radius  $O_{41}B$ . Point  $B$  is moving relative to the reference point  $A$  in the circle with radius  $AB$  with center in point  $A$ . Equation (5) is solved in a vector diagram in Fig. 3a.

Velocity  $v_B$  of the member 4 we determine also with rule of the viewing angles (Fig. 2) :

$$\operatorname{tg} \beta_{v31} = \frac{v_A}{K_{31}A} = \frac{v_B}{K_{31}B} = \omega_{31} \quad (6)$$

$$\frac{v_A}{K_{31}A} = \frac{v_B}{K_{31}B} \Rightarrow v_B = \overline{K_{31}B} \cdot \frac{v_A}{K_{31}A} \quad (7)$$

The velocity  $v_C$  of the point  $C$ , which lies on the members 4 and 5 construct by the sentences of viewing angle. End point of the velocity vector we see from immediate centre of rotation at the same angle  $\beta_v$ .

The velocity  $v_D$  of the point  $D$  of member 5 and 6 we established by the basic decomposition of general plane motion 5:

$$\mathbf{v}_D = \mathbf{v}_C + \mathbf{v}_{DC} \quad (8)$$

In equation (8) is the vector  $\mathbf{v}_C$  fully understood. The tangent of the vectors  $\mathbf{v}_D$  and  $\mathbf{v}_{DC}$  we can determine. The trajectory of the point  $D$  is the line and trajectory of the point  $D$  regard to point  $C$  is circle with radius  $CD$ . Equation (8) is solved by a vector diagram in the Fig. 3b.

The velocity  $\mathbf{v}_E$  of the point  $E$  is equal to the velocity  $\mathbf{v}_D$ , because points  $E$  and  $D$  are lies in the same member 6. The member 6 is moving translational. For the acceleration of the point  $B$  we write:

$$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{BA} \quad (9)$$

Each member of the equation (9) we decompose the tangential and normal component:

$$\mathbf{a}_{Bt} + \mathbf{a}_{Bn} = \mathbf{a}_{At} + \mathbf{a}_{An} + \mathbf{a}_{BAt} + \mathbf{a}_{BAN} \quad (10)$$

where:

$\mathbf{a}_{Bt}$  – tangential component,

$\mathbf{a}_{Bn}$  – normal component, can be obtained by Euclidean construction,

$\mathbf{a}_{At} = 0$  because  $\omega_{21} = \text{constant}$ ,

$\mathbf{a}_{An}$  – is normal component of the acceleration of the point  $A$ , we obtain:

$$a_{An} = \frac{v_A^2}{\overline{O_{21}A}} \quad (11)$$

The normal component of the acceleration  $\mathbf{a}_{An}$  of the point  $A$  we construct with Euclidean construction from the velocity of the point  $A$  and radius  $O_{21}A$  of the trajectory point  $A$  based on the know velocity  $\mathbf{v}_B$  ( $\mathbf{v}_{BA}$ ) and the center of curvature of trajectory of points  $S_B = O_{21}$  ( $S_{BA} = A$ ) we can construct then the normal component of the acceleration  $\mathbf{a}_{Bn}$  ( $\mathbf{a}_{BAN}$ ).

Wearers of the tangential component of acceleration  $\mathbf{a}_{Bt}$  and  $\mathbf{a}_{BAt}$  are collinear with the respective velocity. In equation (10) only two remain unknown  $\mathbf{a}_{Bt}$  and  $\mathbf{a}_{BAt}$ .

Therefore we know construct the vector diagram of acceleration, from which we determine the size of the components  $\mathbf{a}_{Bt}$  and  $\mathbf{a}_{BAt}$ . Member 4 performs rotational movement around a point  $O_{41}$ . When constructing the tangential component of the acceleration at point C  $\mathbf{a}_{Ct}$ . We will use the sentence of the viewing angles  $\beta_{At}$ , since we know  $\mathbf{a}_{Bt}$ . Normal component of the acceleration of point C  $\mathbf{a}_{Cn}$  we construct by the Euclidean construction by velocity  $v_C$  and axis of curvature of the trajectory of point C. For acceleration of the point D we obtain the expression:

$$\mathbf{a}_D = \mathbf{a}_C + \mathbf{a}_{DC} \quad (12)$$

we write:

$$\mathbf{a}_{Dt} + \mathbf{a}_{Dn} = \mathbf{a}_{Ct} + \mathbf{a}_{Cn} + \mathbf{a}_{DCt} + \mathbf{a}_{DCn} \quad (13)$$

where  $\mathbf{a}_{Dn} = 0$ .

