TOPOLOGICAL STRUCTURE AND MOBILITY OF THE MECHANISMS USED IN CAR MECHANICAL JACKS

Viorica VELIȘCU, Railroad Transportation H. S. of Craiova, viorica_2000@yahoo.com
Dan MESARICI, Railroad Transportation High School of Craiova, mesarici@yahoo.com
Dr. Păun ANTONESCU, „Politehnica" University of Bucharest, panton38@hotmail.com

Abstract: *This paper presents a structural analysis of the mechanism of high topological type jack - screw and translator rectilinear- patina and mobility mechanism analysis using various generally applicable formulas.*

Keywords: lifting mechanism, jackscrew, mechanical jack, topological structure, mobility

1. INTRODUCTION

Jacks are devices used for lifting loads at a low height without any flexible lifting part. Jack building forms depend both on the load lifting way and on their driving type.

Furthermore, we shall present several kinematic schemes for different types of lifting mechanisms used for car mechanical jacks [1, 2].

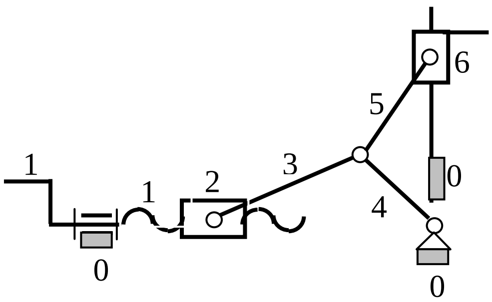


Fig. 1.1. Screw and patina lifting mechanism

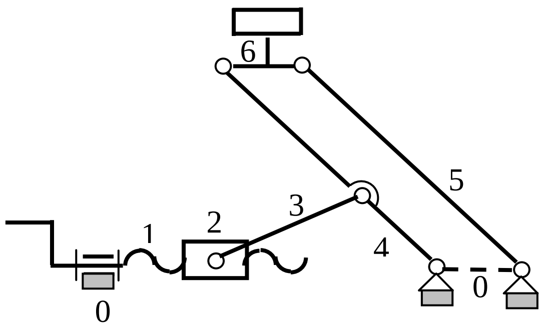


Fig. 1.2. Screw and parallelogram lifting mechanism

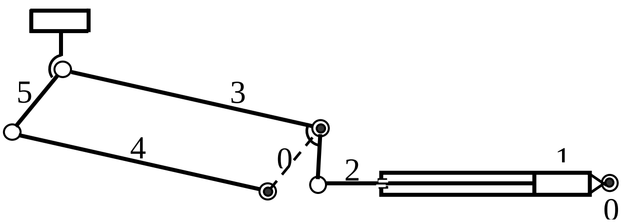


Fig. 1.3. Lifting mechanism with pneumatic actuator parallelogram

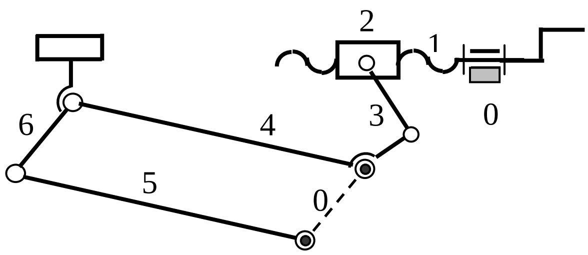


Fig. 1.4. Screw and parallelogram lifting mechanism and mechanism

Besides these relatively simple kinematic schemes, there are also complex ones (fig. 1.5 ... 1.11).

