MAIN TYPES OF MECHANISMS USED AS WINDSHIELD WIPER

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Abstract: *This paper deals with the main types of windshield wiper mechanisms, consisting of bars and gear links. These mechanisms are classified into two groups: those with constant length arm and those with variable length arm. For each type of mechanism used as a windshield wiper, the paper highlights the main advantages and disadvantages regarding the wiped windshield surface and the constructive structural complexity.*

Keywords: windshield wiper mechanism, bar, gear, degree of mobility, kinematic diagram

1. GENERAL CONSIDERATIONS

Windshield wipers are plane or spatial mechanisms, having one, two or three driven elements, in terms of wiping arms, with elastic blades on which the rubber blades that wipe the windshield glass or the rear window glass are attached [2 - 7].

Electric motors of continuous current are used to drive the windshield wipers, which are power by the car battery. This electric drive ensures the oscillation of the wiping arm within certain imposed frequency limits. [2]. With windshield wipers with a single constant length arm, the wiped surface is smaller than with those provided with two arms that are more often used [5]. Modern cars have telescopic arm windshield wipers, which ensures maximum coverage of the windshield surface [4, 8, 9, 10].

Windshield wipers are designed and built as mechanisms with articulated bars, cams and gears. [7]. The paper analyses the main types of mechanisms used as windshield wipers (ws. w.) from a structural and topological point of view.

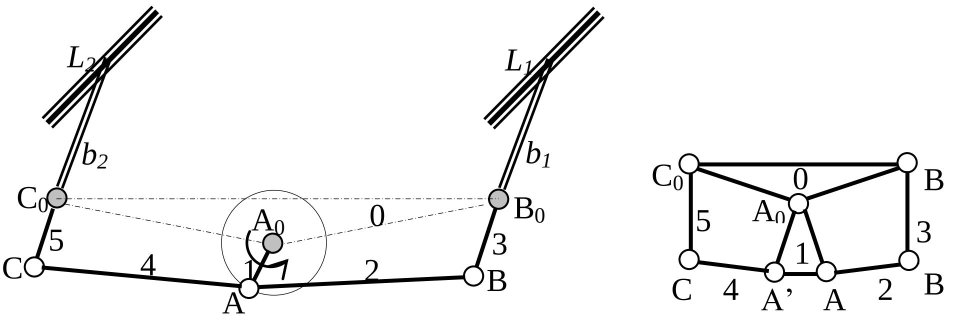
2. WS. W. MECHANISMS WITH ARTICULATED BARS

This type of ws. w. mechanism with articulated bars (fig. 1) is used for the majority of road vehicles. It has the advantage of being a simple mechanical structure, which is safe during operation (at several operating speeds), as well as very reliable.

Each of the two arms b_1 *and* b_2 are provided at the upper edge with an elastic blade (L_1, L_2). These arms are connected to the equalizing bars 3 and 5, which rotate around the fixed points B_0 and C_0.

The two equalizing bars (3, 5) are driven by the same crank 1 (articulated in A_0 at the bottom), by means of the reciprocating rods 2 and 4, articulated in the same point A at the crank. The degree of mobility of the ws. w. mechanism is determined by formula [11]

$$M = \sum_{m=1}^{5} mC_m - \sum_{r=2}^{6} rN_r \tag{1}$$



a) *b)*

Fig. 1. Kinematic (a) and structural (b) diagrams of the ws. w. mech. provided with two parallel arms

In formula (1) C_m stands for the number of *m* operational class kinematic couplings, and N_r stands for the number of *r* rank independent closed contours. These structural-topological parameters are highlighted in the matrix

$$\begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 \\ N_2 & N_3 & N_4 & N_5 & N_6 \end{bmatrix} = \begin{bmatrix} 7 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 & 0 \end{bmatrix} \quad (2)$$

Having these numerical values, formula (1) is written: $M = 1\cdot 7 - 3\cdot 2 = 1$ (3)
Which shows that the analysed ws. w. mechanism (fig. 1) has a single degree of mobility; this consists in the movement of the leading element, that is crank 1.

In fact, the 3 fixed articulations in A_0, B_0, C_0 do not have rigurously parallel axes. That is the reason why the kinematic couplings in points A, B, C are spherical articulations.