In equation (13) we know component of the acceleration at point C, the tangential with  $\mathbf{a}_{Dt}$  and  $\mathbf{a}_{DCt}$ .

Normal component of the acceleration  $\mathbf{a}_{DCn}$  we construct by the Euclidean construction because we know the velocity  $v_{DC}$  and center of curvature of the trajectory of point C,  $S_{DC}=C$ . The tangential components of the acceleration  $\mathbf{a}_{Dt}$  and  $\mathbf{a}_{DCt}$  are collinear with the respective speeds.

We can construct the vector diagram of acceleration that detects the size and orientation of the acceleration  $\mathbf{a}_D = \mathbf{a}_{Dt}$  and  $\mathbf{a}_{DCt}(\mathbf{a}_{DC})$ .

The member 6 is moving translational. The acceleration  $\mathbf{a}_E$  of the point E is equal to the acceleration  $\mathbf{a}_D$ , because points E and D are lies in the same member 6, we write:  $\mathbf{a}_E = \mathbf{a}_D$ .

For angular velocity and angular acceleration of member 3 we write:

$$\omega_{31} = \frac{v_{BA}}{AB}, \quad (14)$$

$$\alpha_{31} = \frac{a_{BAt}}{AB}, \quad (15)$$

$$\omega_{31} = \frac{v_A}{AK_{31}} = \frac{v_B}{BK_{31}}. \quad (16)$$

The senses of values  $\omega_{31}$  a  $\alpha_{31}$  are designed according  $v_{BA}$  a  $\mathbf{a}_{BAt}$  and their location are given to the point A.

Angular velocity and angular acceleration of the member 4:

$$\omega_{41} = \frac{v_B}{BO_{41}}, \quad (17)$$

$$\alpha_{41} = \frac{a_{Bt}}{BO_{41}}. \quad (18)$$

Angular velocity and angular acceleration of the member 5:

$$\omega_{51} = \frac{v_{DC}}{CD}, \quad (19)$$

$$\alpha_{51} = \frac{a_{DCt}}{CD}, \quad (20)$$

$$\omega_{51} = \frac{v_C}{CK_{51}} = \frac{v_D}{DK_{51}}. \quad (21)$$

In Fig. 2 is the model in graphic form with velocities of points A and B.

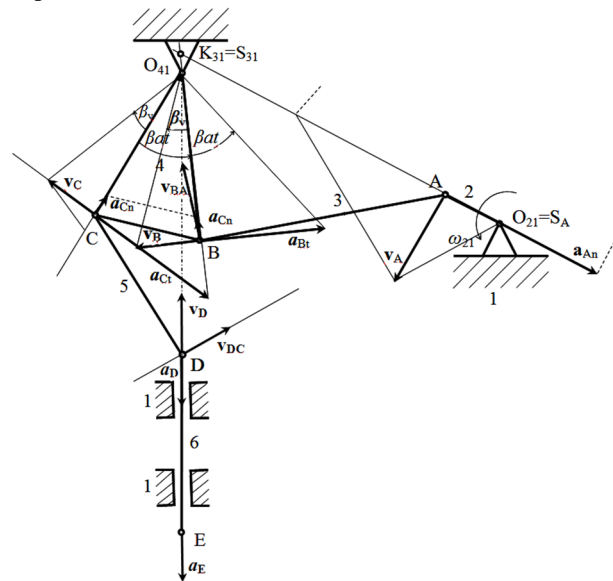


Figure 2 Mechanism with vertical motion - velocity vector of the point A and B

In Fig. 3a is the vector diagram velocity of the points A and B and the vector diagram velocity of the points C and D is on Fig. 3b.