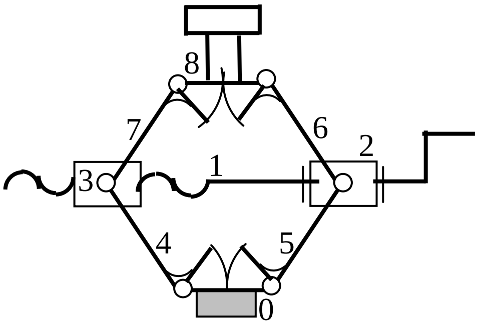


Fig. 1.5. Lifting mechanism with screw hexagonal chain and cylindrical gears

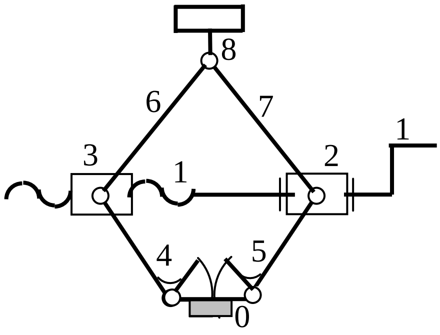


Fig. 1.6. Lifting mechanism with screw, pentagonal chain and cylindrical gear

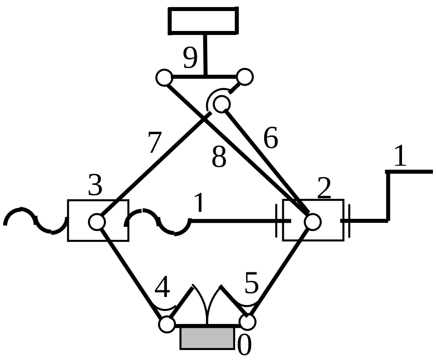


Fig. 1.7. Lifting mechanism with screw, articulated bars and a cylindrical gear

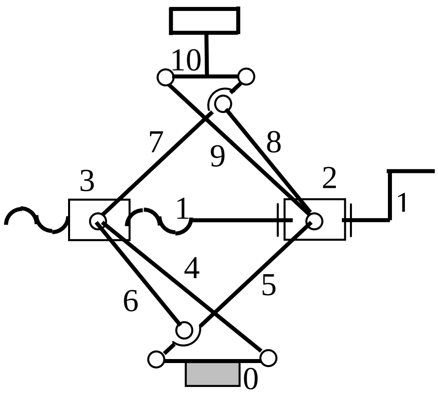


Fig. 1.8. Lifting mechanism with screw and articulated bars

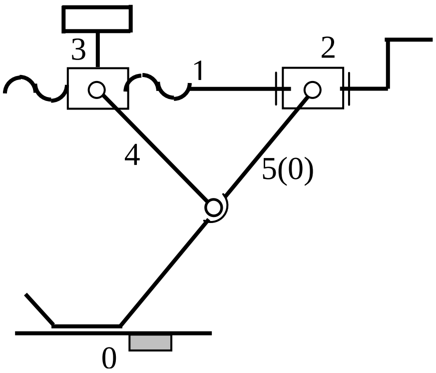


Fig. 1.9. Lifting mechanism with screw and a flexible support bar

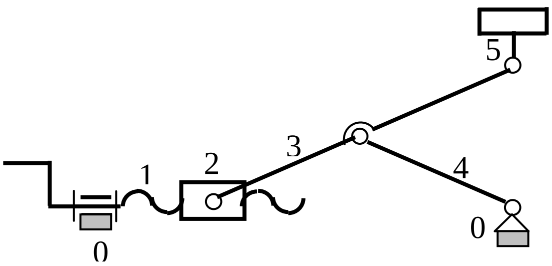


Fig. 1.10. Lifting mechanism with screw and articulated bars

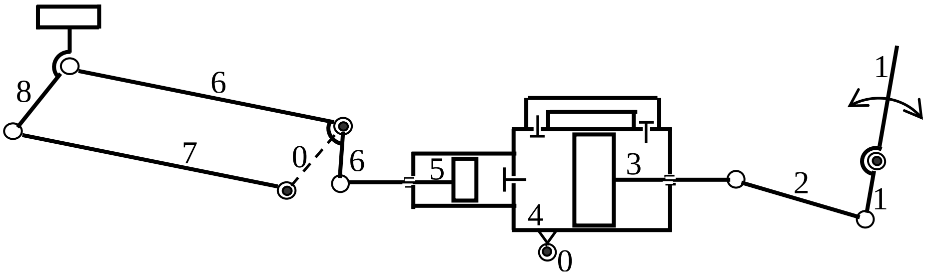


Fig. 1.11. Lifting mechanism with two hydraulic cylinders and parallelogram, manual drive

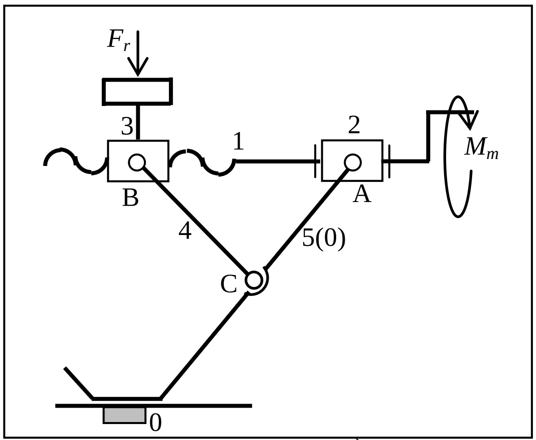
2. STRUCTURE AND MOBILITY OF THE VARIABLE DIRECTION JACK-SCREW MECHANISM.