The structural-topological matrix of the actual mechanism is written according to (2) as

$$\begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 \\ N_2 & N_3 & N_4 & N_5 & N_6 \end{bmatrix} = \begin{bmatrix} 3 & 0 & 4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2 \end{bmatrix} \quad (4)$$

And the degree of mobility is inferred from (1): $M = (1\cdot 3 + 3\cdot 4) - 6\cdot 2 = 3$ (5)

The two additional mobilities are represented by the rotations of bars 2 and 4 as to the axes AB and CD.

If we consider the mechanism in terms of a plane mechanism (fig. 1a), the structural-topological diagram (fig. 1b) shows that it results from the Watt kinematic chain.

With this plane mechanism we identify two open kinematic chains of the dyad type (2, 3) and (4, 5), paralleled to the fundamental mechanism MF (0, 1), which corresponds to the aggregation formula of the motor mechanism (MM):

$$MM = MF(0,1) + \begin{cases} LcD(2,3) \\ LcD(4,5) \end{cases} \quad (6)$$

Even though this kinematic diagram (fig. 1) is simple, the solution has the disadvantage that the surface wiped on the windshield (by the rotating oscillating arm) is nevertheless limited. For ws. w. with a single rotating oscillating arm (usually used for the rear window), longer wiping blades are mounted.

Another kinematic diagram of ws. w. mechanisms [1, 7] uses a complex topological structure (fig. 2), where the kinematic chains are connected serially.

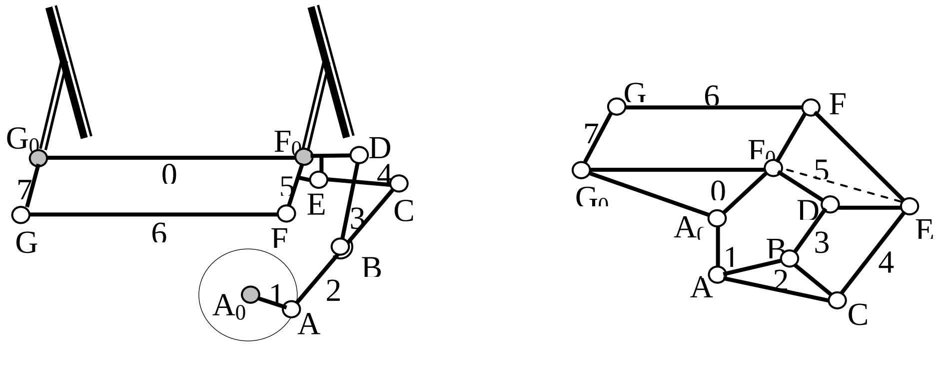


Fig. 2. Kinematic (a) and structural (b) diagrams of ws. s. M. with two serial arms

We can notice a complex topological structure, where 3 and 4 bars (criss-crossing each other) form together with the kinematic elements 2 and 5, a closed kinematic contour of the quadrangle type (BCEDB). The wiping arms (connected to bars 5 and 7) are serially linked by means of bar 6, and the quadrangle $F_0FGG_0F_0$ is an articulated parallelogram. In order to determine the degree of mobility of this ws. w. M. (fig. 2a), we write the structural matrix:

$$\begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 \\ N_2 & N_3 & N_4 & N_5 & N_6 \end{bmatrix} = \begin{bmatrix} 10 & 0 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 & 0 \end{bmatrix} \tag{7}$$

The degree of mobility is obtained from formula (1):

$$M = 1 \cdot 10 - 3 \cdot 3 = 1 \tag{8}$$

The structural-topological diagram of this type of ws. w. m. (fig. 2b) corresponds to a complex kinematic chain, where we can distinguish two open kinematic chains with zero mobility, which are identified in the order of a possible disaggregation: LcD(6, 7) and Lc tetrade type LcTt(2, 3, 4, 5). The structural-topological formula of the complex ws. w. m. (fig. 4) can be written after stating the driving element, that is crank 1:

$$MM = MF(0,1) + LcTt(2,3,4,5) + LcD(6,7) \tag{9}$$

3. WS. W. MECHANISMS WITH BARS AND GEARS WITH A CONSTANT LENGTH ARM

Ws. w. m. with a constant length arm [3, 10] can be grouped into two variants, different from the construction point of view: those with a translational gear rack T (fig. 3) and and with a roto-translational gear rack R+T.

