Geometric optimization of the windshield wiper mechanisms using virtual prototypes

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Abstract In this paper, the geometric optimization of the windshield wiper mechanisms of the motor vehicles is performed, considering as example the wiper system of a domestic passenger car, DACIA type. Using a virtual prototype that was modeled with the mechanical system analysis and simulation software ADAMS makes the optimization. Parameterizing the model, by transforming some geometric characteristics from the wiper system in design variables, design studies and design optimization were performed, having in view different specific objective functions that describe the behavior of the wiper mechanism.

Keywords: windshield, wiper system, virtual prototype, optimization.

1. Introduction

The increasingly growing demand for more comfortable vehicles imposes a new way for kinematic and dynamic analysis of the different subsystems, including the windshield wiper mechanism, by taking into consideration virtual models that are closer to the physical models on the vehicle. In this way, the complexity of the theoretical model is increasing, and for this reason such models can't be analyzed with classical methods and programs.

Therefore, it is necessary to use mechanical systems analysis and simulation environments, namely MBS (Multi-Body Systems) software. These programs automatically formulate and solve the kinematic and dynamic equations taking into consideration the geometric - elastic model of the system. This technology is called Virtual Prototyping and consists mainly in conceiving a detailed model and using it in a virtual experiment, in a similar way with the real case. Virtual Prototyping solution allows important advantages, such as: reduces time and cost, reduces the product cycles, reduces the number of expansive physical prototypes, allows making virtual measurements in any point and area of the system and for any parameter, and optimizing the wiper system long before building the physical prototype.

In the last years, the author realized a series of researches, including scientific papers, in the field of analysis, optimization and simulation of the mechanical system using commercial multibody systems environments.

In this paper, the geometric optimization of a virtual prototype for a windshield wiper mechanism (DACIA type) is presented. The virtual prototype of the wiper system was made using the multibody systems software ADAMS. Parameterizing the prototype, defining the design variables, defining the objective function for optimization and performing design study makes the optimization.

2. Wiper System

The windshield wiper mechanisms 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 base-plate, crank linkage, pivot-shaft assembly with oscillating crank, and second pivot-shaft assembly with plate (for parallel wipe pattern), respectively. The linkage forces are supported by the sheet metal of the car body.

For the present-day vehicles, the following wiper systems are frequently used: single-lever systems with parallel wipe patterns, single-lever systems with sector wipe patterns, opposed-pattern double-lever systems with parallel wipe patterns, opposed-pattern double-lever systems with overlapping sector wipe patterns, tandem-pattern double-lever systems with overlapping sector wipe patterns, tandem-pattern three-lever systems with extra-wide overlapping sector wipe patterns.

For this paper, a tandem pattern double lever wiper system (corresponding to a domestic passenger car – DACIA type) was considered (fig. 1). The wiper mechanism contains two planar four-bar linkages: ABDE – to command the right wiper arm & blade, and ACFG – to command the left wiper arm & blade, the connections between elements being made through revolute joints.

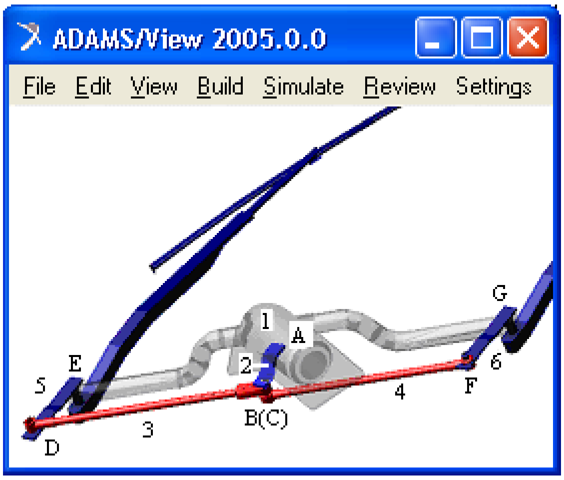


Fig. 1: tandem pattern double lever wiper system.

The wiper mechanism has one degree of freedom, namely the rotation of the motor crank. For the kinematic model, a motion generator kinematically controls this degree of freedom. Considering the input speed n_2 = 60 [rot/min], will results the kinematic constraint: $\omega_2 = \pi n_2 /30 = 6.28$ $\rightarrow \varphi_2 = \omega_2 t = 6.28$ t [rad/sec].

The analysis of the wiper mechanism is made having in view to determine the specific parameters that define the kinematic behavior: parking position (the wiper arm's rest position on the windshield), wiping angle, and wipe-pattern size. The input data consist from the windshield size, the installation point for drive unit, and the clamping length.