The variable direction jack-screw (fig. 1.9, 2.1) is fixed to the ground by means of a flexible support leg frame bar 5.

Among mechanical jacks, the most common ones are those provided with a motion screw, where the jack is actuated by rotating the lever attached to the screw.

Such a jack type is presented in the figures below with:

- the kinematic scheme of the lifting mechanism (fig.2.1.a).
- photo image of the jack-screw with a flexible support arm under load (fig.2.1.b).



a)

b)

Fig. 2.1. Lifting mechanism of a jack-screw with a flexible support arm

The kinematic scheme of the analyzed mechanism (fig. 2.1) shows that it includes a closed kinematic chain, formed of the elements 1, 2, 3, 4 and 5. Among these kinematic elements, bar 5 acts as a fixed element 0, once it is supported on the horizontal plane.

This closed kinematic chain is a spatial 3D chain as the rotation of element 1 (the driving screw) goes beyond the motion plane of the other parts.

In order to use this jack (fig. 2.1b) we mount the support bar 5 (fig. 2.1a) on the horizontal surface close to the car body that is about to be lifted.

The space associated to the closed kinematic chain has the rank $r = 4$, and thus the mobility of this screw mechanism can be determined with formula [3]

$$M = \sum_{m=1}^{5} mC_m - \sum_{r=2}^{6} rN_r \qquad (2.1)$$

Visually inspecting the jack mechanism (fig. 2.1a), we notice that all kinematic couplings have a single mobility ($m = 1$) and therefore $C_m = 5$. Kinematic couplings are the overlapping articulations A(1,2) (2,5) and the articulations B(3,4) as well as C(4,5).

It should be mentioned that the screw coupling (1,3) overlaps in B, whose mobility $m = 1$, just like with the articulation, as there is an interdependence between the two relative rotation and translation motions φ and *s*, through the *p* lead of the motion screw: $p\varphi = 2\pi s$.

In this particular case $N_r = 1$ (number of rank *r* contours), formula (2.1) is written

$$M = C_m - r = 5 - 4 = 1 \qquad (2.2)$$

The result obtained is $M = 1$, which proves that this mechanical jack works by means of rotating the joint lever with screw 1 (fig. 2.1a).

Thus, by rotating lever 1 with momentum M_m object 3 moves vertically and surpasses the resistance force F_r represented by the gravity force of the car body.

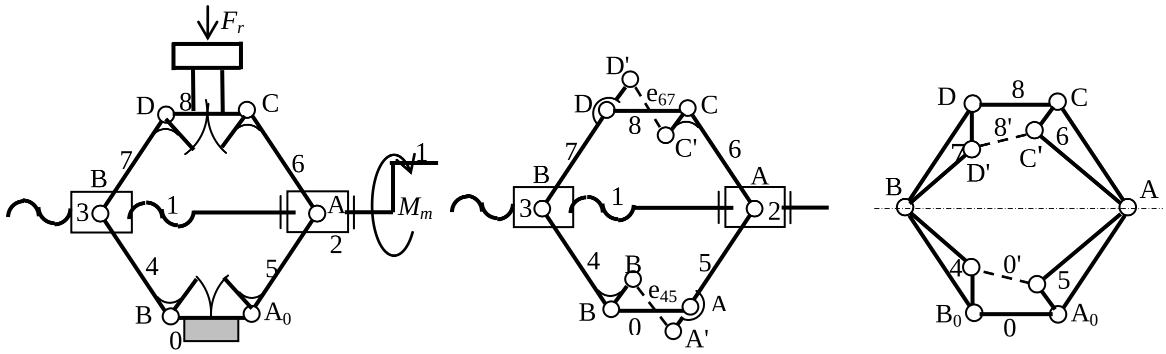
3. TOPOLOGICAL STRUCTURE AND MOBILITY OF THE JACK-SCREW WITH BARS AND CYLINDRICAL GEARS.

