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Invalid vehicles: mechanisms for changing the overall size across the width

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Abstract. The paper presents the research results in the field of transformable invalid vehicles with the possibility of changing the overall size according to the width. The estimation of the general situation on this issue in the printed media and on the Russian market of invalid equipment is described in this document. The variants of using various mechanisms for changing the overall size according to the width are considered to be taken into account in the design of the wheelchair and the location of the drive wheels. According to the test results, the most promising model of a wheelchair and the mechanism used for changing the overall size across the width is described. The presented comparative analysis confirms the market demand and relevance of the presented research subject.

1. Introduction

The world and Russian market of wheelchair technology have shown steady growth in recent years. About one-third of the rehabilitation equipment market is wheelchairs. The relevance of new developments for this market, its quantitative characteristics, and features of the Russian market were mentioned earlier in [1-2].

Studies in the prospective area of developing invalid vehicles with various characteristics are being conducted at the Department of Engineering Technology of Novgorod State University named after Yaroslav the Wise for about 30 years. The main contribution to the development of this topic was made by Professor Shchegolev V. A., Professor Emelyanov V. N., Professor Timofeev V. V., Associate Professor Bordashev K. A., and others.

The accumulated experience and information made it possible, by 2013, to formulate a specific technical task for a transformable invalid electric vehicle (TIEV), which, taking into account the conditions of Russian operation and the situation on the Russian market, should allow to solve the tasks of social and professional rehabilitation of disabled people, mainly with disabilities of the musculoskeletal system, as well as central and peripheral nervous systems.

2. Solutions to the task

To solve the abovementioned tasks, the TIEV should meet the following requirements:

1. TIEV should be equipped with a mechanism to change the overall size to the width to overcome doorways with a width of 600 mm, which is especially important for Russian operating conditions.

2. The TIEV should be equipped with a backrest and armrests that fold into one level with the seat, which will allow moving from the seat plane in any direction, increasing the mobility of the TIEV user.

3. TIEV should have a reduced weight (less than 40 kg) and the cost of the final product up to 100 thousand rubles. That will allow it to compete in the low price segment with analogues of Chinese production that do not possess the abovementioned properties.

4. Transformation processes must be carried out by the user of TIEV independently without assistance and additional tools.

We carried out an analysis of the design of electrically powered wheeled vehicles (IV) [3 - 9]. It can be argued that the main problem considered by modern specialists relates to the electric drive of the wheelchair, its subsystems, and operational parameters. In this case, we are interested in the mechanism of changing the overall size in width and its integration into the overall design of a wheelchair, taking into account the location of the drive wheels.

The problem of passing through narrow doorways is considered mainly in the context of changing the environment for the needs of disabled people [10 - 13], rather than the design of the IV itself, and does not raise the issue of the location of the mechanism for changing the overall dimensions along the width and arrangement of the drive wheels on the IV.

As mentioned earlier [14], within the framework of the present research, the variants of the formulas of three-wheeled wheelchairs are not considered, because such an arrangement is not capable of providing the necessary static and dynamic stability [15 - 17] when fulfilling a number of dimensional requirements given in the terms of reference. Proceeding from this, the developments were based on the four-wheel formula of TIEV.

Note that most of the models on the market have a drive to the rear wheels, but this design feature is not determinative. The leading models of the market-leading company Otto Bock can have a drive, both on the rear and the front axle of the IV. Each of the drive circuits has its advantages and disadvantages.

3. Design options and design of the mechanism for changing the overall size across the width

The design with four driving wheels is the most effective in overcoming obstacles, however, the high cost of its production, the complexity of the design, the increase in the total mass of the IV and the reduction in the power reserve do not allow considering this scheme in the framework of this work.

The arrangement of the driving wheels on the front axle of the wheelchair makes it possible to simplify the structure of the carcass and the mechanism for changing the overall dimensions along the width. At the same time, the front-wheel-drive TIEV can have an insufficient grip of the front wheels with the surface, especially when lifting to the ramp (with a lifting angle exceeding the normative - more than 10 °), which leads to slippage. The occurrence of such a problem depends on the location of the user on the seat, the coefficient of adhesion of the driving wheels to the road surface and a number of other conditions.

