Dynamic Analysis of the Shaping Machine Mechanism

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Abstract This paper considers the problem of dynamic analysis of a shaping machine mechanism. Mathematical model for the mechanism was compiled and computer simulation was done in the program MSC Adams/View. The results of the computer simulation are kinematical parameters of individual members of the mechanism.

Keywords: mechanism, Equation of Motion, dynamic analysis, simulation, MSC Adams


1. Introduction

Development of mechanization and automation of production processes requires the construction of new machines and mechanisms. Today’s time forces us to technological development still improve and expedite the creation of new mechanical systems. Computer simulations bring ease to and accelerate the innovation of mechanical systems.

One of the most widely used software for dynamic analysis is MSC ADAMS (Automatic Dynamic Analysis of Mechanical Systems). MSC Adams includes a number of modules. MSC Adams/View module is used to for simulation and visualization of the model and it facilitate the evaluation of the analytical results. With Adams/Solver it forms a tool that allows us to deal with all types of MBS (multi-body systems) [4].

With the development of society also arises the need in progress in automation and mechanization of production processes. This creates the need for constructing new machinery and equipment. Instruments and machines consist of different mechanisms having substantially different functions and structure. Despite this fact a number of mechanisms have common basic functions and structure.

2. Mathematical Model of the Mechanism

The basic and also most universal method for the dynamic analysis of mechanical systems is the method which uses the second Newton’s law. The mathematical model of a four member mechanism in Figure 1 was derived by using this method. The driving torque Mh is exerted on the driving member 2. The resistive force F acts on the driven member 4 with the known geometric and mass properties. In the dynamical analysis the friction between respective members was neglected [1,2,3].

\[
m_4a_4 = -F + A_{34}, \quad (1)
\]

\[
I_4a_4 = C_{14}b_1 - Fh + A_{34}y_1, \quad (2)
\]

where \( m_4 \) is the weight, \( a_4 \) the acceleration, \( I_4 \) the moment of inertia and \( a_4 \) the angular acceleration of the member 4.

For member 4 stays that \( a_{4y} = 0 \) and \( a_{4} = 0 \). Thus the equations of motion have the form

\[
0 = -B_{14} + C_{14} - G_4, \quad (3)
\]

\[
0 = C_{14}b_1 - Fh + A_{34}y_1, \quad (4)
\]
while
\[ y_1 = b_2 - y_2 = b_2 - b \sin \varphi_2, \]

(5)

Figure 3. Analysis of member 3

Member 3 describe in Figure 3 of the mechanism performs curvilinear translational movement considering it as a particle. The equations of motion the member 3 are
\[ m_3 a_{3x} = A_{23x} - A_{43}, \]

(6)
\[ m_3 a_{3y} = - A_{23y} - G_3, \]

(7)
where \( m_3 \) is the mass of the member 3 and \( a_{3x}, \ a_{3y} \) are components of the acceleration of member 3.

By application of the principle of action and reaction stands \( A_{43} = A_{34} \).

Figure 4. Analysis of member 2

The member 2 performs rotational motion around a fixed axis of rotation perpendicular to the plane of movement and going through point \( O_{21} \). The sliding action of forces acting on member 2 is zero, therefore the equations of motion are
\[ O_{21x} - A_{32x} = 0, \]

(8)
\[ -O_{21y} + A_{32y} - G_2 = 0, \]

(9)
\[ I_{20} \alpha_2 = M_h + A_{32y} b \cos \varphi_2 - A_{32x} b \sin \varphi_2 - G_2 b / 2 \cos \varphi_2, \]

(10)
where \( A_{32x} = A_{23x}, A_{32y} = A_{23y}, I_{20} \) is the moment of inertia of member 2, \( \alpha_2 \) is the angular acceleration of member 2 and \( m_2 \) is mass of the member 2, while
\[ I_{20} = 1/3 m_2 b_2^2, \]

(11)
\[ x_A = x_3 = x_4 = -b \cos \varphi_2, \]

(12)
\[ a_{3x} = a_4 = b \alpha_2 \sin \varphi_2 + b \dot{\varphi}_2^2 \cos \varphi_2, \]

(13)
\[ y_A = y_3 = b \sin \varphi_2, \]

(14)
\[ a_{3y} = a_3 = b \alpha_2 \cos \varphi_2 - b \omega^2 \sin \varphi_2, \]

(15)

The movement of the system is described by a system of equations. Given the complexity of solving this system of equations the simulation in MS Adams is chosen as the further step in the analysis [8,9].

3. Simulation in MSC Adams/View

For dynamic analysis of individual members of a four-member mechanism we compiled its model in MSC Adams in Figure 5. After running the simulation we can measure the movements of individual members exerted by the driving force and observe the time diagrams of respective kinematical variables [5,6].

Between members 1 and 2 is rotational joint as well as between members 2 and 3. Member 3 also performs translational movement relative to member 4 therefore these members have also a translational joint. Measures are used to observe the forces in the joint \( A \) and \( O_{21} \) and are placed in the respective locations [7].

Figure 5. Model of the mechanism in MSC Adams/View

The next step is entering the boundary conditions and running the simulation in MSC Adams/View. The result of the simulation is the kinematical parameters of individual members of the mechanism. The individual measures in joints give the respective forces in a defined time interval. In time \( t = 0.25 \) s the force \( A = 10.02 \) N in Figure 7 and in Figure 8. The translational joint between member 3 and 4 was measured force \( A_{34} = A_{43} = 9.97 \) N in Figure 9.

Figure 6. Model with links and joints

Figure 7. Time diagram of force in joint A

Figure 8. Time diagram of force in joint \( O_{21} \)
Movement of member 3 is given by the displacement \( y_3 \), velocity \( v_3 \) and acceleration \( a_3 \). Their time diagrams are in Figure 10.

Member 2 performs rotational movement around the pivot and is rotated by angle \( \phi_{21} \) relative to the base i.e. the member 1. In the Figure 11 there is the time diagram of the rotation angle \( \phi_{21} \). The time diagram of the angular velocity \( \omega_{21} \) of member 2 is in Figure 12.

Movement of member 4 is given by displacement \( x_4 \), velocity \( v_4 \) and acceleration \( a_4 \).

The time diagram of these parameters is in Figure 13, Figure 14, Figure 15 and Figure 16.
4. Conclusion

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 Adams/Solver they represent a tool that is able to addresses various types of mechanisms with many degrees of freedom. The results obtained by the simulation of four-member mechanism of the shaping machine were processed by the postprocessor program of MSC Adams/View.

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