

DESIGN ALGORITHM OF THE WINDSHIELD WIPER MECHANISMS OF THE PASSENGER VEHICLES

**Cătălin Alexandru
University "Transilvania" of Braşov
29 Bd. Eroilor, 500036 Braşov
Romania**

ABSTRACT

In this paper, we attempt to present the design algorithm of the windshield wiper mechanisms. In order to analyze the windshield wiper mechanisms, three mechanical models are developed: kinematic model – to evaluate and optimize the kinematic function of the mechanism; inverse dynamic model – to determine the crank turning torque applied to the input element in order to generate the kinematically prescribed behavior; dynamic model – to evaluate the "real" behavior of the wiper system (i.e. the virtual prototype), under the force action.

Keywords: motor vehicle, windshield wiper mechanism, multibody system.

1. INTRODUCTION

Important publications reveal a growing interest in analysis methods for multibody systems that may facilitate the self-formulating algorithms, having as main goal the reducing of the processing time in order to make possible real time simulation. These methods were used to develop powerful modeling and simulation programs (MBS - MultiBody Systems) that allow building and simulating a virtual model of any mechanical system in a fraction of the cost of traditional hardware prototyping [3].

Virtual prototyping has become very important in the automotive industry. Every major manufacturer uses virtual prototyping platform to refine and prove out their suspension design, vehicle dynamics, engine design, powertrain engineering, body hardware engineering, tire - roadway interaction, driver behavior, controls design, safety systems, vehicle durability. Regarding the body hardware engineering, the virtual prototyping is frequently used in door, trunk, and hood latch design, trunk and hood hinge linkage design, seat mechanism design, window mechanism design, windshield wiper simulation and so on [1].

Regarding the windshield wiper mechanisms, these are vehicle-specific systems in which the wiping motion is transferred from the wiper motor to the pivot-shaft assemblies via linkages. A compact wiper system consists of the following components: wiper motor with thermo-switch, wiper gearing, motor crank, steel baseplate, crank linkage, and pivot-shaft assembly with oscillating crank [6].

In this paper, we attempt to present the analysis algorithm of the windshield wiper mechanisms. Considering a tandem pattern double-lever wiper system, the kinematic & dynamic analysis is made using the MBS software ADAMS of MSC. At the same time, the controlling of the mechanical model is made using ADAMS/Controls and MATLAB. The modeling of the windshield wiper mechanisms as multibody systems, in order to performe the analysis with MBS environment, was presented in [2].

2. ANALYSIS ALGORITHM

In ADAMS, the steps to create a virtual model of the windshield wiper mechanism mirror the same steps to build the physical model, as follows: build - create parts, constrain the parts (geometric restrictions), create forces and torques acting on the parts; test - measure characteristics, perform simulations, review numeric results as plots; validate - import test data, superimpose test data on plots; refine - add friction, define flexible bodies, implement force functions, define controls.

The analysis of the wiper systems is made having in view to determine specific parameters, as follows: the parking position, the wiping angle, the wipe-pattern size, and the reaction forces. The input data consist of: windshield size, installation point for drive unit, and clamping length (maximum thickness of the sheet steel to which the pivot-shaft assembly is fastened).

In order to analyze the windshield wiper mechanisms, three mechanical models are developed (fig. 1):

a. kinematic model – contains the rigid parts from the wiper mechanism, connected through geometric constraints (joints), and the geometric parameters that define the mechanism; the input is made using a kinematic restriction, applied in the joint between the motor crank and the body's baseplate, which controls the angular position / velocity of the motor crank;

b. inverse dynamic model – includes the kinematic model and, in addition, the external & internal loading (the friction forces between the wiper blade and windshield, and the mass characteristics); this model is used to determine the turning moment applied to the motor crank;

c. dynamic model – includes the inverse dynamic model, but the input is made through the above-determined torque; the aim is to evaluate the “real” behaviour of the wiper system (virtual prototype).

As example, a tandem pattern double-lever wiper system (corresponding to a domestic passenger car) is considered. The windshield wiper mechanism contains two four-bar spatial linkages (fig. 2): ABCD – command mechanism, from the motor crank to the left wiper arm / lamella, and DC'FE – connection mechanism, which transmits the revolute motion to the right wiper arm / lamella.