Let us consider a mechanical jack-screw with bars and cylindrical gears (fig. 1.5, 3.1) in the rest position, next to a car (fig. 3.1a) and under load, in the working position (fig. 3.1b).

a) *b)*

Fig. 3.1. Jack-screw with bars and gears: rest position (a) and working position (b)

The kinematic scheme of the mechanism used for this mechanical jack (fig. 3.2a) symbolises a hexagonal contour of articulated bars, two circular gears (segments) and a motion screw 1 as the driving element.



a) *b)* *c)*

Fig. 3.2. Kinematic scheme of the mechanism - real (a), equivalent (b) and kinematic chain (c)

To obtain the equivalent mechanism (fig. 3.2b) we equate each cylindrical gear: gear (6,7) with a bar-type kinematic element e_{67} and two articulations C' and D', and the gear (4, 5) with fictive bar e_{45} and the articulations A' and B'.

Fictive bar e_{45} forms with bar 0 and bars 4 and 5 a second tetradic chain (4, 5, 0, e_{45}) symmetrical to the other with respect to the screw axis 1. Thus, the lifting mechanism results from a hexagonal kinematic chain achieved by means of the symmetrical connection of the two tetradic chains (fig. 3.2c), when the potential articulations A and B become active.

Following the kinematic scheme of the mechanism (fig. 3.2a) we identify an articulated hexagonal contour A_0B_0BDCA(0, 4, 7, 6, 5), whose kinematic associated space has the family $f_1 = 3$ and the rank $r_1 = 6 - f_1 = 3$.

The driving element 1 (the screw), together with patinas 2 and 3, divide the hexagon into two articulated pentagons, each having a space corresponding to $f_2 = 2$ respectively $r_2 = 4$.

Each cylindrical gear defines, together with bar 0 or 8, a closed independent contour: (0, 4, 5) and (6, 7, 8), and each has a corresponding space $f_3 = 3$ and $r_3 = 3$. To determine the mobility of the mechanism (fig. 3.2a) we use formula [3]

$$M_{fa} = (6 - f_a)\cdot n - \sum_{k=1}^{5}(k - f_a)\cdot C_k \tag{3.1}$$

On the kinematic scheme of the mechanism we can identify ten couplings class $k = 5$ and two couplings class $k = 4$. Subsequently $C_5 = 10$, these are (0,4), (0,5), (1,2), (2,5), (2,6), (1,3), (3,4), (3,7), (6,8), (7,8) and $C_4 = 2$, being the gears (4,5) and (6,7).

Inspecting the kinematic scheme of the analysed mechanism (fig. 3.1a) we identify the existence of four independent closed contours, with the specific restrictions given by the families mentioned above: $f_1 = 3, f_2 = 2, f_3 = 3, f_4 = 3$. The apparent family f_a is determined as the arithmetic mean of the four real families:

$$f_a = \tfrac{1}{4}\sum_{i=1}^{4} f_i = \tfrac{1}{4}(3+2+3+3) = 11/4 \tag{3.2}$$

All numerical data shall be replaced in the formula (3.1) and it is obtained

$$M_{11/4} = (6-11/4)\times 8-(5-11/4)\times 10-(4-11/4)\times 2 = 1 \qquad (3.3)$$

This result proves the fact that there is a single driving element – screw 1, which, by means of rotation, transmits the motion of all the elements including bar 8.

The mobility of the mechanism can be also determined by means of the formula [3]

$$M = \sum_{m=1}^{5} mC_m - \sum_{r=2}^{6} rN_r \qquad (3.4)$$

For the analysed kinematic scheme we identify the following values ($C_m = C_k$): $C_1 = 10$ class 1 kinematic couplings, of which nine couplings are plane articulations and one is the coupling screw-nut (1,3); $C_2 = 2$ class 2 kinematic couplings, these being the gears (4,5) and (6,7); $N_3 = 3$ rank 3 closed contours ($r = 3$); $N_4 = 1$ rank 4 closed contour ($r = 4$).

After replacing these numerical values in the formula (3.4) we obtain

$$M = (1\times 10+2\times 2)-(3\times 3+4\times 1) = 1 \qquad (3.5)$$

The result obtained by means of formula (3.4) coincides with the previously obtained one $M = 1$, which proves the univocal transmission of the screw 1 motion to all the other kinematic elements.

4. THE JACK-SCREW MECHANISM WITH ARTICULATED BARS

4.1. The kinematic scheme of the jack-screw and the operation mode

According to the kinematic scheme of the jack-screw with articulated bars (fig. 4.1), this is manually driven with the help of a screw provided with a lever.