The location of the drive wheels on the rear axle avoids slipping when climbing the ramp, but in a rear-wheel drive design, it is more difficult to implement a mechanism for changing the overall width dimension while maintaining high reliability and low cost. In addition, when the width is changed, inversion of the TIEV control via the joystick occurs, which causes inconvenience in the control and creates a number of additional problems.

There are known structures of IV on muscular strength with a mechanism for changing the width (for example, model KY-901), in which changes in the overall size of the width are made by reducing the width of the seat, which imposes severe restrictions on the operation of such IV wheelchair users with excess weight or with a wide the hip joint. Such mechanisms do not allow changing the overall width during driving, and sometimes without the assistance of an accompanying person and/or a special tool. This option does not allow talking about the independence and mobility of disabled wheelchair users in the Russian conditions.

The option of creating a wheelchair with a constant width of less than 600 mm is also ineffective. This design can only be used in the models of children's IV. Otherwise, the design will not meet the above requirements for static and dynamic stability and will not be able to provide comfortable operation for the disabled in terms of placement on the seat. In addition, passing through a narrow doorway requires the availability of a margin in width between the IV clearance points and the door frame.

Based on the analysis of models of electric IV present on the Russian market [18-23] and based on the experience of earlier domestic developments [24,25], it was decided to consider both versions of the TIEV drive schemes and two options of the mechanism for changing the overall width. The final choice between them was to be made at the prototype testing stage.

In the process of searching for the most effective and relevant constructive solutions to this issue, various options of the designs and mechanisms for changing the overall size in width, presented in the figures, were considered.

For TIEV model 3.2 with a drive to the rear wheels, a previously developed and patented [26-28] mechanism was used (Figure 1). Due to the swivel supports, on which the asymmetrical forks for attaching the wheels are located, and the overall size is changed in width. The axis of symmetry of the fork is remote from the axis of symmetry of the wheel by a distance e, which allows the stable construction of the stroller in the decomposed position A (Lmax ~ 700 mm). In position B (Lmin ~ 500 mm), the wheelchair is able to overcome the narrowest door openings, from those encountered in real operation.

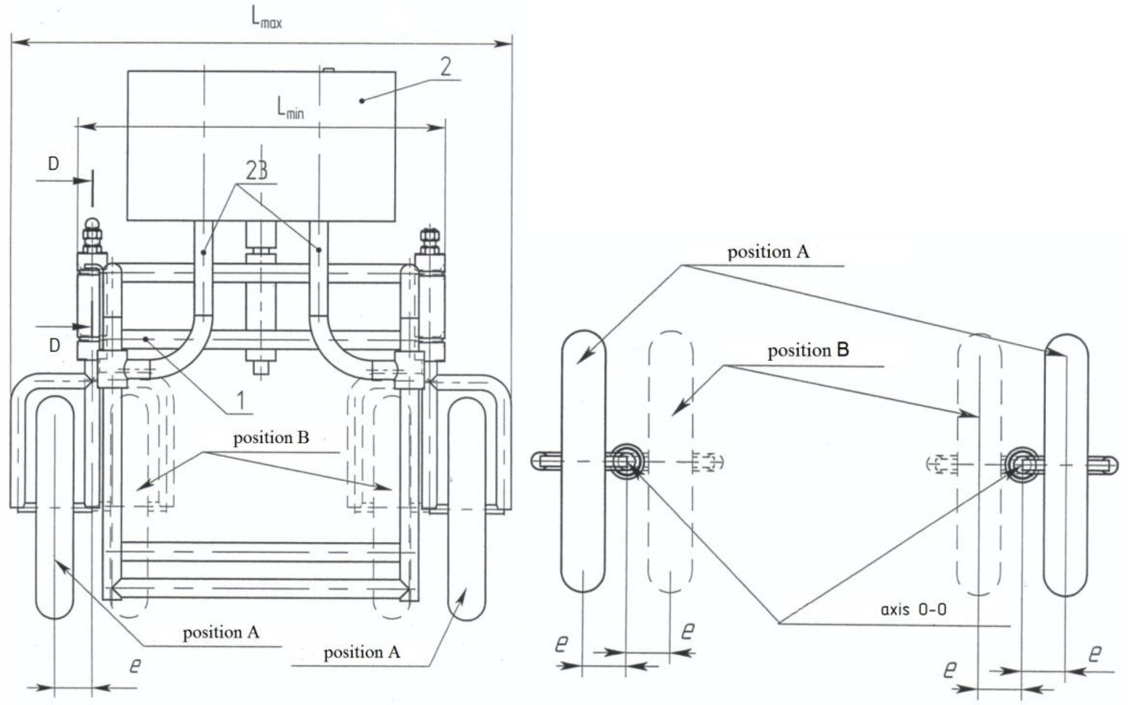

Figure 1. Mechanism of changing the overall width due to the console fork of the rear drive wheels