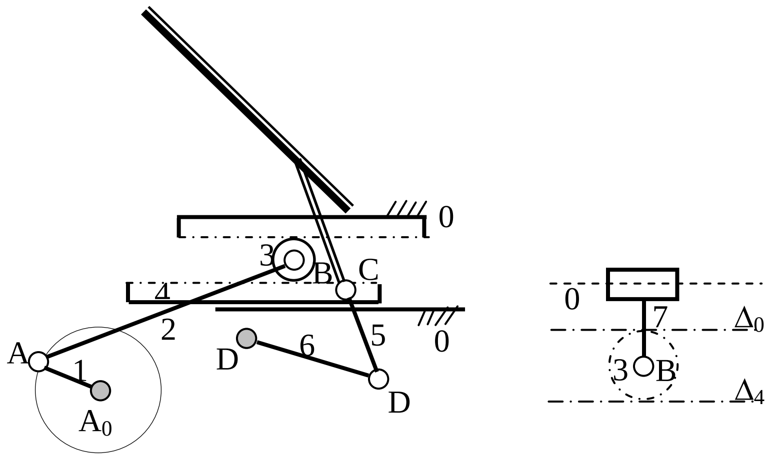


Fig. 3. Kinematic diagram of the ws.w.m. with a T gear rack

The Ws.W.M. with translational gear rack_(fig. 3) is provided with a single wiping arm, connected to bar 5; thus it has a plane roto-translational motion.

From crank 1, as driving element, motion is transmitted by means of the reciprocating rod 2 to the B axis of the gear 3 (pinion type).

Pinion 3 engages at the same time to the upper side with the fixed gear rack 0 and to the lower side with a mobile translational gear rack 4.

To the translational gear rack 4 the kinematic dyadic chain LcD (5, 6) is articulated in point C, with the fixed articulation D_0.

The translational motion of point B along the fixed guide 0 is provided by the double engagement of pinion 3 with the two gear racks.

Thus, skid 7, ensuring the translational motion of point B (fig. 3b), together with the two couplings (rotational and translantional) is not represented in the kinematic diagram (fig. 3a).

The structural matrix of the bar and gears plane mechanism (fig. 3a) is completed taking into account the two kinematic couplings of skid 7:

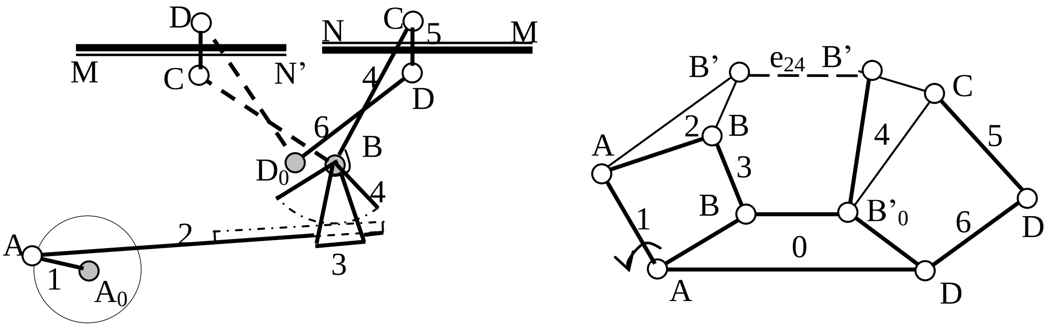
$$\begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 \\ N_2 & N_3 & N_4 & N_5 & N_6 \end{bmatrix} = \begin{bmatrix} 9 & 2 & 0 & 0 & 0 \\ 0 & 4 & 0 & 0 & 0 \end{bmatrix} \qquad (10)$$

If these numerical data (10) are replaced in (1), we determine the real mobility degree

$$M = 1\cdot 9 + 2\cdot 2 - 3\cdot 4 = 1 \qquad (11)$$

This result (M=1) verifies the existence of a single element 1 with an independent motion.

Ws. W. M. with a roto-translational gear rack (fig. 4) has a single wiping arm connected to bar 5 with a plane-parallel motion.



a) *b)*

Fig. 4. Kinematic (a) and structural (b) diagrams of the ws.w. M. with a roto-translational gear rack

The rotation motion of crank 1 (fig. 4) is transmitted to the gear sector 4 by means of the bar – gear rack 2. This is guided in the oscillating box 3, which keeps it in contact with the gear sector 4:

The oscillating rotation motion of gear sector 4 is sent to an antiparallelogram mechanism made up of bars 4, 5 and 6, with fixed articulations in B_0 and D_0. The wiping blade MN is mounted and fixed on bar 5, perpendicular to CD, whose motion is plane roto-translation.