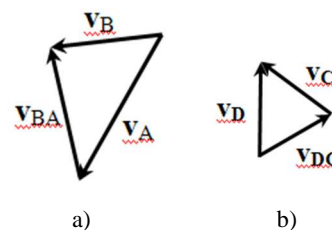


Figure 3 Vector diagram of the velocity a) of the point A and B, b) of the point C and D

#### 4 Simulation of the mechanism using MSC Adams/View

Six-member mechanism was modeled in MSC ADAMS/View. In the initial window of the program MSC Adams/View we set data folder, name of the project, units and the working grid. We created the individual bodies of the mechanism. We selected the rigid body geometry Link and Plate from the Toolbox.

We created member 2, 3, 5 and 6 with geometry Link. Member 4 we created with geometry Plate in next points (Fig. 5). We defined the geometry, length, width and depth of the link. As the first we created a member 4 through defined point (Fig. 4). As the first we created a member 4 through defined point (Fig. 4).

	Loc_X	Loc_Y	Loc_Z
POINT_1	-105.0	472.0	0.0
POINT_2	-415.0	80.0	0.0
POINT_3	-71.0	-27.0	0.0

Figure 4 Table editor with Point\_1, Point\_2 and Point\_3

The complete member 4 geometry plate is created on Fig. 5.



Figure 5 Creation of the points of the member 4 of mechanism

The member 4 should be rotated about  $O_{41}$ . Then connected the member 3 and 5 geometry Link with member 4 (Fig. 6).

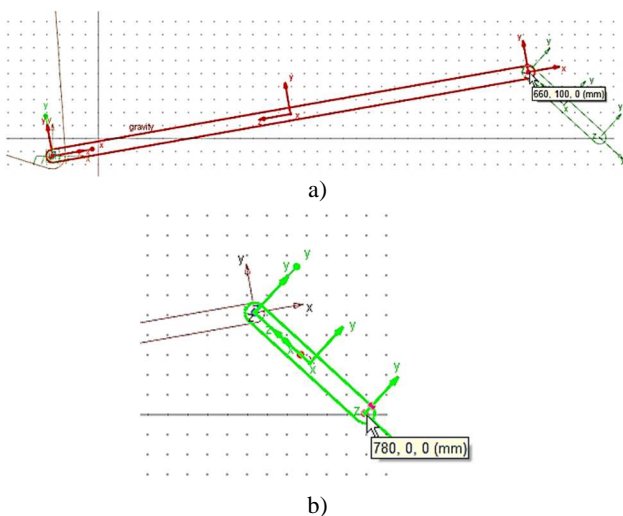


Figure 6 Creation of the model of mechanism: (a) member 3; (b) member 2

On Fig. 7a is shown member 5 and on Fig. 7b member 6 of mechanism. On Fig. 8a is basic model and on Fig.8b spatial model of mechanism.