The 3D-solid model was made using CAD software (CATIA). The geometry was transferred to ADAMS using the STEP format. The wiper blade was modelled with FEA software (NASTRAN), the transfer to ADAMS being made by the MNF file format.

The motor crank (1) and the left & right wiper arms (3, 5) are connected to the grounded part (i.e. car body) using revolute joints A, D, and E. The crank linkages (2, 4) are connected to the motor crank, respectively to the wiper arms, using spherical joints B, F and cylindrical joints C, C', respectively. The degree of mobility of the wiper system is: $DOM = 6 \cdot n - \sum r_g = 30 - 29 = 1$, where “n” represents the mobile parts (bodies) and “ $\sum r_g$ ” is the number of geometric constraints. The kinematic and inverse dynamic models are controlled using a motion generator, $\varphi_1(t) / \omega_1(t)$. For the dynamic model, the kinematic constraint is replaced by the motor torque applied to the input crank.

The friction forces that act on the wiper blades depend on the friction coefficient between rubber and windshield, and the normal force generated by the spring mounted between arm and oscillating crank. The direction of the friction force depends on the sign of wiper arm's velocity, which is modelled in ADAMS by the SIGN function (using Function Builder) [5]. This function transfers the sign of one

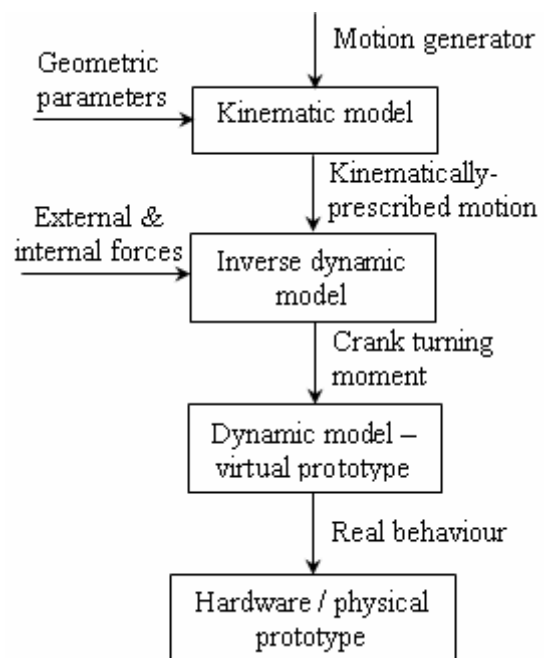


Figure 1. Analysis flow-chart.

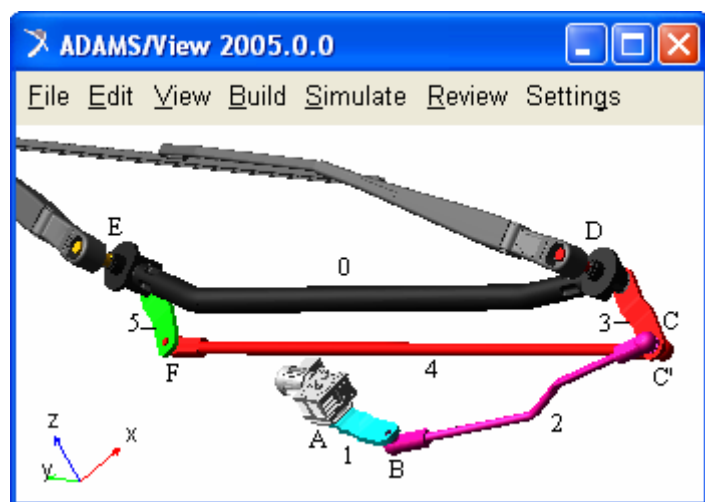


Figure 2. Tandem pattern double-lever wiper system.

expression representing a numerical value to the magnitude of another expression representing a numerical value, as follows: $SIGN(a1, a2) = ABS(a1)$ if $a2 \geq 0$, $SIGN(a1, a2) = -ABS(a1)$ if $a2 < 0$. In our case, “a1” represents the friction force’s magnitude, and “a2” is the angular velocity of the wiper arm.

In order to obtain the torque that move the motor crank, a control system is developed using ADAMS/Controls and MATLAB. ADAMS/Control is a plug-in to ADAMS/View that allows integrating motion simulation and controlling system design in the virtual model. ADAMS/Controls allows connecting the ADAMS model to block diagrams that are developed with control applications.