The antiparallelogram B_0CDD_0 mechanism (fig. 4a) is represented by a dotted line in the extreme left position, in which we notice the position of the wiping blade M'N' rotated at 180^0 as to the initial position MN. The structural matrix of the ws.w.M. includes the number of the kinematic couplings of functional classes C_m with m =[1,5] and the number of closed independent contours N_r of rank r =[2,6]:

$$\begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 \\ N_2 & N_3 & N_4 & N_5 & N_6 \end{bmatrix} = \begin{bmatrix} 8 & 1 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 & 0 \end{bmatrix} \quad (12)$$

The mobility of the analysed mechanism is determined by means of the formula (1) in which we replace the data in (12): $M = 1\cdot 8 + 2\cdot 1 - 3\cdot 3 = 1$ (13)

The structural-topological diagram of this mechanism (fig. 4b) is obtained after equating the upper coupling (represented by the engagement of gear rack 2 with the gear sector 4). This engagement equates with a binary element, with two lower kinematic couplings [3]. The structural-topological formula is: MM = MF(0,1) +LcD(2,3) +LcD(e_{24},4)+LcD(5,6) (14)

4. WS. W. MECHANISM WITH BARS AND GEARS OF A VARIABLE LENGTH ARM

With these variable length arm ws.w. M. [4, 7, 10], the wiping blade does a plane roto-translational motion consisting in a rotation of an oscillating bar and a translational along this one on a radial direction (fig. 5a).

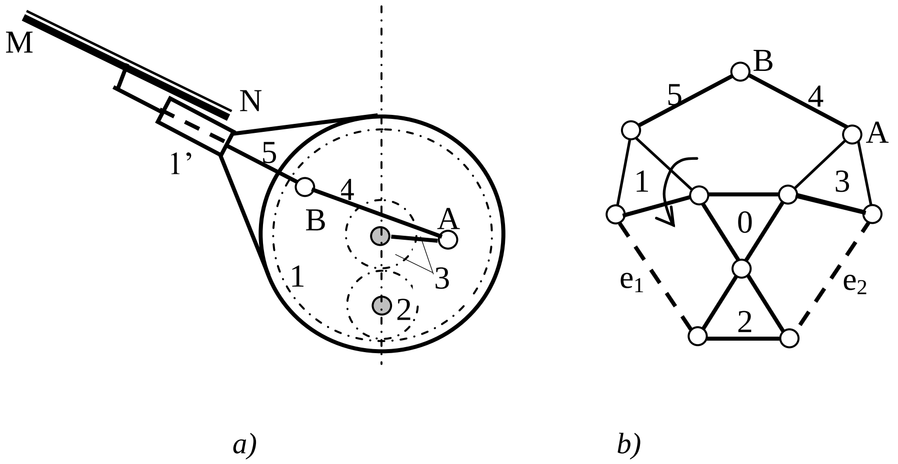


Fig. 5. Kinematic diagram of the ws. w. M. with a variable length arm

The wiping blade MN is fixed on the rod 5, and the latter does the translational motion along the oscillating guide 1’ connected to the gear 1, which has inside teeth.

Together with the oscillating rotation of the box-gear 1, motion is sent to crank 3 (by means of the gears 2 and 3), and from here, by means of bar 4, the rotation motion is changed into translational motion at rod 5 (fig. 5a).

The surface wiped by the blade MN corresponds to the stroke of rod 5, a relative translational motion along the oscillating guide 1’ .

