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Assessment of the impact of the shape of the handle on the ergonomics of operating a handbrake

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Abstract. This thesis addresses the ergonomic problem of conflict between hand-operated mechanical brakes and center rests on certain types of vehicles. The hand brake is one of the basic means of control of a personal vehicle and its smooth and comfortable mastery directly affects traffic safety and driver well-being. The paper outlines a possible solution to this problem through the shape of the mechanical handbrake handle. The proposed solution is validated by using Tecnomatix Jack, which is primarily intended for solving ergonomic problems in the context of Digital Human Modeling. Specifically, in order to verify the solution, the Comfort Assessment tool is used, which in itself contains several published studies looking at driver comfort in accordance with the bending of specific joints. The results of this thesis can be used for future mechanical handbrake designs in cars.

Key words: Handbrake, Driver Ergonomics, Digital Human Modeling, Personal vehicle.

INTRODUCTION

Currently, the issue of the ergonomics of passenger car cabins is considered an increasingly important part of the structure of a new vehicle (Ge et al., 2007; Wang et al., 2007). An optimally ergonomically-designed driver platform, as well as the crew of the car, plays a significant role in vehicle safety and the wellbeing of the driver and passengers (Reed, 1998). Today, the economic success of the car often depends on the ability to optimally design all of the control and communication elements of the vehicle. The mechanical handbrake is among the basic control elements of cars. Despite the emergence of many alternative solutions, for example on the basis of electronic controls, the mechanical handbrake is still widely used. It can be assumed that conventional control of a handbrake will not disappear in the future. However, the conventional solution for handling a handbrake, along with the armrest for the right hand (on the left side of the car for right-hand driving), creates a classic ergonomic problem whose solution has not yet been sufficiently and satisfactorily defined.

For safe handling of a mechanical handbrake, the driver must involve virtually all the major muscles and three major joints of the upper limb – shoulder joint (*articulatio humeri*), elbow joint (*articulatio cubiti*) and wrist joint (*articulatio radiocarpalis*). In addition, in order to grip the *(flexi)* handle of the mechanical handbrake, the driver must use also use finger joints. In some cases, movement of the torso is also involved, which helps the upper limb in reaching the handle. Even though the mobility of the upper limbs of a healthy person is very large, there is a range of rotation of each of the joints during which a person can feel considerable symptoms of discomfort (Kapandji, 2007). These ranges can be achieved when operating conventionally-designed and situated mechanical handbrakes while interacting with the armrest. This paper deals with one possible solution to this ergonomic problem, which is based on the structural and shape adjustment of the handle of the mechanical handbrake.

In order to resolve the above problem, a hypothesis was formulated that suitably adjusting the design of the handle of a mechanical handbrake will decrease the amount of flexion required for each of the affected joints, and thus improve the overall level of ergonomic solutions for passenger cars.

MATERIALS AND METHODS

All of the measurements described below are shown in degrees and are based on a so-called basic anatomic position, which is important for determining the direction and extent of bending of each joint and represents the zero reference position for all of the derived measurements. This position is defined as an erect position with upper limbs hanging loosely at the sides of the body with palms facing forward. The position of the lower limbs is not important for the case being evaluated, and will therefore not be examined in this investigation.

Software and analytical tools

In order to accurately identify and test the hypothesis, the Tecnomatix Jack software tool was used, which is primarily designed to assess the ergonomics of a person, and which contains the analytical tools for evaluating the above hypothesis.

In practice, it is very difficult to physiologically define the natural range of motion of a person's individual joints. There are a number of values in professional literature that are divergent in degrees, and that is why ranges that are defined by the Tecnomatix Jack program were used for this study. This program uses the knowledge of several ergonomic studies that deal with the comfort of a driver while driving (Porter & Gyi, 1998; Krist, 1994). It also uses these ergonomic studies, inter alia, for determining the ranges of rotation of the joints of the upper limbs specified below.

Table 1 shows the bending ranges of individual joints of the upper limb as they are set out in the basic module of the Tecnomatix Jack program. According to basic human physiology findings, the elbow joint can be bent in only one plane, and therefore only values of angles on the Y plane are used.