When implementing the IV scheme with front-wheel drive, the rear wheels are self-aligning, and as a consequence, various mechanisms for displacing the vertical axes of the self-aligning wheels can be used to vary the width of the track of the rear wheels. The application of a similar circuit, as well as for the model with a drive to the rear wheels, is possible and is represented in Figures 2 and 3.

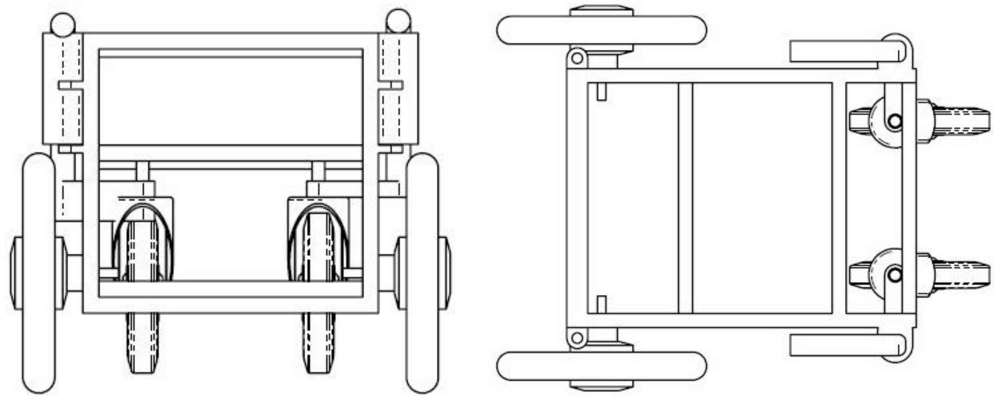

Figure 2. Mechanism for changing the overall dimensions in width due to the console fork of self-aligning (rear) wheels (minimum overall dimension)

The main drawback of this mechanism is an insufficient distance between the tilting wheels in a folded state, which leads to loss of stability of the whole structure, and there is a risk of lateral tilting of the IV. Further, excessive displacement vane wheel under the seat and backrest of the wheelchair reduces the useful space under it, causing problems with folding backrest in a level with **the seat.**

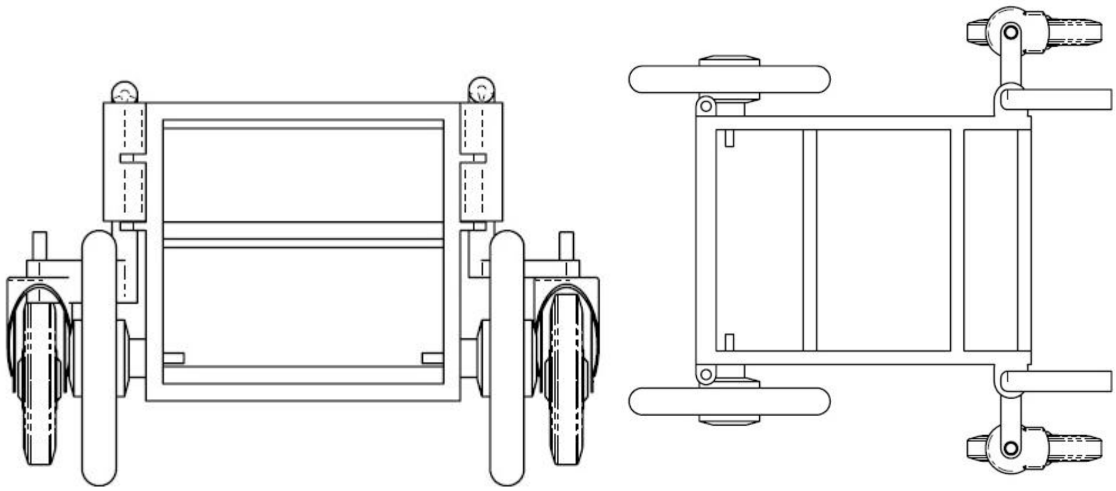

Figure 3. The mechanism for changing the overall width due to the console fork of self-aligning (rear) wheels (maximum overall size)

