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## DRIVE MECHANISM ANALYSIS OF DOOR WINDOWS TO ROAD VEHICLES

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**Abstract:** This paper is meant to present a description as well as a classification of the mechanisms for manipulating the windows of road vehicles. A life-size 2D modeling was performed for the handling mechanism with two arms crossed and motorized drive. A structural, kinematic and kinetostatic computer assisted analysis was made using SAM in actual operating conditions.

**Keywords:** mechanism, kinematic analysis, kinematic joint

### 1. INTRODUCTION

With the development of the car making industry, in addition to an increase in cars' technical performance, as well as the development of engines, transmissions, the improved aerodynamics of bodywork, the electronic systems (on-board computer) or of the passive safety features, automobile manufacturers insist increasingly more on the driver and passenger comfort, the cabin ergonomics, and on the idea that the driver in particular and passengers make a minimal effort to handle various parts of the vehicle systems. This can be achieved by "mechanization" of these systems, as well as by placing the actuation commands within the driver's reach.

One of these systems is the motorized drive mechanism to the windows. With different vehicles we can find several variants for the drive of the windows. Some of these are presented below.

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- Window actuator mechanism with cable reel and drum (Figure 1): is a mechanism that is directly connected to the window carrier rail, and is activated by a drum. This type of mechanism is used primarily to drive the rear door windows of motor vehicles.

- Window drive mechanism with hydraulic cylinder (Figure 2): it is a mechanism with fixing points close to the window, guided on either side by

the rail fixed to the door of the vehicle. The guiding rail of this mechanism can be curved following the curvature of the window glass.

- Window drive mechanisms with articulated bars, single arms, (Figure 3), with two arms crossed with motorized drive (Figure 4), and with manual drive (Figure 5).

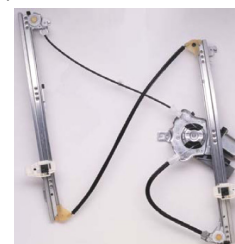


Figure 1. Drive mechanism with cable reel and drum

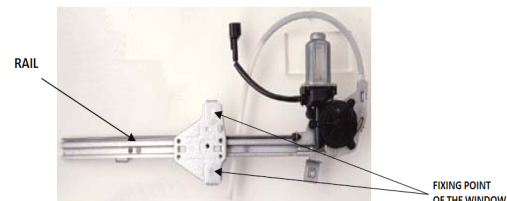


Figure 2. Drive mechanism with hydraulic cylinder



Figure 3. Single arm driver mechanism

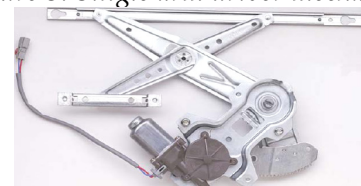


Figure 4. Two arms crossed mechanism with motorized drive

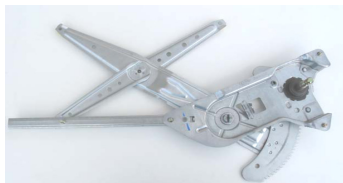


Figure 5. Two arms crossed mechanism with manual drive

The variant of window driver mechanism to road vehicles under study beneath is that with articulated bars, with two arms crossed with motorized drive (Figure 4).

Since both front doors (if applicable the rear ones two) of the vehicle are equipped with motorized mechanism for manipulating the windows, they will have a symmetric structure (Figure 6).

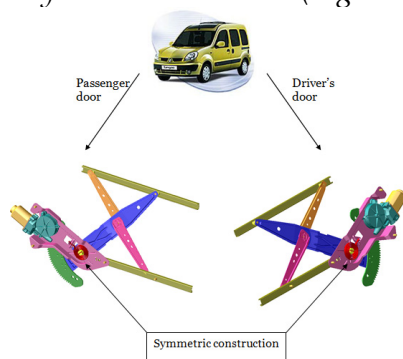


Figure 6. Symmetric construction of the drive mechanism

With the kinetostatic study and analysis of the drive mechanism of the window, its external loads must be taken into account, i.e. the weight of the glass ( $P = 30$ ) and the resistance of the window guide ( $R_g$ ). The layout of these external loads for lifting and lowering movements is shown in Figure 7.