3. Optimization Process

The optimization of the virtual prototype is made with the following steps: parameterizing the prototype, defining the design variables, defining the design objective for optimization, performing design study, and optimizing the model on the basis of the main design variables.

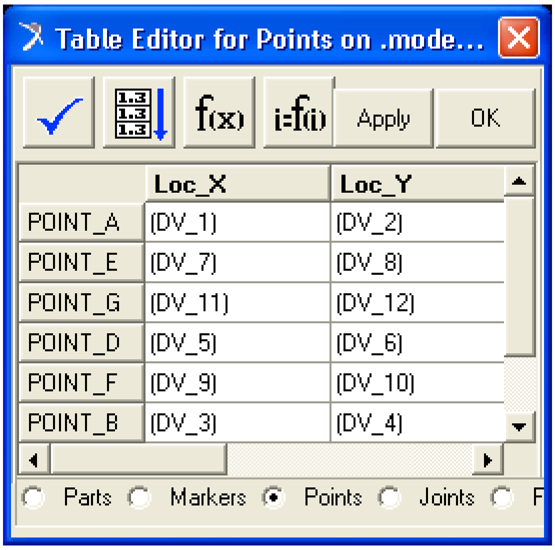
The parameterization of the wiper mechanism is made by the points that define the structural model, in fact the locations of the kinematic joints (see fig. 1). The parameterization simplifies changes to model because it helps to automatically resize, relocate and orient parts. In this way, relationships into the model are created, so that when a point is changed, any other objects (bodies, joints) that depend on it will be updated.

Design variables represent elements in model that allow creating independent parameters and tie modeling objects to them. In our case, the design variables represent the locations for the design points. Design variable allows running automated simulations that vary the values of the variable over specified ranges to understand the sensitivity to the variable or to find the optimum values.

In addition, using design variables, design studies can be performed. Design study represents a set of simulations that help to adjust a parameter to measure its effect on the performance of the wiper system model. Design study describes the ability to select a design variable, sweep the variable through a range of values and then simulate the motion behavior of the various designs in order to understand the sensitivity of the overall system to these design variations. As result, design study allows to identify the main design variables, with great influence on the behavior of the wiper system.

Therefore, for beginning, the points that define the structural model of the windshield wiper system were modeled in the global coordinate frame, which is an inertial frame attached to car body. Afterwards, the geometry of the bodies and the locations of the joints from the wiper system were attached to the design points. Thus, when a coordinate will be modified, the objects that depend on it (bodies, joints) will be accordingly changed.

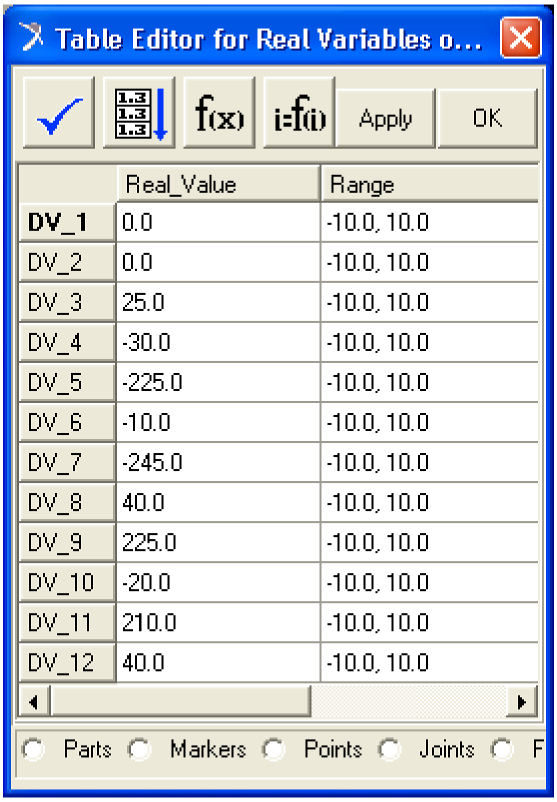
In the next step, the global coordinates of the points were transformed in design variables, having in view to control the virtual model in the optimization process. Each coordinate is a design variable, therefore for the above-described planar wiper mechanism, 12 design variables will result, as follows (XY is the plane of motion): DV_1 → X_A, DV_2 → Y_A, DV_3 → X_B, DV_4 → Y_B and so on (fig. 2). To create design variables, in the table editor for points, select the cell for the coordinate that will be parameterized, right-click the Input text box, point to Parameterize, point to Create Design Variable, and then select Real. In this way, ADAMS creates a variable with the initial value, inserts an expression into the text box, and modifies the point to use the design variable as the coordinate value.