The four-step process of combining controls with a mechanical system involves (fig. 3): build the virtual mechanical model, which includes all necessary geometry, constraints, forces; identify the ADAMS inputs and outputs - the outputs describe the variables that go to the controls application, and the inputs describe the variables that come back into ADAMS; build the block diagram - build the control system block diagram with a control software, and include the ADAMS plant in the block diagram; simulate the combined mechanical model and control system.

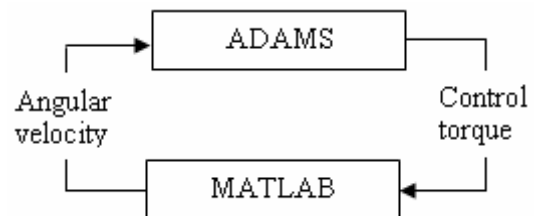


Figure 3. Combining controls with the mechanical system.

To drive the wiper mechanism, a CC electric motor (having the input voltage V) is used, so that the objective is to control the angular velocity ω of the motor crank, which is perturbed with the crank turning moment T (fig. 4). This torque is obtained having in view the mechanical model of the wiper mechanism, on which act the external forces (i.e. the external environment). The transfer functions $G_T(s)$ and $G_V(s)$ depend on the motor characteristics, using Laplace’s transformation [4].

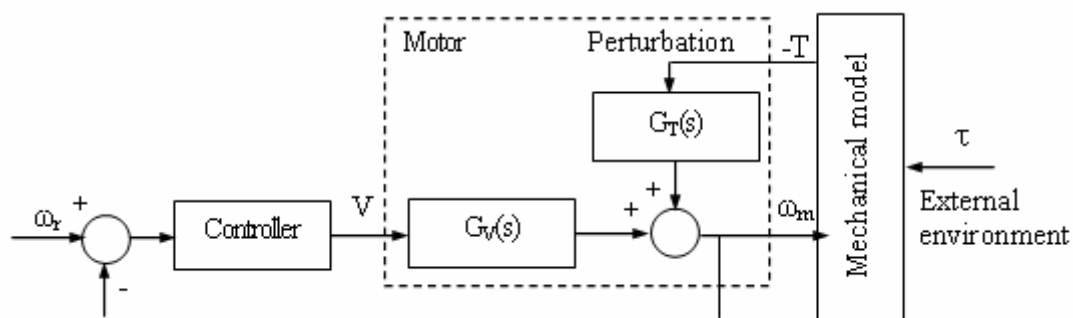


Figure 4. Control system block of the windshield wiper mechanism.

The input in the windshield wiper model is the angular velocity of the motor crank. The output, which will be transmitted to the controller, is the crank turning moment. ADAMS/Controls and control application communicate by passing state variables back and forth. Therefore, it is necessary to define the model’s input and output variables, and the functions that those inputs and outputs reference, with a set of ADAMS state variables.

For the input state variable, representing the angular velocity of the motor crank, the run-time function is 0.0 during each step of the simulation, because the velocity will get its value from the control application. The run-time function for the input variable is VARVAL(angular_velocity), where VARVAL (Variable Value) is an ADAMS function that returns the value of the given variable [5]. In other words, the input angular velocity gets its value from the input variable.

For the output state variable, representing the crank turning moment, the run-time function returns the sum of torques on body (motor crank) at location (a marker placed in the joint between motor crank and chassis). Thus, the function assigns the motor torque to the output state variable.

The next step is for exporting the ADAMS plant files for the control application. The Plant Input refers the input state variable (angular_velocity), and the Plant Output refers the output state variable (control_torque). ADAMS/Controls save the input and output information in an “*.m” file (specific for MATLAB). It also generates a command file (*.cmd) and a dataset file (*.adm), which will be used during the simulation process.

With these files, the control system block is created in MATLAB/Simulink, in order to complete the link between the controls and mechanical systems. ADAMS/Controls and MATLAB communicate by passing state variables back and forth. ADAMS accepts the control inputs from MATLAB and integrates the mechanical model in response to them. At the same time, ADAMS provides the control torque information for MATLAB to integrate the Simulink model. This simulation process creates a closed loop in which the control inputs from MATLAB affect the ADAMS simulation, and the ADAMS outputs affect the control input levels.