As the size of the console on which the vane wheel is fixed decreases in order to solve the problems described above, the difference between the maximum and minimum overall dimensions across the width decreases significantly, which makes the mechanism extremely ineffective in terms of the stated problem of maintaining stability in the unfolded (maximum) position of the weathervane wheels. Due to the listed shortcomings of such a mechanism, its use had to be abandoned.

For the scheme with the front wheel drive, another version of the mechanism for changing the overall width, shown in Figure 4, was developed.

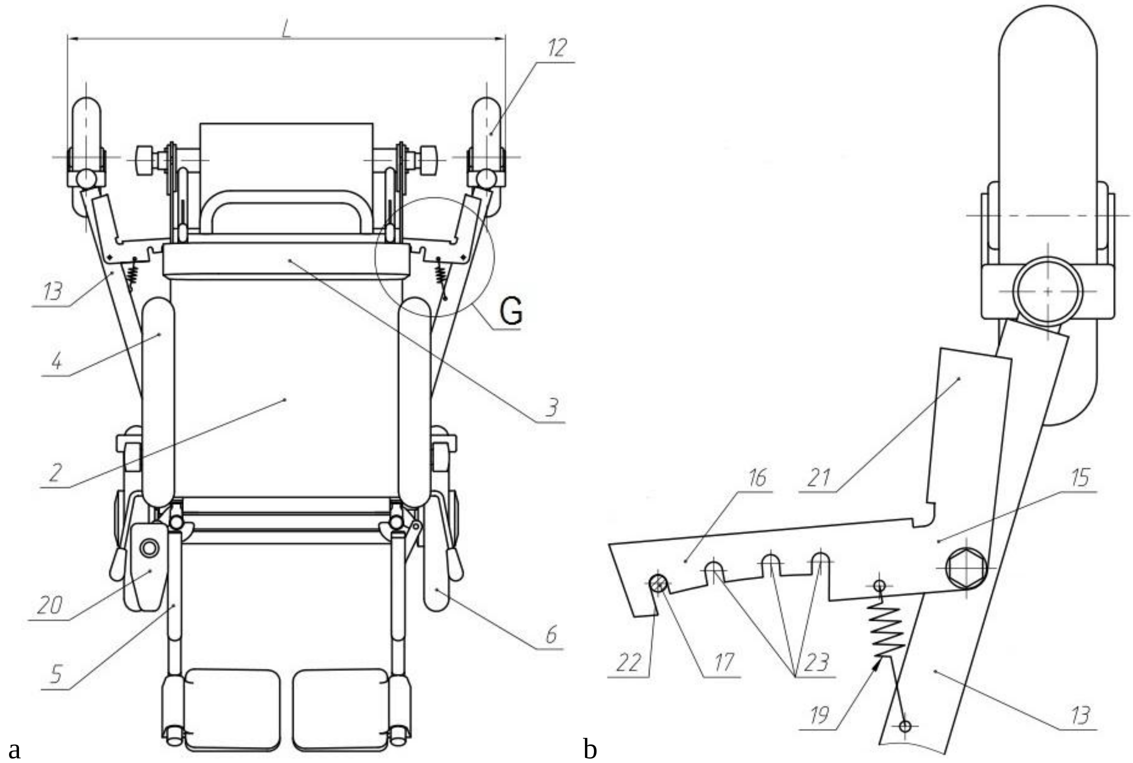

Figure 4. Mechanism of changing the width at the TIEV with front wheel drive. a - top view; b - view of G by b (increased). 2 - the seat; 3 - backrest, 4 - armrests; 5 - feet support; 6 - front driving wheel; 12 - rear wheel; 13 - the upper rod of the side frame 8; 15 - two-arm lever; 16 - shoulder of double-armed lever 15 with grooves 22-23; 17 - retainer; 19 - tension spring; 20 - joystick; 21 - the shoulder of the two-arm lever 15; 22, 23 - grooves of the shoulder 16 of the two-arm lever 15.