	Loc_X	Loc_Y
POINT_A	(DV_1)	(DV_2)
POINT_E	(DV_7)	(DV_8)
POINT_G	(DV_11)	(DV_12)
POINT_D	(DV_5)	(DV_6)
POINT_F	(DV_9)	(DV_10)
POINT_B	(DV_3)	(DV_4)

Fig. 2: table editor for design points.

The initial value (real value) and the variation field (range) for each design variable, shown in figure 3, can be modified in order to keep the wiper system in rational constructive limits.



	Real_Value	Range
DV_1	0.0	-10.0, 10.0
DV_2	0.0	-10.0, 10.0
DV_3	25.0	-10.0, 10.0
DV_4	-30.0	-10.0, 10.0
DV_5	-225.0	-10.0, 10.0
DV_6	-10.0	-10.0, 10.0
DV_7	-245.0	-10.0, 10.0
DV_8	40.0	-10.0, 10.0
DV_9	225.0	-10.0, 10.0
DV_10	-20.0	-10.0, 10.0
DV_11	210.0	-10.0, 10.0
DV_12	40.0	-10.0, 10.0

Fig. 3: table editor for design variables.

The design objectives are represented by the parameters that describe the kinematic behavior of the system (see chapter 2). In this paper, the wiping angle was considered as goal for optimization. For beginning, measures that define the wiping angles for the left and right arms were modeled using the part’s orientation by Euler angles (fig. 4), and then the design objectives were attached to these measures (fig. 5).

In order to increase the wiping angles, the maximum absolute values during simulation were taken into account. The design studies were performed to identify the influence of the design variables on the design objectives.

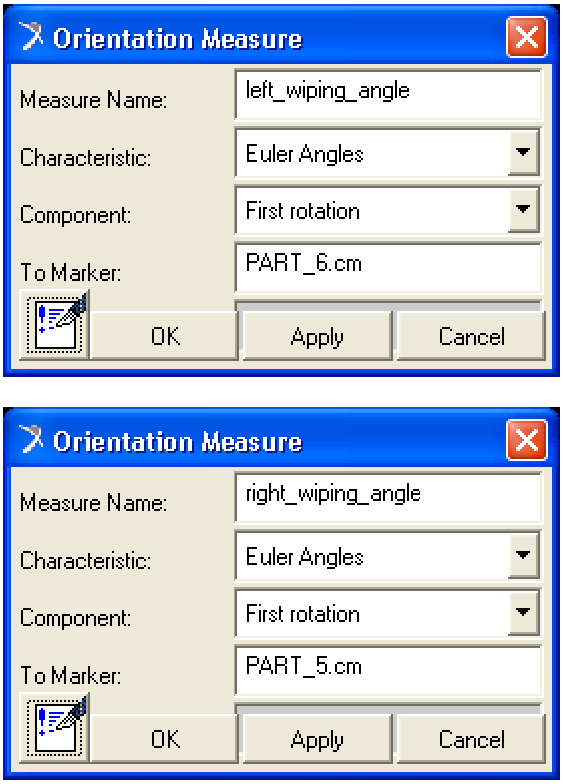


Fig. 4: measures that define the wiping angles.

4. Results and Conclusions

The design studies were successively performed for each design variable, in their variation fields (ranges). In this way, two types of design variables are obtained: main variables (with great influence on the design objectives), and secondary variables (their influence can be neglected). As example, in figure 6-10, the influences of some design variables on the above described design objectives (left & right wiping angles) are shown.

Finally, analyzing such comparative results, the following main design variables were identified (see fig. 1 - 3): DV_1, DV_2, DV_3, DV_5, DV_7, DV_9, and DV_11 (DV_5 & 7 - only for OBJECTIVE_2, DV_9 & 11 - only for OBJECTIVE_1). Afterwards, considering the main design variables makes the optimization of the wiper system. However, because DV_1, DV_2, DV_7 and DV_11 are assigned to the fixed points on car body (A, E, and G), only DV_3, DV_5, and DV_9 will be taken into consideration.

