SPECIFICS OF THE UTILISATION OF A MOTORCAR BY A PERSON WITH A LOCOMOTIVE DISABILITY

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Abstract

The possibility of utilisation of an individually adjusted personal motorcar is one of important preconditions to undertake professional activities by persons with a considerable locomotive disability. This refers, in particular, to persons who move with the assistance of wheelchairs. Typical, serially manufactured personal motorcars are adapted to the requirements resulting from a disability. The original construction of such cars usually does not take into consideration specific needs of disabled persons. The objective of this study was to elaborate a list of specific car design requirements for a driver with a locomotive disability. The object of the performed analyses was the process of car driving (problems associated with independent loading and unloading of a foldable wheelchair were omitted). Furthermore, the authors did not study ergonomic issues associated with the maladjustment of individual devices adapting the car. The analysed data were obtained following interviews based on questionnaires submitted by disabled users of personal cars. All respondents moved about with the aid of wheelchairs and their disability was the result of injuries of the spinal cord (paraplegia and tetraplegia). The result of the investigations is a catalogue of specific ergonomic requirements regarding the operating space of the personal car driver.

Keywords: *personal motorcar, car ergonomics, a driver with disability, questionnaire investigations*

1. Introduction

1.1. Car utilisation by persons with locomotive disabilities

In accordance with the national census, which was carried out in Poland in 2002, every seventh inhabitant of our country is a disabled person or, at least, considers him/her to be one (this constitutes approximately 5.5 million people). Dysfunctions of motor organs constitute the most common cause of all causes of disabilities in the above-mentioned group of persons. Persons with considerable locomotive disabilities move about with the assistance of wheelchairs. It is estimated that, in Poland, the number of people who depend on wheelchairs to move around, including, primarily, persons after injuries of the spinal cord (ISC), reaches approximately 100 000 (0.26 % of the entire population) and this number increases by over 1000 persons every year [2]. The analysis of the professional situation of persons after ISC derived from different countries in the world proves that only about one third of such persons return to professional activity [3]. Among factors seriously hindering the return of these persons to professional activities, the lack of properly adjusted means of public transport ranks very high and that is why, very frequently, a

suitably adapted personal car remains the only alternative for persons who decide to return to professional activity. In addition, individual transport is a much more effective alternative in comparison with public transport. Apart from professional activisation, a personal car is an important factor affecting directly the possibility of independent life.

The adaptation process of a typical personal car to the requirements of a disabled driver involves a change of equipment of steering and control systems [1, 6, 8] frequently carried out by specialised workshops but it is also possible to purchase a typical car and have it adjusted by the manufacturer. However, in both cases, it is a serially manufactured car that undergoes adaptation whose construction only slightly takes into consideration subjective requirements of wheelchair users. The aim of the above-mentioned adjustment is to allow independent utilisation of a motorcar by a person who moves about on a hand-operated wheelchair.

Although the adaptation of steering systems of a car is a relatively simple task, a serious reconstruction of the driver's space is, practically speaking, impossible. The need to match internally with one another (with regard to space and forces to be applied) three elements of an anthropo-technical system: disabled person – wheelchair – personal car as well as the interaction of this system with the environment requires the cooperation of designing processes of two different technical means (wheelchair-car) in order to adjust them to man's requirements. The following areas of problems emerge: (1) ergonomics of the man-wheelchair system [5], (2) ergonomics of the wheelchair-car system and (3) ergonomics of the man-car system [4].

This study undertakes issues associated with the specificity of interactions between the driver with a locomotive disability and the inside of an individually adapted personal car. The analysed data were obtained from interviews carried out on the basis of a questionnaire with 38 disabled users of personal cars. The investigations were restricted only to the process of car utilisation leaving out problems connected with the getting in and out of the car and independent loading and unloading of the wheelchair. The obtained data is to allow the elaboration of data for a universal design of the interior of personal car cabins taking into account the requirements of disabled persons regarding the setting of regulated elements in the car cabin.

1.2. Type of disability

From the point of view of the extent and kind of the necessary changes to be made in a car, drivers with locomotive disabilities are divided into groups of persons: (1) with dysfunctions or lack of one leg, (2). With dysfunctions of upper limbs (amputation, paresis etc.), (3) With hemiplegia (paresis of one half of the body – left or right), (4) with dysfunctions or lack of both legs (paraplegia, amputation etc.), (5) with dysfunctions of four limbs (tetraplegia, dystrophy, etc.).

This study focuses on persons belonging to the last two groups. Persons with such disabilities usually move about with the assistance of wheelchairs, hence they have the most serious problems associated with independent movement due to considerable locomotive disability.