The structural matrix of this ws. w. M. (fig. 5a) is

$$\begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 \\ N_2 & N_3 & N_4 & N_5 & N_6 \end{bmatrix} = \begin{bmatrix} 6 & 2 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 & 0 \end{bmatrix} \quad (15)$$

From this numerical data the mobility of the ws. w. M. is inferred with the formula (1):

$$M = 1 \cdot 6 + 2 \cdot 2 - 3 \cdot 3 = 1 \quad (16)$$

The structural-topological diagram (fig. 5b) is done after equating the two upper kinematic couplings (1, 2) and (2, 3), which are inside and outside engagements. The structural-topological formula is written (fig. 5b):

$$MM = MF(0,1) + LcD(2,e_{12}) + LcD(e_{23},3) + LcD(4,5) \quad (17)$$

6. WS. W. M. WITH THE WIPING BLADE IN A CIRCULAR TRANSLATIONAL MOTION

This kind of ws. w. M. is used for buses where the surface of the windshield screen is flat and much larger than it is for cars. The wiping blade MN is placed vertically, fixed to the reciprocating rod 4 of a plane mechanism of an articulated parallelogram type (fig. 6), in which the sides -bars 3 and 5 are much longer than horizontal sides.

In the practical solution, bar 5 is thin as compared to bar 3, which receives the oscillating rotation motion from crank 1, by means of bar 2 (fig. 6a).

The structural matrix of that mechanism contains:

$$\begin{bmatrix} C_1 & C_2 & C_3 & C_4 & C_5 \\ N_2 & N_3 & N_4 & N_5 & N_6 \end{bmatrix} = \begin{bmatrix} 7 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 & 0 \end{bmatrix} \quad (18)$$

Thus, the mobility degree of the Ws.W.M. (fig. 6a) is determined with formula (1) in which we introduce the data in (18): $M = 1 \cdot 7 - 3 \cdot 2 = 1$ (19)

The structural-topological diagram of the Ws.W.M. analysed above corresponds to the Watt kinematic chain (fig. 6b). The structural-topological formula is (fig. 12):

$$MM = MF\ (0, 1) + LcD\ (2, 3) + LcD\ (4, 5) \quad (20)$$

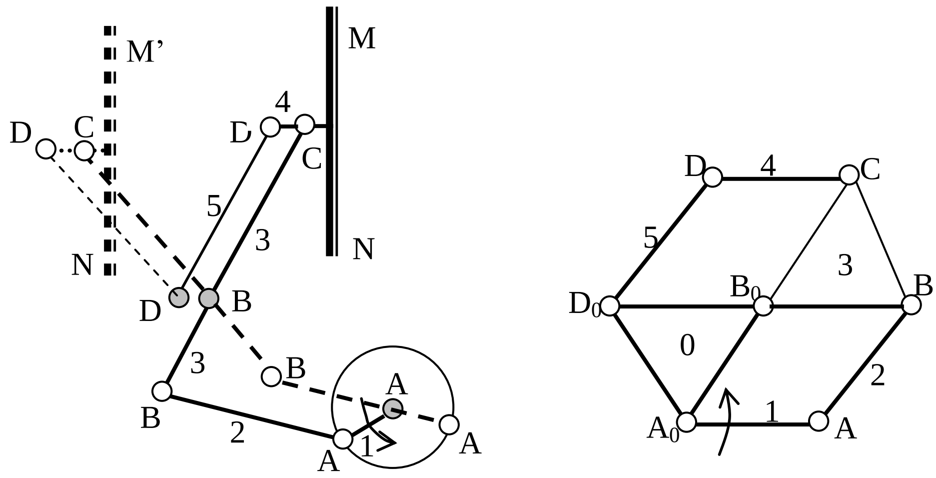


Fig. 6. Kinematic (a) and structural diagrams (b) of the Ws. W. M. with the blade doing a R+T motion

7. CONCLUSIONS

Ws. W. Mechanisms have a diverse topological structure, being made both as spatial mechanisms and as plane mechanisms with bars and gears.

The paper aimed at a classification of the Ws.W.M. according to: the kinematic elements used (bars, gear racks, cylindrical gears with outside and inside teeth), the number of wiping blades, their motion and their serial or parallel connection. The Ws.W.M. is driven by means of continuous current electric motors, powered by the car battery.

The wiping arm is moved together with the elastic blade. It is a rotational motion in the case of bar ws.w.m., or a roto-translational motion for those with bars and gear elements.

Comparing the 6 kinematic diagrams analysed, we pointed out the complexity of the variable length arm Ws.W.M. from the structural and the construction point of view.

From the structural-topological analysis of the main types of Ws.W.M. used for cars, we find out that most of them consist of dyadic kinematic chains, created either of articulated bars or of rack and pinion or gear sectors, or outside / inside cylindrical gears.

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