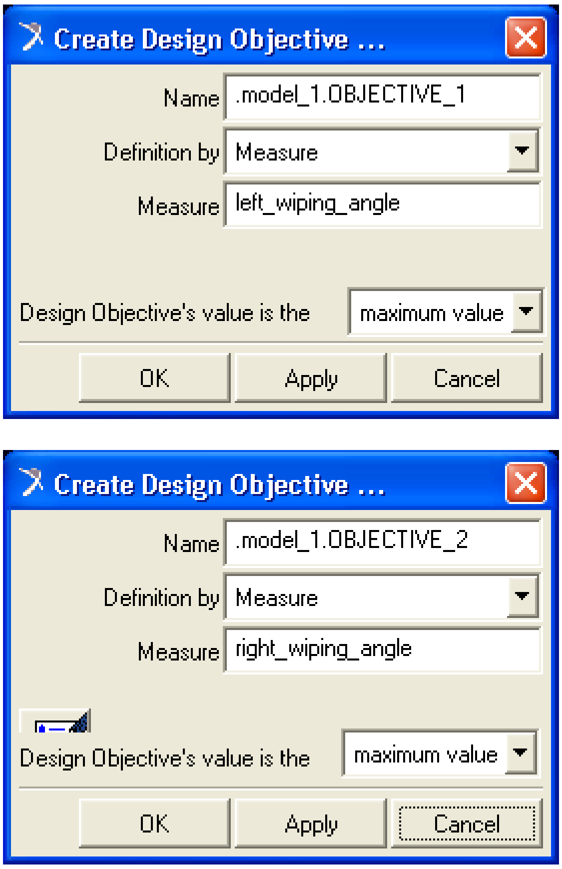


Fig. 5: design objectives defined by wiping angles.

The optimized values of the specific design variables are: DV_3: 26.639, DV_9: 220.45 [mm], which correspond to the maximum absolute value of the design objective - 136.78° (for comparation, the initial value is 122.9°).

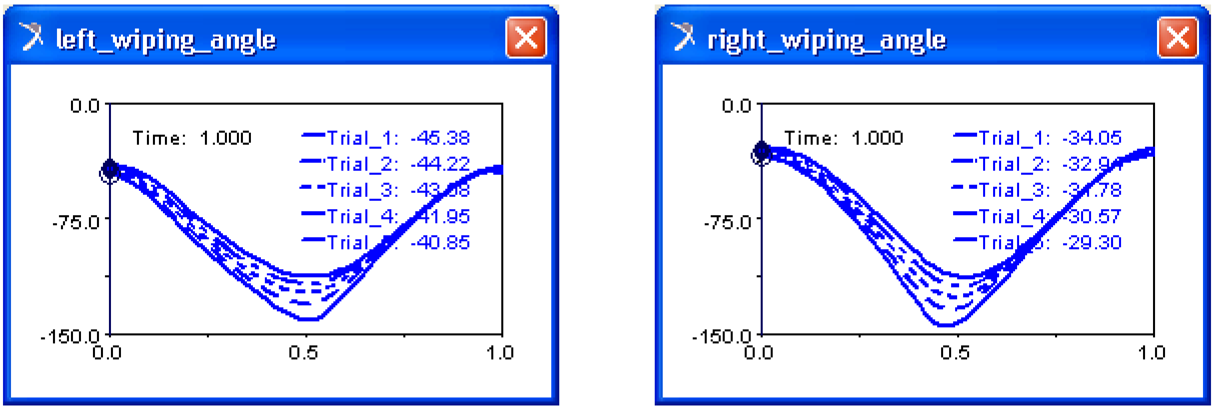


Fig. 6: design study results for DV_1 (X_A).

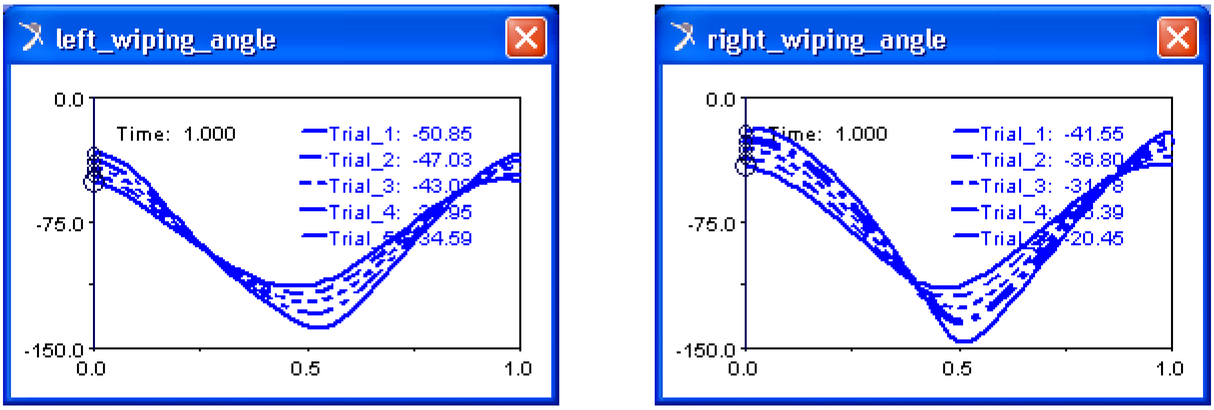


Fig. 7: design study results for DV_2 (Y_A).