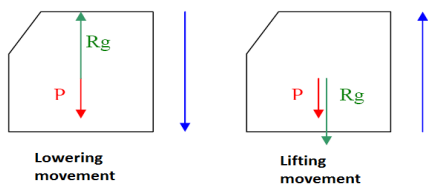


Figure 7. External loads of the mechanism

To end with, for the study of the mechanism of the motorized window drive the following is considered:

- ✓ The mechanism should operate smoothly and vibration free
- ✓ The tare weight of the glass is  $P = 30$
- ✓ The estimated resistance force of the window guide:  $R_g = 50$  N
- ✓ The most adverse condition, from the point of view of loads, is when lifting the window ( $P + R_g = 80$  N)

## 2. STRUCTURAL ANALYSIS OF THE HANDLING MECHANISM

The kinematic diagram of the mechanism for handling the windows in the doors of road vehicles is shown in Figure 8, and has the following technical characteristics (from the design theme) and geometric dimensions (resulting from the design of the mechanism):

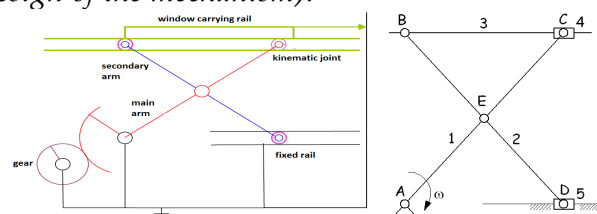


Figure 8. Kinematic scheme of the drive mechanism

- ✓ lifting/lowering strokes - 510 mm
- ✓ time for window lifting - 10 s
- ✓ time for window lowering - 10 s
- ✓ the angle of rotation of the driving element for the lowering stroke - 97 degrees, and for the lifting stroke - 97 degrees
- ✓ loading of the mechanism for lifting stroke (adverse event) - 80 N

Geometrical dimensions of the constitutive kinematic elements:

- $l_1$  (main arm) = 340 mm
- $l_2$  (secondary arm) = 340 mm
- $l_3$  (window carrying rail) = 400 mm

By analyzing the kinematic diagram of the mechanism (Figure 8) the following may be specified:

- ✓ The mechanism consists of five mobile cinematic elements ( $n$ ), main arm (1), secondary arm (2), window carrying rail (3) and background (4) and (5).
- ✓ The mechanism consists of seven kinematic couplings class V ( $C_5$ ), A (R 0-1), B (R 2-3), C (R 1-4), C (T 3-4), D (R 2-5), D (T 0-5) and E (R 1-2)
- ✓ The mechanism can be considered plane, so the family will be three.

Thus:  $f = 3$ ;  $n = 5$ ;  $C_5 = 7$ .

The number of degrees of mobility of the mechanism is given by the equation (1):

$$M = 3n - 2C_5 = 3 \cdot 5 - 2 \cdot 7 = 1 \quad (1)$$

The number of degrees of mobility being equal to 1, the drive mechanism is well defined (desmodrom), i.e. each position of the leading element has specified positions of the other kinematic elements.

**Kinematic analysis of the driving mechanism**

The kinematic analysis of the drive mechanism using the program SAM51 was done for the kinematic cycle consisting of the lifting phase, as well as the lowering phase of the window and implies the following steps.

- Modeling of mechanism: the mechanism will shape the least extreme position, based on the coordinates of kinematic couplings, resulting from the geometric synthesis: Coupling 1-A (0,0); Coupling 2 - E (112.44, -127.5); Coupling 3 (R + T) - C (224.89,-255); Coupling 4 (R + T) - D (224.89, 0); Coupling 5 - B (0,-255)

Geometric model of the mechanism is shown in Figure 9:

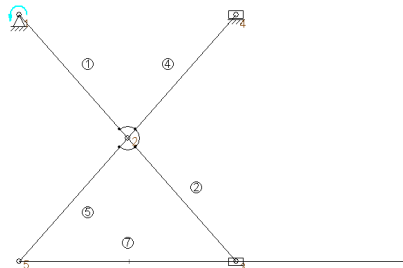


Figure 9. Geometric model of the driving mechanism  
- specifying the drive movement of the mechanism: the drive movement of the mechanism will be a uniform rotation with kinematic coupling 1 (angular acceleration  $\varepsilon_1=0$ ), according to Figure 10, consisting of two components: for the lifting phase - rotation angle "+97"degrees, lifting time 10", whereas for the lowering phase - rotation angle "-97" degrees, lowering time 10". We considered for analysis 360 calculation intervals for each phase of the movement.

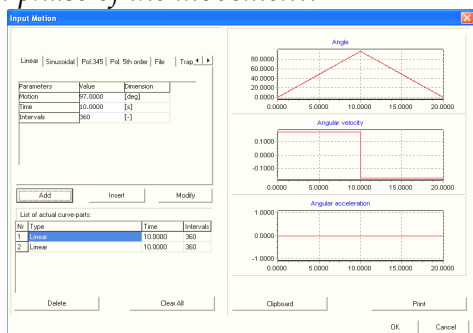


Figure 10. Motion of the drive mechanism

**Actual kinematic analysis**

What is aimed at is obtaining, in the form of graphics, variations of the kinematic dimensions of the component kinematic elements in the time frame in which the lifting / lowering stroke of the window is performed. With demonstration

purposes Figure 11 shows the variation of the position, velocity, as well as of the acceleration of the window carrying rail (driving element)

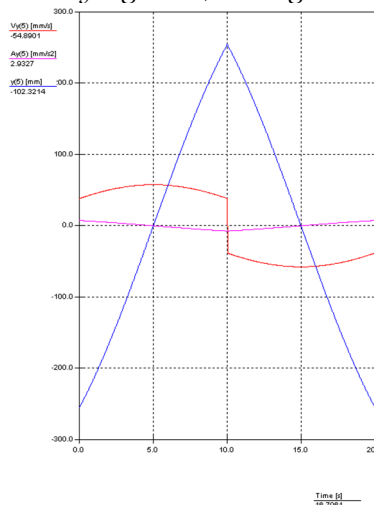


Figure 11. Kinematics of the window carrying rail  
**3. KINETOSTATIC ANALYSIS OF THE DRIVING MECHANISM**

The kinetostatic analysis of the driving mechanism has been developed for the lifting phase of the window, considered unfavorable in terms of loads compared to the lowering phase, and presumes the following steps:

- Establishing the external load of the mechanism (Figure 12a) - what is taken into account is the force that loads the mechanism,  $F = 80$  N, concentrated on the window carrying rail.

- Defining the masses, the moments of inertia and the position of the gravity centers of the kinematic elements - it will be developed individually for each item as shown in Figure 12b. Although the kinematic elements have no considerable masses, in calculations, their forces of gravity will still be taken into account. For simplicity's sake the centers of gravity will be positioned at half of the length of the elements, while the moment of inertia around an axis passing through the center of gravity will be considered equal to 1.

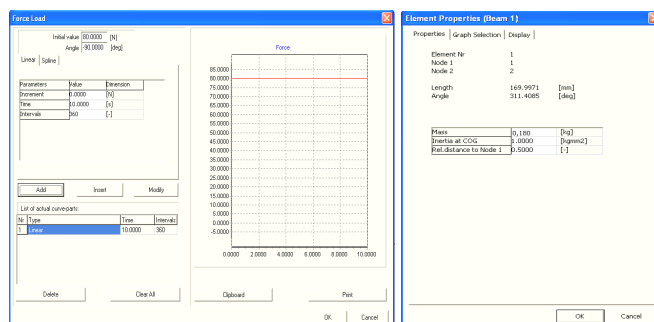


Figure 12. Establishing and defining

The loading scheme of the driving mechanism in the lowest position, developed in the above described way is shown in Figure 13.