3. RESULTS AND CONCLUSIONS

According to the above-presented design algorithm, and considering the wiper mechanism shown in figure 2, specific results are obtained in order to evaluate the kinematic and dynamic behavior of the windshield wiper system. For example, in figure 5, there are presented the time - history variations of the angular velocity of the motor crank, the crank turning moment, and the wiping angle described by the left wiping arm / lamella. The results correspond for two complete rotations of the motor crank ($2 \times 360^\circ$). The control system generates the angular velocity of the motor crank: in the regime phase, $\omega_1 \cong 360$ [degrees/second].

Driving the mechanism by using the motor torque is more realistic than attaching a motion generator to the input crank and driving the motion directly. By applying a torque, we can look at issues related to motor size in an actual mechanical system.

The application presented in this paper is a typical example of virtual prototyping of the windshield wiper mechanisms using multibody systems environment. One of the most important advantages of this kind of analysis - simulation is the possibility to perform, fast and easy, virtual measurements in any point and/or area of the system and for any parameter. This is not always possible in the real cases due to the lack of space for transducers placement, lack of appropriate transducers or high temperature. This helps designers to make quick decisions on any design changes without going through expensive prototype building and testing.

The Romanian Ministry of Education financially supported the publishing of this paper in the frame of the CNCIS research grant - code 1321 / 2006.

4. REFERENCES

- [1] Alexandru C.: Simulation of the mechanical systems, Lux Libris Publisher, Braşov, 2000,
- [2] Alexandru, C., Barbu, I.: Modeling of the windshield wiper mechanisms as multibody systems, The 9-th International Conference TMM'04, Liberec, Czech Rep., p. 29-34, 2004,
- [3] Haug, E.J.: Computer aided kinematics and dynamics of mechanical systems, Allyn & Bacon Publisher, 1989,
- [4] Pozna, C.: Analysis of the automated systems, MatrixRom Publisher, 2003,
- [5] *** Getting started using ADAMS, MSC Software, 2005,
- [6] *** Wiper systems for commercial vehicles, Robert Bosch GmbH, 1997.

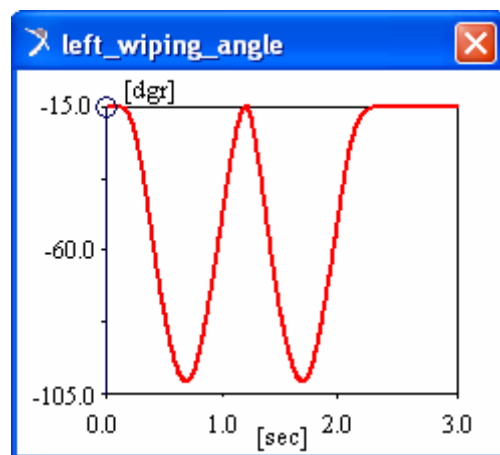
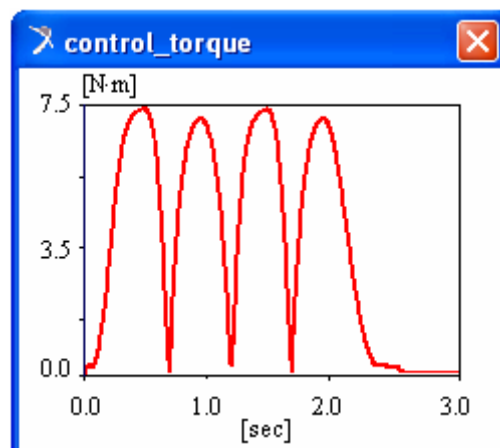
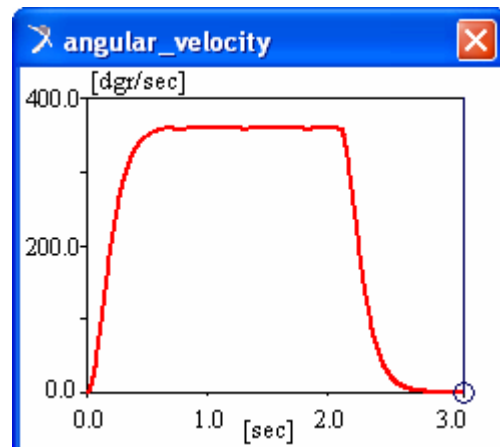


Figure 5. Postprocessing results.