Table 1. Ranges of rotation of the joints of the upper limb according to the Tecnomatix Jack program

Joint	X(°)	Y(°)	Z(°)
Articulatio humeri	0–180	-45–135	-135–90
Articulatio cubiti	–	0–142	–
Articulatio radiocarpalis	-85–100	-45–45	-113–77

Spatial situation of the location of a mechanical handbrake in a passenger car

Due to the differences in the design of individual types of vehicles, it is evident that the structure and relative position of the handbrake handle and armrest will vary in individual vehicle models. It is not the aim of this study to describe a specific solution, but rather the general principles, and thus a model universal solution was created which does not assume the particular dimensions of any real type of vehicle, but instead only serves to demonstrate the chosen principle of the solution. This solution, however, is generally dimensionally-based on mid-sized VW vehicles. The aim of this study is not to identify specific, precise dimensions and values, as they are very variable with respect to statistical models of the population.

In order to create a spatial arrangement model, the following dimensions were determined:

- Height of armrest above the lower level of the seat.
- Height of the axis of the handle of the handbrake above the lower level of the seat.
- Distance of the axis of the handle of the handbrake from the longitudinal axis of the seat.

As is evident from Fig. 1, the test environment is based on the classic location of the mechanical handbrake and armrest.

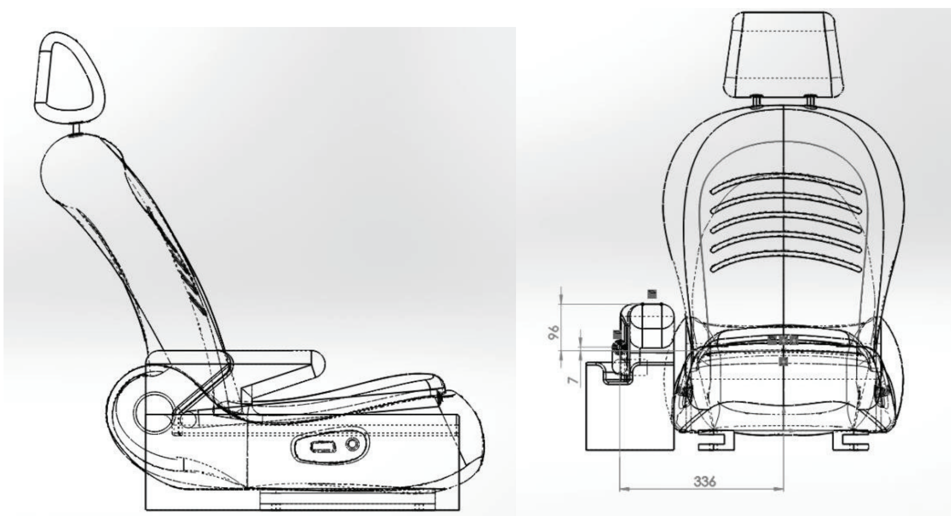

Figure 1. Situational drawing of a general seat in a passenger car with armrest and handbrake.

It is clear that in particular due to the influence of height-adjustable seat, the spatial situation will change depending on the height of the seat. Therefore, it is necessary to select one test position, which in this case represents a distance of 96 mm between the top edge of the armrest and the axis of the handle of the handbrake, 7 mm between the axis of the handle of the handbrake and the lowest point of the seat, and 336 mm between the axis of the handle of the handbrake and the longitudinal axis of the seat. In order to operate a conventional mechanical handbrake, as described above, the driver must achieve limiting bends, in particular in the wrist Joint (*articulatio radiocarpalis*), as was empirically determined. These torsions are achieved with this solution despite the fact that there is practically a direct interaction between the forearm and the armrest (see Fig. 2), and hence this leads to the inconvenient deformation of the forearm.

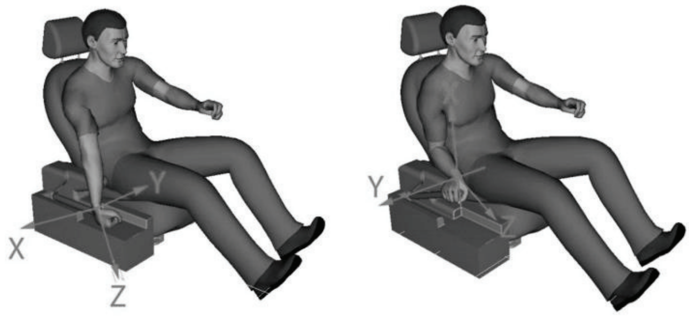

Figure 2. Position of the driver when gripping the handle of the mechanical handbrake with a classic design

Solution Methodology

In order to confirm the hypothesis that an appropriate adjustment to the handle design of the mechanical handbrake handle will lead to a reduction in the required flexion of each affected joint, initial conventional solutions were defined based on the classic placement of the mechanical handbrake and armrest in a passenger vehicle. Furthermore, structural modifications were designed for the handle, and both solutions were implemented as a 3D model and transferred to the Tecnomatix Jack program, where they were numerically analysed and verified.