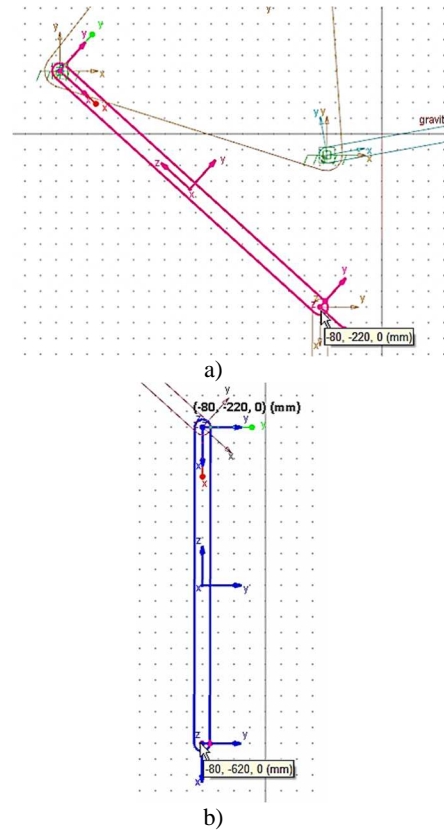


Figure 7 Creation of the model of mechanism: (a) member 5; (b) member 6

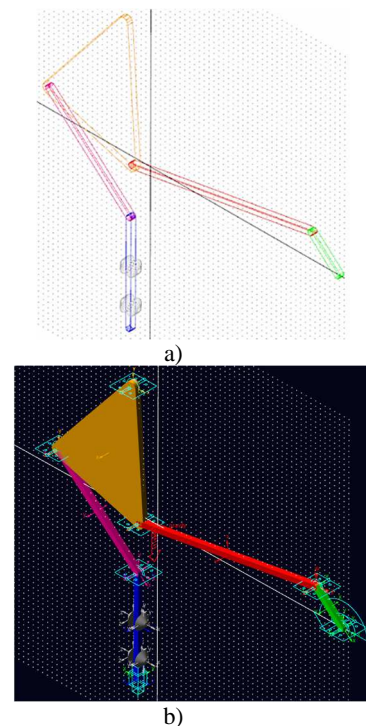


Figure 8 Creation of the model of mechanism: (a) basic model; (b) spatial model

On Figure 9 is shown position, velocity and acceleration of the center of mass of member 3.

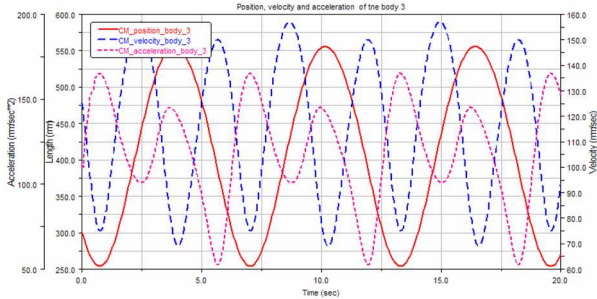


Figure 9 Position, velocity and acceleration of the center of mass of member 3

On Fig. 10 is shown position, velocity and acceleration of the center of mass of member 5.

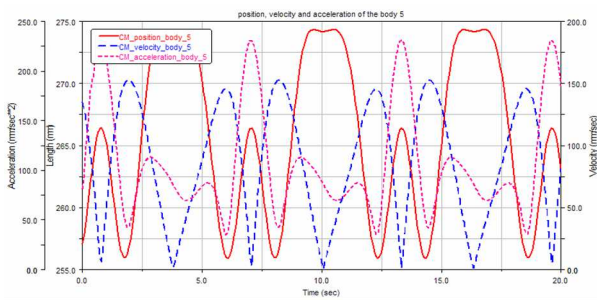


Figure 10 Position, velocity and acceleration of the center of mass of member 5

On Fig. 11 is shown position, velocity and acceleration of the center of mass of member 6.

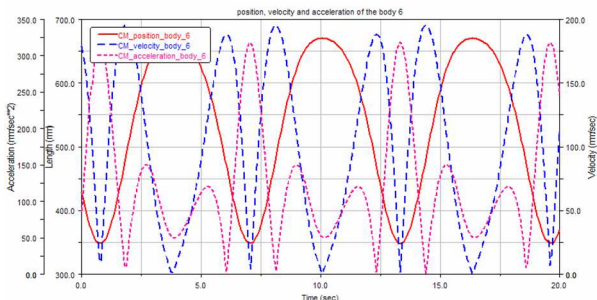


Figure 11 Position, velocity and acceleration of the center of mass of member 6

It is possible determine the result data for angle  $\varphi_{41}$ , angular velocity  $\omega_{41}$  and angular acceleration  $\alpha_{41}$  of the member 4 (Fig. 12).