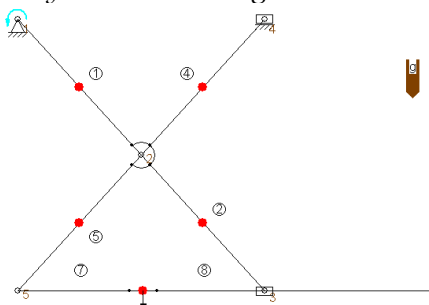


Figure 13. Scheme of the mechanism loading - obtaining graphical form variations of the reactions in the kinematic couplings for the lifting phase of the window from the lowest position to the highest (10"). With demonstration purposes Figure 14 shows the case of the kinematic coupling A (drive).

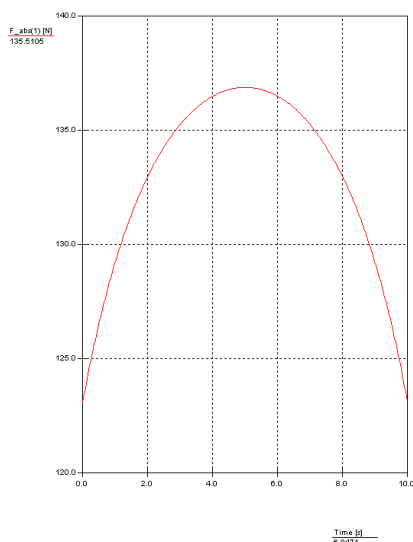


Figure 14. Reaction force variation in coupling A. The maximum values of the reaction forces in the kinematic couplings obtained in this way are:

- ✓ Reaction force in coupling 1 (A):  $R_A = 136,9 \text{ N}$
- ✓ Reaction force in coupling 5 (B):  $R_B = 0,30$ ;
- ✓ Reaction force in coupling 3 (C):  $R_C = 0,45 \text{ N}$
- ✓ Reaction force in coupling 4 (D):  $R_D = 54 \text{ N}$ ;
- ✓ Reaction force in coupling 2 (E):  $R_E = 1,5 \text{ N}$

#### Sizing the bolts of the kinematic couplings

Using the highest values in reactions, sizing calculations of the bolts (pins) materializing the rotational kinematic couplings have been made. The scheme of the bolt strain is shown in Figure 15, the main strain being one of shearing in the contact area between the two kinematic elements which make that particular coupling.

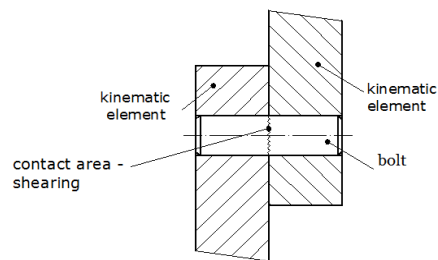


Figure 15. The scheme of the bolt strain. The diameter of bolt results of the shear strength condition (2).

$$\tau_f = \frac{R}{A} \Rightarrow A_{nec} = \frac{\pi d_{nec}^2}{4} = \frac{R}{\tau_{af}} \Rightarrow d_{nec} = \sqrt{\frac{4R}{\pi \cdot \tau_{af}}} \quad (2)$$

where:  $R$  - the maximum values of the reaction force in the kinematic couplings;  $\tau_{af}$  - the allowable shear stress for the bolt material; for the material the bolts - OL50,  $\tau_{af} = 112 \text{ MPA (N/mm}^2)$

Results the following diameters: coupling 1 (A) -  $d_1 = 6 \text{ mm}$ ; coupling 2 (E) -  $d_2 = 6 \text{ mm}$ ; coupling 3 (C) -  $d_3 = 6 \text{ mm}$ ; coupling 4 (D) -  $d_4 = 6 \text{ mm}$ ; coupling 5 (B) -  $d_5 = 6 \text{ mm}$

#### 4. CONCLUSION

The kinematic and kinetostatic analysis of the handling mechanism of the door windows of road vehicles has been carried out with the help of SAM application. After analyzing we developed the variation of the kinematic parameters of kinematic elements, as well as the reactions in the kinematic couplings both in the form of graphics. The kinematic parameters developed in this way are in concord with reality and fit into the requirements of the design theme

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