1.3. Kind of adaptation

In modern personal cars, many activities performed by the driver driving the vehicle are realised completely or are assisted by mechatronic control systems, e.g. a system preventing wheel blockage during braking (ABS), aiding the maintenance of the desired direction of driving (EPS), assisting parking (PTS), maintaining a safe distance from the preceding car (DISTRONIC) and many others. However, vehicle basic driving functions are carried out by the driver who uses for this purpose a number of signalling and controlling devices. In the collection of the SEA J1903 recommendations, these devices are divided into three groups [7]:

- Principal basic control mechanisms which exert a direct influence on the direction and speed of driving of the vehicle (the steering wheel, brake, accelerator),
- Principal additional control mechanisms (gear lever, clutch pedal, indicator switch, light switch, windscreen wiper switch, rear mirror regulation, ignition, window heating switch),

- Remaining additional devices (seat position controls, steering wheel regulation, control of the lift for wheelchair loading, internal light switch, heating/air conditioning controls, radio switch, window lift actuator, door opening and locking mechanisms etc.).

In the course of vehicle adjustment, depending on the requirements resulting from the kind of driver's disability, the type and number of modular adaptive devices from the first two of the above-mentioned groups are selected. Additionally, it is also possible to make adjustments of the remaining assistive devices of the driver's space improving their ergonomics from the point of view of the disabled users. In the process of car driving by a disabled person, one of the significant factors is the appropriate adjustment to the driver's disability of executive systems. One of the important problems guaranteeing effective driving by a disabled person is the appropriate adjustment of all elements found inside the cabin to this person's particular disability in order to compensate difficulties resulting from: (1) disability, (2) realisation of activities loading the skeletal system and (3) partial special limitations caused by the installed additional equipment.

2. Specificity of requirements of disabled persons

Typical problems occurring in the course of car utilisation can be attributed to the fact that the driver's zone construction as well as the construction of steering-control devices tends to fail to take into account the specificity of disabled persons. In the course of interviews with car users, a number of problems associated with the driver's zone ergonomics were identified. They are listed in Table 1 which is divided into parts: persons suffering from paraplegia (P) and those form tetraplegia (T). Basic problems associated with the utilisation of the control-steering appliances in personal cars are presented in Table 2.

Tab. 1. Ergonomic problems with assistive steering devices

No.	Description of the problem	P	T
1	Contact zone between the body and the car seat is too hard, the disabled person is significantly confined in her/his possibilities of changing position in the course of driving	++	++
2	The body support system in the seat fails to provide sufficient stability, especially in driving conditions	++	+++
3	Upholstery of the driver's door does not ensure possibilities of long-term propping in order to assist stability	++	+
5	The extent of the driver's seat regulation is insufficient	+	+++
6	No servo-system with automatic controls for the driver's seat adjustment	+	+++
7	Insufficient access to device controls regulating the driver's seat	+	++
8	Mechanical strength of handles situated above the driver's seat is insufficient	+++	0
*(0) – no problems, (+) – slight problem, (++) – big problem, (+++) – very big problem			

3. Recapitulation

A relatively rapid progress has been observed recently in the area of adaptation of the steering-control systems of personal cars to disabled persons and the main direction of this progress is mechatronics. At the moment, there are systems allowing, for example, the integration of the control of assistive functions with one switch, the control of all functions necessary to drive a car with the assistance of a joystick or voice. During the adaptation work, careful attention is paid to the passive safety of the driver driving an adapted car. Moreover, investigations are carried out on the behaviour of the additional equipment during collisions as well as interactions between airbags and the assistive equipment.

Tab. 2. Ergonomic problems associated with principal basic and additional control mechanisms

No.	Description of problem	P	T
1	Force needed to steer is too big, frequently even in the case when the original power steering is mounted	0	+++
2	Operation of the road/passing lights switch requires taking the left hand off the steering wheel (the right hand is operating the accelerator at this time)	++	++
3	Various types of switches, e.g. windows actuator switch, emergency lights switch are not designed to be operated by persons with manual disabilities	0	++
4	Handbrake is operated by leg	+++	+++
5	Handbrake construction makes it difficult to operate	0	+++
6	Shortcomings in car equipment (e.g. electric controls of windows, mirror heating, windscreen heating, tempomat, backing up sensors, lights automatic switch-off, automatic switch-off of wipers, voice-operated audio equipment, central lock, automatic window closure, etc.)	+++	+++
*(0) – no problems, (+) – slight problem, (++) – big problem, (+++) – very big problem			

The progress in the field of adaptation of steering-control equipment is not accompanied by advances in the area of inside ergonomics of cars.

It is evident from the data of the Institute of Industrial Design in Warsaw that the anthropometric measurements of the population of disabled persons are significantly smaller than those of the corresponding population of the able-bodied persons. This refers to such measurements as: the height of the body, the height of the plane of vision as well as measurements of side, upper, lower and front reaches of arms.

It seems that in the nearest future Reverse Engineering methods will be employed in the course of designing types and extent of car adaptation for individual drivers, in particular, methods of virtual image processing. Analyses employing the results of 3D scanning of specific drivers with locomotive disabilities conducted in virtual environments of biomechanical programs will allow much better adjustment of the interior of a car to the requirements of a disabled driver.

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