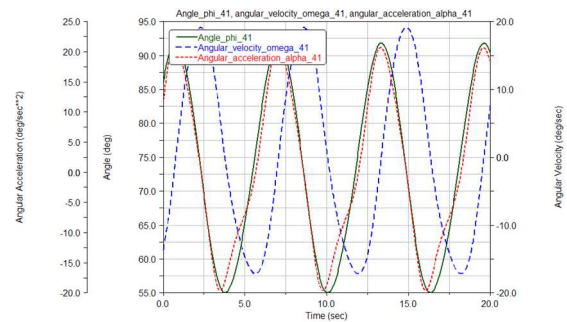


Figure 12 Angle  $\varphi_{41}$ , angular velocity  $\omega_{41}$  and angular acceleration  $\alpha_{41}$  of the member 4

In the window of the Postprocessor we selected window with animation of the mechanism and windows with results data in graphics form for angle  $\varphi_{41}$ , angular velocity  $\omega_{41}$  and angular acceleration  $\alpha_{41}$  of the member 4 (Fig. 13-15).

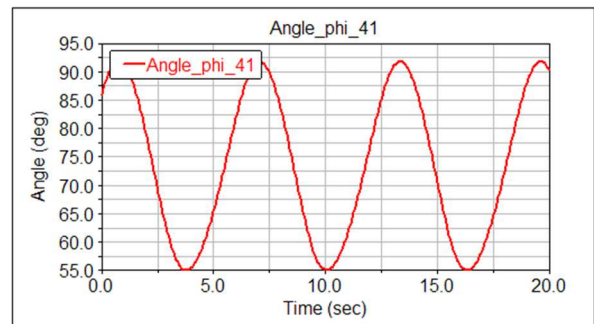


Figure 13 Angle  $\varphi_{41}$  of the body 4

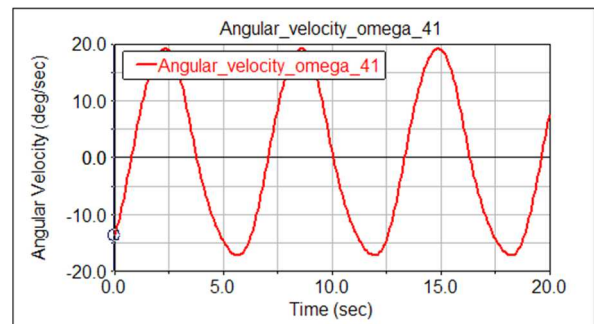


Figure 14 Angular velocity  $\omega_{41}$  of the body 4

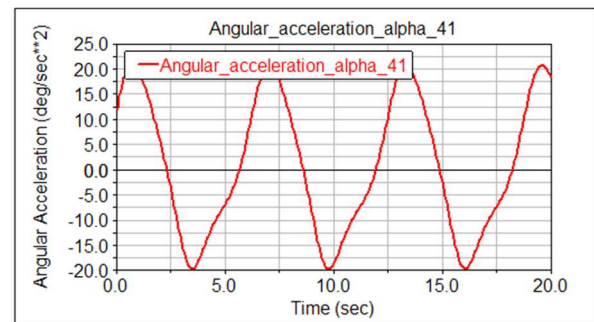


Figure 15 Angular acceleration  $\alpha_{41}$  of the body 4

## Conclusion

MSC ADAMS/View contains a specialized interface for creating virtual objects consisting of rigid and deformable parts linked to each other with different kinematics links. This allows create static, kinematics and dynamic analysis of virtual prototypes by computer simulation.

We investigated a functional model of a six-member mechanism. The whole modeling simulation was carried out by simulation program MSC ADAMS/View.

In the work is shown a procedure for solving kinematics problem of the mechanism using analytical and graphical solution and modeling in MSC Adams View. MSC Adams View allows simulate moving of such mechanical systems. Results are obtained in form of time diagram of the desired variables. Tasks are solved numerically model is compiled by using program MSC Adams View [4-7]. The results obtained by the simulation of six-member mechanism of the mechanism were processed by the postprocessor program of MSC Adams/View.

Program MSC Adams/View makes it easy to analyze complex mechanical systems with multiple degrees of freedom. In the paper one module of the number of modules namely MSC Adams/View was used as a tool which allows a better simulation and visualization of the model and easier evaluation of the results obtained. With the module MSC Adams/View they represent a tool that is able to addresses various types of mechanisms with many degrees of freedom. Mastering this methodology provides a suitable tool for solving problems of teaching and practice.

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## Review process

Single-blind peer reviewed process by two reviewers.