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APPLICATION OF MECHATRONICS IN SEATING FURNITURE

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Abstract

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Mechatronics is gradually being used in different fields of the production process and final products. In the field of home seating furniture, it has not been formally declared as such yet. The purpose of further development of seating furniture is to improve its ergonomic parameters, to improve user comfort in controlling and using seating furniture or to provide new additional functions of seating furniture. Application of mechatronic principles can be presumed within the framework of this development. An analysis of the current state of reclining seating furniture, which uses mechanical and electromechanical positioning mechanisms, is conducted in order to formulate possible fields of applying mechatronics. The analysis defines individual ergonomic parameters which are influenced in reclining of seating furniture. This analysis is used as a basis for formulating a hypothesis describing potential development fields of applying mechatronics in home seating furniture.

Keywords: mechatronics, electromechanics, mechanics, reclining seating furniture, ergonomics, motor, safety elements

INTRODUCTION

Mechatronics is the interdisciplinary field of engineering dealing with the design of products whose function relies on the integration of mechanical and electronic components coordinated by a control architecture Alciatore (2011).

At present, mechatronics is used within the framework of production processes and also as a part of the function of final products. First applications of mechatronics are currently emerging in the field of home interiors e.g. a mechatronic shower Smart Shower (2012). The mechatronic designation is at the same time becoming a significant element of the promotion of products. Although, in the field of home seating furniture, mechatronic applications have not been presented or declared in a conspicuous way, it is already possible to use this designation to describe certain applications.

The definition of mechatronics implies a cooperation between electromechanical systems and logical control elements. It is exactly the presence of logical elements which distinguishes mechatronic systems from their predecessors – electromechanical and mechanical systems. The aim of the article is to define the border area between electromechanical and mechatronic applications in reclining seating furniture and to define the potential fields for further development of mechatronic applications in seating furniture.

METHODS

The starting point of the article comprises of an analysis of the existing state of positioning furniture with a mechanical and electrical positioning system. The analysis defines individual ergonomic parameters which are influenced in positioning of seating furniture. The analysis includes specification of individual functional parts of a positioning system of seating furniture. This analysis is used as a basis for formulating a hypothesis describing potential development fields of applying mechatronics in home seating furniture.

RESULTS

Furniture with reclining parts can be described as reclining furniture. The purpose of reclining the individual parts of seating furniture is to adjust the geometrical parameters of seating – the ergonomic quality of seating. From the point of view of the method of control by a user, the existing positioning mechanisms of seating furniture can be divided into:

- mechanical – manually operated positioning mechanisms,
- positioning mechanisms with an electric motor.

Mechanical Positioning Systems

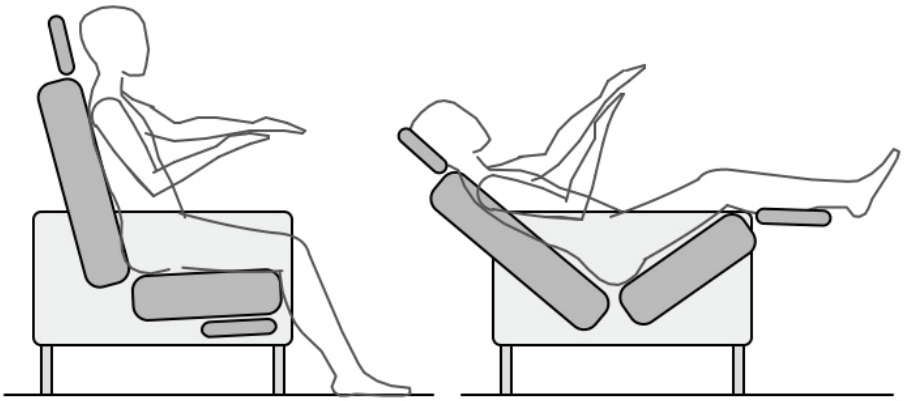
Manually controlled positioning mechanisms can be classified in the category of mechanical applications in seating furniture. The following types of mechanical reclining furniture may be observed in the market:

Reclining Armchairs

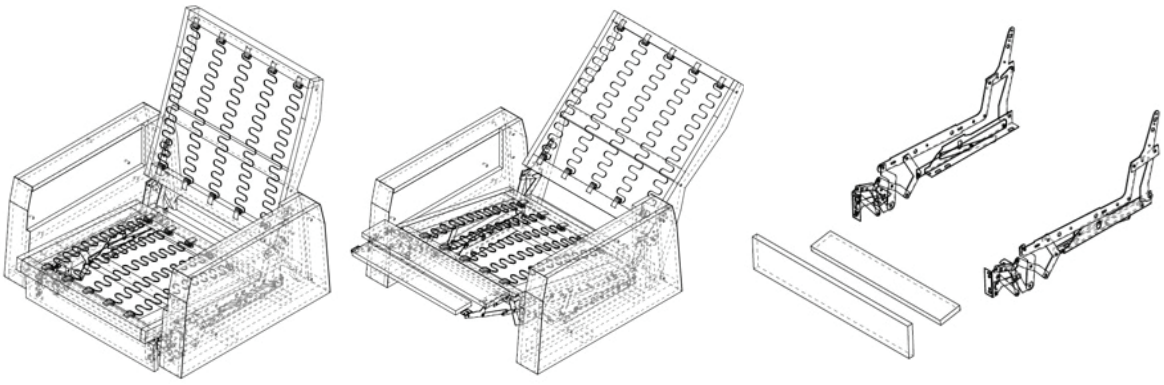
Independent reclining armchairs with a mechanical positioning device which enable to adjust the inclination of the backrest with regard to the seat, or possibly simultaneous extension of the footrest, have been already available in the market for several decades. See Figs. 1 and 2. These reclining armchairs allow a variable selection and change of a sitting position. When the brake of the mechanism is released and the seated person exerts pressure by his or her back, the backrest is reclined with a simultaneous slight back tilting of the seat and extension of the footrest. The sitting position is exchanged for a position for relaxing lying with stretched-out legs. In order to lock a position in the reclining range, positioning mechanisms are equipped with a mechanically controlled brake. Mechanisms without a brake enable only movement from the front sitting position to the back reclining one, sitting in an intermediate position is not possible. In order to return from the lying position to the sitting position, it is necessary to push one's legs against the footrest while at the same time taking the load off the backrest. The positioning mechanism then allows the armchair to return to the initial sitting position. Shorter and lighter persons can have a problem with exerting sufficient pressure on the footrest for returning to the sitting position.

Reclining Segment of a Seating Set

Contemporary lounge sets offer the option of choosing the location of a positioning mechanism in a selected segment of a seating furniture set. A lounge set thus enables to set the seating parameters independently in individual seating segments.



1: *Seating and relaxation position in reclining chair*



2: *Structural scheme of positioning chair with three-way recline scissors mechanism*

Inclining of a Backrest Part

Contemporary sofas and armchairs are abandoning the ergonomic tilting of the seat by 3–5° for upright sitting and they very often use a horizontal seat. Apart from sitting, the sofas presuppose also transverse lying down which is more comfortable on a horizontal seat. A horizontal seat is often fitted with an extended seat for relaxing stretching-out of legs. The sitting position with a horizontal seat can be adjusted by tilting the backrest against the seat which remains in the horizontal position. Some mechanisms enable smooth tilting of the backrest by pushing one's back against the backrest after releasing the brake. After repeated releasing of the brake and decreasing the pressure of the back against the backrest, the backrest returns to the upright position. Less comfortable control requires that a standing person tilts the backrest and that there is no weight against the backrest. See Fig. 3.

Folding Backwrest

Folding backwrest enables overall elavation of backwrest and support of head. See Fig. 4.