A 50 percentile male dummy from the ANSUR (Clauser, 1988) database was used in the Tecnomatix Jack testing program. It had a height of 176 and weight of 78 kg for testing both solutions. At the beginning, the dummies used for all imaging solutions have the same working position based on the position of the driver while driving the vehicle. A difference in the positions of individual dummies only occurs in the event of rotation of joints necessary for achieving a handle of the mechanical handbrake so as to avoid penetration between the forearm and the body of the armrest. The bends of other joints remain the same so long as there is no rotation caused by movement of the upper limb. These secondary movements of joints relate in particular to the spine.

A simple comparison of the rotation of individual angles of the joints of dummies in various positions was used for evaluation, as well as the comfort of the driving position according to the Dreyfuss 3D study (Tilley, 2002). The comfort values presented in Henry Dreyfuss Associates 'The Measure of Man and Woman' (Tilley, 2002), represent a compilation of comfort values from a variety of sources. These sources include Grandjean, Pheasant and NASA studies (Grandjean, 1987; NASA, 1978; Pheasant & Chasle, 1986). These data are more general than either Rebiffé or Grandjean, applicable to most sitting tasks. In some regards, the Dreyfuss 3D study uses a different methodology for evaluating the range of bending of joints than the basic Tecnomatix Jack module, wherein, on the basis of own parameters, it defines the level of comfort of the driver in a determined position. Yet the main parameters defining the bending of the joints of the upper limb and the bending of the torso are defined similarly to the basic Tecnomatix Jack module.

RESULTS AND DISCUSSION

In order to achieve smaller angles of bending of the individual involved joints, it was necessary to choose a design modification that would primarily minimize the bending of the wrist Joint *(articulatio radiocarpalis).* After a series of tests, an optimal solution was chosen in which the mechanical handbrake handle was rotated by 110° toward the driver (Fig. 3). This structural adjustment was implemented as a 3D model and then confirmed in the Tecnomatix Jack program. Based on the methods described above, it was experimentally ascertained that such a selected handle shape better corresponds to the natural physiological position of the upper limb than the conventionally used solution (Fig. 4).

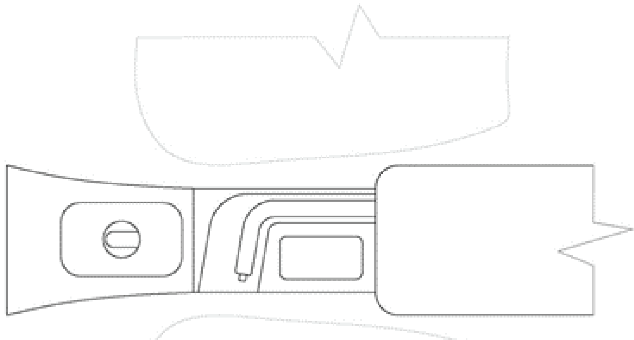

Figure 3. Overview of the designed structural solution with the handle bent at an angle of 110°.

Figure 4. Position of the driver whilst gripping the handle of the handbrake with the structural design solution in both extreme positions.

Tables 2 and 3 show the resulting measured values of angles during bending of all of the involved joints. It is evident from the values that in particular during bending of the wrist joint *(articulatio radiocarpalis),* the newly selected structural solution significantly reduced the ranges of bending (Table 1). The original solution forced drivers to achieve maximum torsion of the wrist joint on two levels, indicating a high degree of discomfort during the control process.