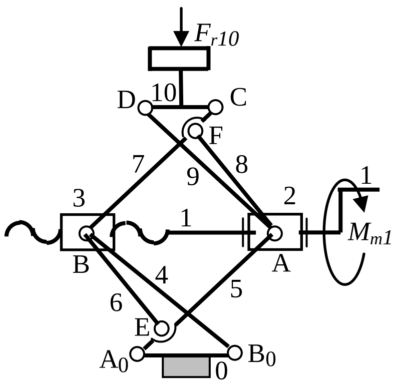


Fig. 4.1. Kinematic scheme of the jack-screw with bars

The topological structure of the mechanism (fig. 4.1) is complex, highlighting a hexagonal contour of articulated bars in a vertical plane with double concavity.

The articulated plane kinematic chain (0,5,9,10,7,4) is a concave hexagon A_0ADCBB_0 consolidated by means of 6 bars (to the lower side) and 8 bars (to the upper side).

Both lower bars (4, 5, 6) as well as upper bars (7, 8, 9) move in vertical parallel planes. The geometrical configuration of the concave hexagonal mechanism (fig. 4.1) supposes the equality of bars 4, 5, 7 and 9. Bars 6 and 8 have an equal length, so that the quadrangle AFBE (fig. 4.1) forms an articulated plane parallelogram.

4.2. Topological structure and calculation of the mechanism mobility

The mechanical jack mechanism (fig. 4.2*a*) consists of two kinematic chains, of which an open kinematic chain (1,2,3), with potential articulations A and B (fig. 4.2*c*) and another closed chain (fig. 4.2*b*), made up of seven mobile kinematic elements (4,5, ... ,9,10) assembled in a complex topological structure with articulated bars, including the fixed element 0.

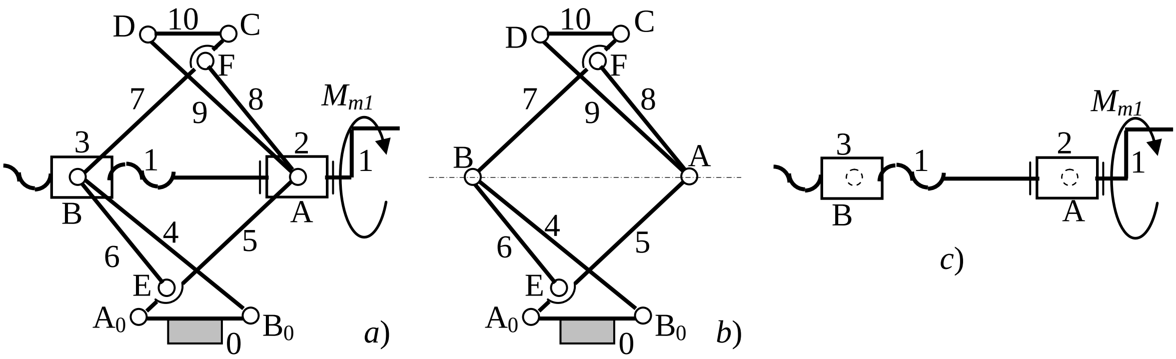


Fig. 4.2. Kinematic scheme of the mechanism (*a*) and the component kinematic chains (*b*, *c*)

The closed kinematic chain (fig. 4.2b) has three independent plane contours with articulated bars: the hexagon (0,4,7,10,9,5), the quadrangle (0,4,6,5) and the parallelogram (5,6,7,8). The open kinematic chain (fig. 4.2*c*) consists of screw 1 connected to patina 2 through a rotation coupling and to the patina-nut 3 through the rotation-translation coupling.

The two kinematic chains are assembled by means of the two potential articulations A and B, and then they become triple articulations (fig. 4.2*a*).

It can be proved that, by the rotation of the motion screw 1, the hexagonal type closed kinematic chain moves all the component bars in a univocally determined way, of which the vertical motion of bar 10 is of interest.

5. CONCLUSIONS

The structural topological analysis of mechanisms used in mechanical jacks has been concluded by deducing the structural formula for each independent kinematic contour and for the entire mechanism.

To determine the mobility of such mechanisms, we have used generally valid formulas, checking that this allows univocal transmission of the driving element's motion to the driven element.

Considering all the things above, it results that the drive element, the one onto which the driving mechanism is attached, does a rotation motion, while the driven element does a translation motion.

REFERENCES

1. Antonescu, P., *Mechanisms and Manipulators, Applications – Projects*, Printech H., Buch., 2000;

2. Antonescu, P., s.a. *Mechanisms and Manipulators – a Laboratory Guide*, Printech H., Buch., 2002;

3. Antonescu, P., *Mechanisms*, Printech Publishing House, Bucharest, 2003.