The control of each mechanism for changing the distance between the rear wheels of the wheelchair is as follows. When moving on a free platform or over wide aisles, the arm 16 of the two-arm lever 15 is in the position shown in Figure 4b. The distance L (figure 4a) between the rear wheels 12, in this case, will be maximum. Before the narrow passage (corridors, doorways in the bathroom, toilet, elevator, etc.), the person driving the wheelchair grips the upper shaft 13 (figure 4b) of the side frame 8 and at the same time the shoulder 21 of the two-arm lever 15. Then it stretches the tension spring 19, thereby removing the groove 22 of the arm 16 of the two-arm lever 15 from engagement with the latch 17. Further, the side frame 8 rotates about the main vertical axis 7 by the upper shaft 13 at the desired angle. Then one of the slots 23 is brought into contact with the latch 17. At the same time, the distance L (figure 4a) between the rear wheels 12 is fixed at a lower value, in which the previous case. The distance L (respectively one or the other of the slots 23) is selected in accordance with the width of the passage.

4. Results and conclusions

Thus, in the framework of this study, prototypes of the TIEV model 3.1 (Figure 5) and TIEV model 3.2 (Figure 6) were developed and manufactured with the above-mentioned mechanisms for changing the overall size in width for subsequent field tests in accordance with GOST R ISO 7176.

a b

Figure 5. TIEV model 3.1 with front drive before transformation (a) and in the transformed state (b)

Analysis of the results of the tests allows us to say that in terms of the static and dynamic stability indicators of the TIEV model 3.1 with the limits of the ramp up to 18°, it exceeds the TIEV model 3.2 (the limiting angle is 13°). In addition, the TIEV model 3.1 has a more ergonomic design, more understandable control of the transformation mechanism, and there is no inversion of the control signal when the overall size changes in width. A very important advantage of this mechanism in comparison with TIEV model 3.2 is the possibility of fixing the mechanism in different positions depending on the operating conditions, whereas the mechanism with an asymmetric rotary fork has only two extremes (maximum and minimum).

a b

Figure 6. TIEV model 3.2 with rear drive before transformation (a) and in the transformed state (b)

Within the framework of the trilateral cooperation of Novgorod State University named after Yaroslav the Wise, the Innovation Support Fund and the Kvant Scientific and Production Association, it is planned to mass-produce a transformable invalid electric vehicle that is structurally close to the prototype TIEV model 3.1. Currently, preparations are carried out for the production and certification of this TIEV model.

The design of the mechanism for changing the overall dimensions along the width is protected by patent for utility model No. 175141 "Wheelchair with variable distance between the rear wheels" [27-28]. The design of this mechanism allows you to talk about the achievement of the planned properties and characteristics of the wheelchair being developed, namely:

1. The patented mechanism for changing the overall clearance along the width allowing to overcome doorways with a width of 600 mm, which is especially important for Russian operating conditions.
2. Convertible to the same level with the seat backrest and armrests allowing to move from the seat plane in any direction, which increases the mobility of the TIEV user .
3. TIEV has a weight of less than 40 kg and an estimated final cost of up to 100 thousand rubles.
4. All the transformation processes are carried out by the user of the IV independently without assistance and an additional tool.

In support of the relevance of the development in Table 1, the comparative characteristics of the TIEV model 3.1 with the main competitors in the market of wheelchair electric wheelchairs of Russian production are given, which is especially important in the context of the import substitution policy.

Table 1 - Comparative characteristics of TIEV 3.1-A with models of "Observer" and "CaterWil" companies

IV Name	Width in operation, mm	Weight, equipped, kg	Can fold the back and arm support to the seat level	Capable to pass the stairs	Price, thousand rub.	Production
Observer Standart	645	61,5	no	no	97	Russia, Kaliningrad
Observer Optimus OB-EW-012	740	186	no	yes	530	Russia, Kaliningrad
CaterWil GTS3	645	115	no	yes	504	Russia, Novosibirsk
TIEV model 3.1	575	38	yes	no	from 80	Russia, Velikiy Novgorod

5. Aknowledgements

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