Table 2. Ranges of rotation of the joints of the upper limb according to the Tecnomatix Jack program

		Elbow	Wrist rotation			Shoulder rotation		
		Y	Y	X	Z	Elevation	Ant/Post	Rotation
	Ranges (°)	**0–142**	**-45–45**	**-85–100**	**-113–77**	**0–180**	**-45–135**	**-135–90**
New	Down (°)	11	5	10	**77**	49	74	-33
handbrake	Up (°)	63	4	33	62	21	59	-20
Classic	Down (°)	21	-16	-40	**77**	51	75	-126
handbrake	Up (°)	92	**-45**	8	**77**	9	58	-35

Table 3. Ranges of rotation of the upper torso and rotation of the torso in the area of the L5 vertebrae according to the Tecnomatix Jack program

		Rotation of the upper torso			Torso rotation - L5		
		Flex	Axial	Lat	Y	Z	X
	Ranges (°)	**-52–84,5**	**-43–43**	**-40–40**	**-6,5–11**	**-2–2**	**-4–4**
New	Down (°)	74	-5	15	**11**	-1	3
handbrake	Up (°)	73	0	0	**11**	0	0
Classic	Down (°)	74	-9	15	**11**	-1	3
handbrake	Up (°)	74	-5	15	**11**	0	3

In order to achieve optimal gripping of the handbrake, it is also necessary to involve the movement of the spinal vertebrae and upper torso. In this area, it is once again necessary to base the results on the principle of the depiction of the human body as in the Tecnomatix Jack program. Movements of the spine and upper torso are divided into two parts – the upper part of the torso bends smoothly via the progressive involvement of all of the vertebrae (shown in Table 3 – the values of 'rotation of the upper torso') and the entire torso as a unit with the pivoting point at the L5 vertebra (shown in Table 3 – the values of 'torso rotation – L5'). In terms of the bending of the spinal vertebrae, the changes between the conventional and the modified solutions are not as evident as in the case of the upper limb. Nevertheless, it is necessary to specify them within the complex perspective on the issue.

The proposed solution was also subjected to testing using the Dreyfuss 3D study. The comfort studies describe comfortable joint posture ranges. The graphs (Figs 5, 6, 7, 8) shows the name of the joint, a bar graph indicating the current deviation from the mode, and text values for the current value, as well as the range and mode of the comfort range. The mode is the 'most often adopted' posture. Fig. 5 and 6 show the main differences in the evaluation of the comfort of the driving position between the conventional and modified solutions when the handbrake is in the down position.

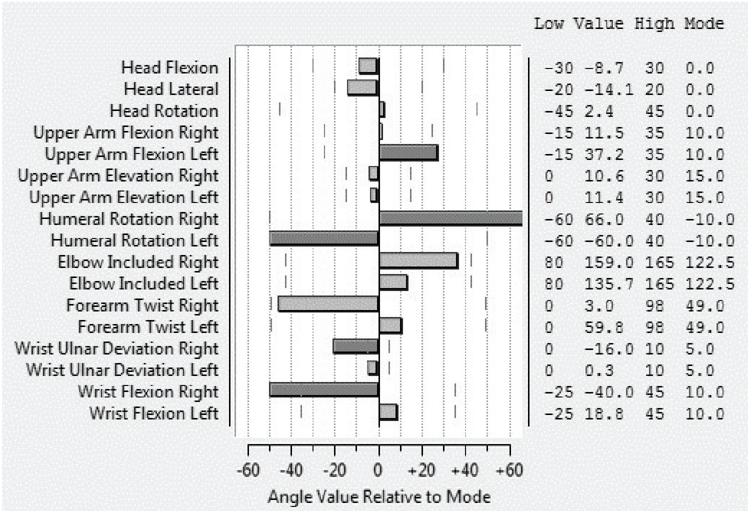

Figure 5. Conventional solution – down position.

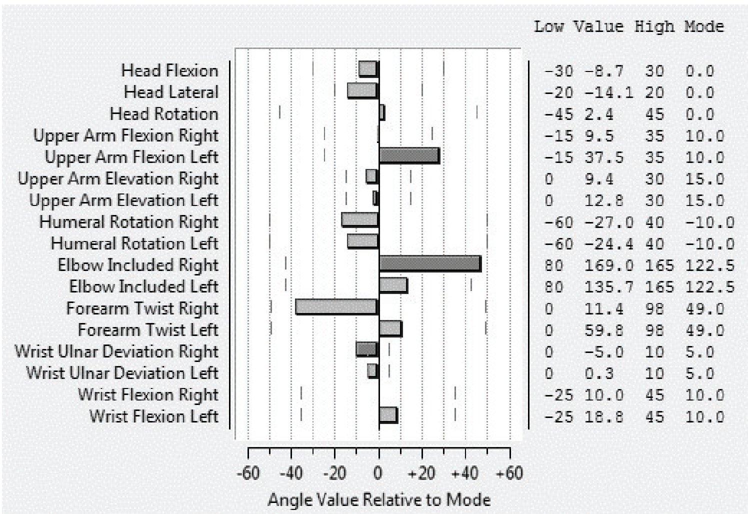

Figure 6. Modified solution – down position.