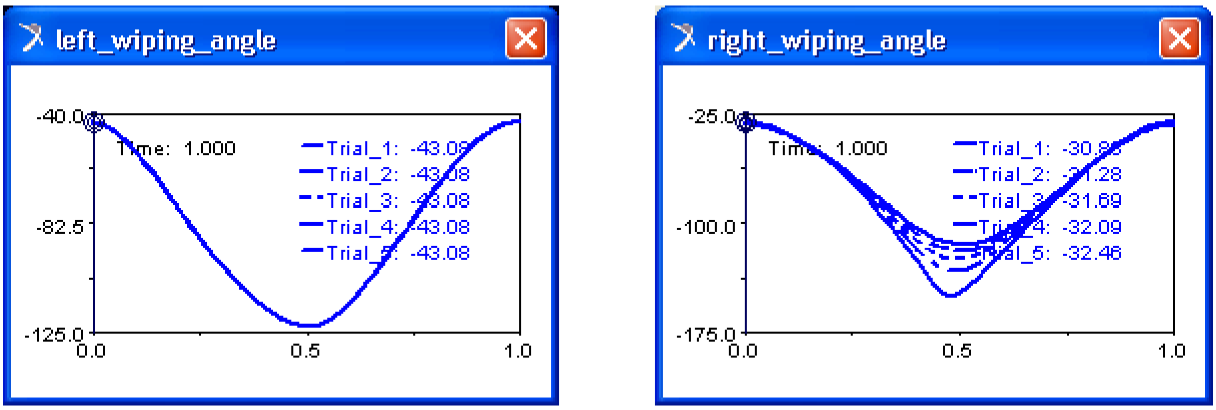


Fig. 8: design study results for DV_5 (X_D).

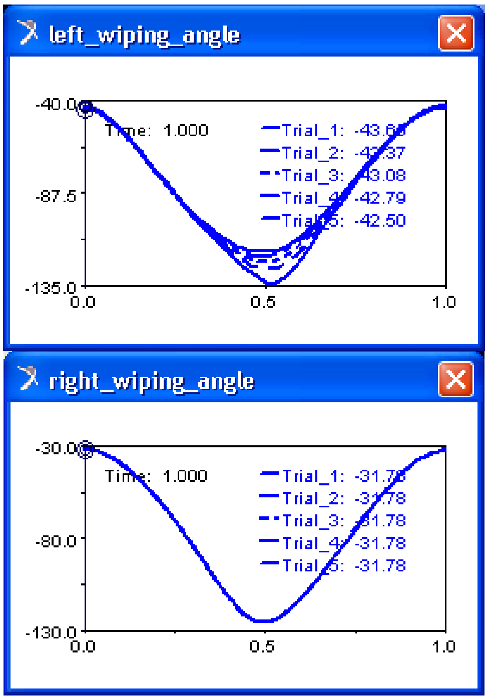


Fig. 9: design study results for DV_9 (X_F).

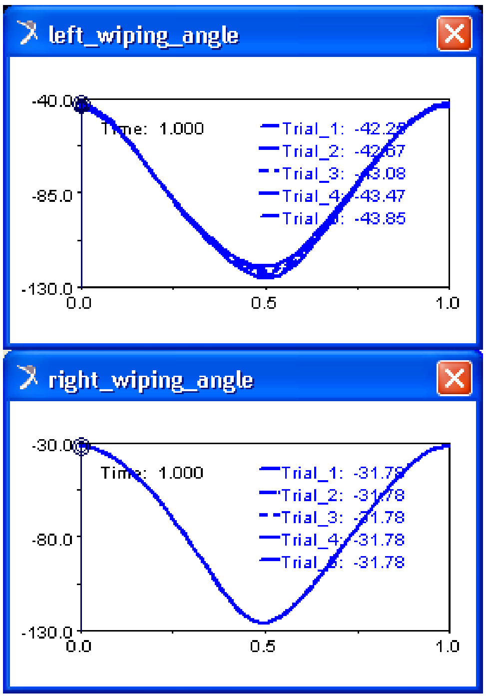


Fig. 10: design study results for DV_10 (Y_F).

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