Figs 7 and 8 show the main differences in the evaluation of the comfort of the driving position between the conventional and modified solutions with the handbrake in the up position. The dark grey-marked values represent the state when the joints achieve bending angles that are defined as uncomfortable. The graphs show that even according to the Dreyfuss 3D study, the modified solution exhibit better results than the conventional arrangement, in particular in the wrist area.

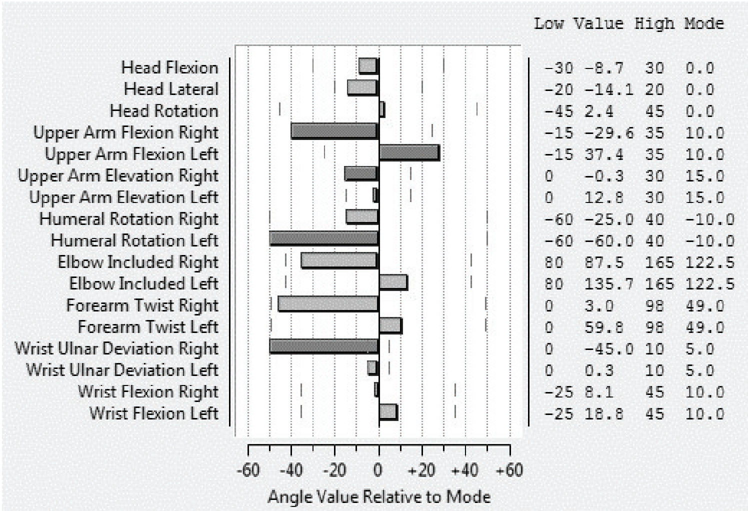

Figure 7. Conventional solution – up position.

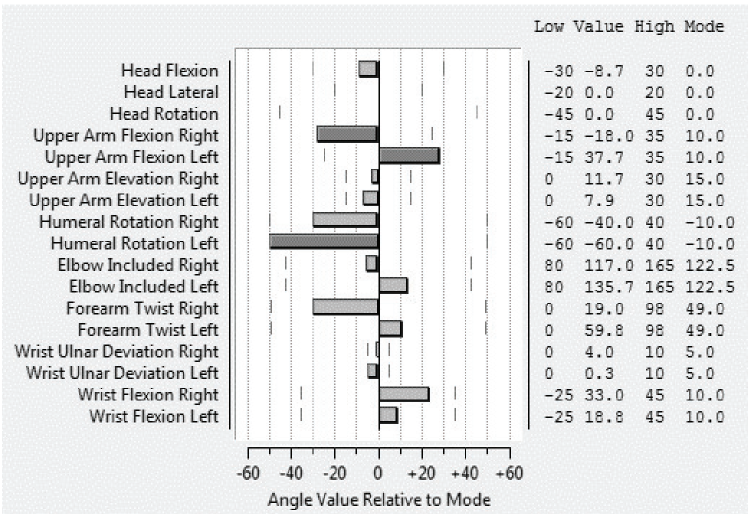

Figure 8. Modified solution – up position.

CONCLUSIONS

The measured values of the solution of the ergonomic conflict of the mechanical handbrake and armrest in a passenger car that are shown above indicate that this solution offers the possibility to significantly improve the comfort of drivers. Despite the fact that in view of the aforementioned facts it is not possible to precisely dimensionally specify the solution, the solution can be utilized as a general concept in terms of an approach to the structural solution of the handling of a mechanical handbrake. In the model arrangement of the handbrake, seats and armrest position that is described in this paper, important differences were ascertained in the values of the bending of the joints of the upper limb between the classic solution and the proposed solution. In particular in the case of the wrist joint, these are notable differences, and it can therefore be stated that the use of the structural design solution with the bent mechanical handbrake handle significantly increased the comfort of the driver. The proposed solution can be described as a technologically easily-resolvable change to the cab structure, and it would not be necessary to invest economically-significant development and production costs in order to implement the solution.

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