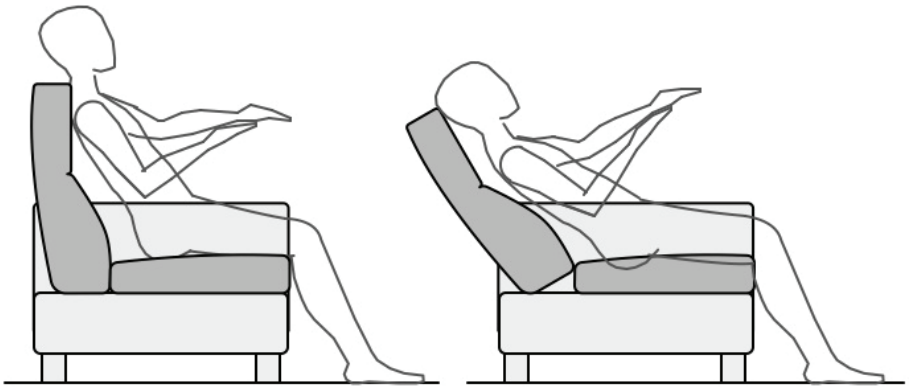
Headrests – Sliding, Tilting

Contemporary modern sofas and armchairs have significantly decreased the height of the backrest in comparison with traditional sofas and armchairs. The modern appearance of sofas with low backrests results in a loss of sufficient back support for upright sitting. The low backrest in combination with the deeper seat makes leaning of the higher part of one's back possible only in a reclined position. The head of a sitting or reclined person is not supported. In order to facilitate comfortable sitting and support the head, the backrest parts of seating furniture with low backrests are fitted with add-on, extension, tilting or foldable headrests. Extension headrests can be inserted in a sleeve which is integrated in a fixed backrest and the height of headrests above the backrests can be adjusted either by degrees or by pulling using a gas-liquid piston. See Fig. 5.

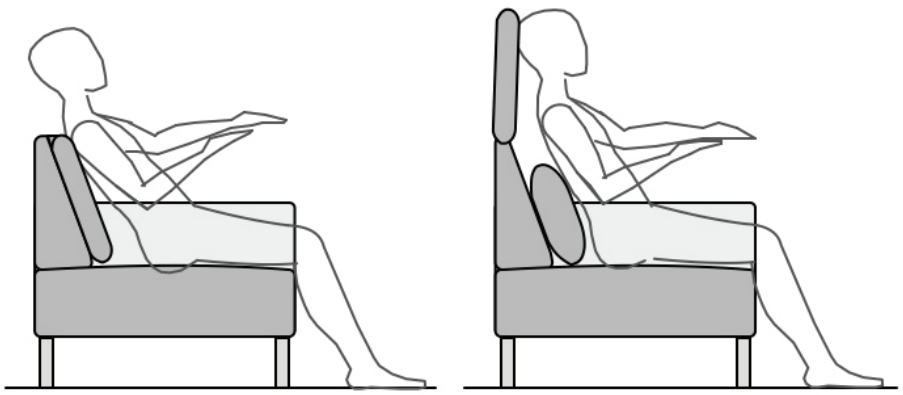
By inclining a tilting headrest it is possible to compensate the missing height of a backrest. Tilting headrests use various principles of tilting – rotation on a pin or sliding on rounded skids in a sleeve. See Fig. 6.

Folding Backrests

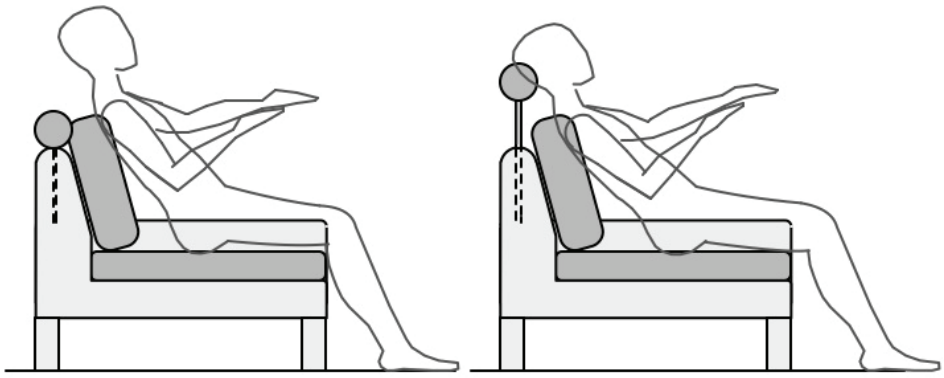
Folding backrests represent yet another principle of increasing the height of a backrest. Unfolding of backwrest increases the hight of backwrest and depth of seat. See Fig. 7.



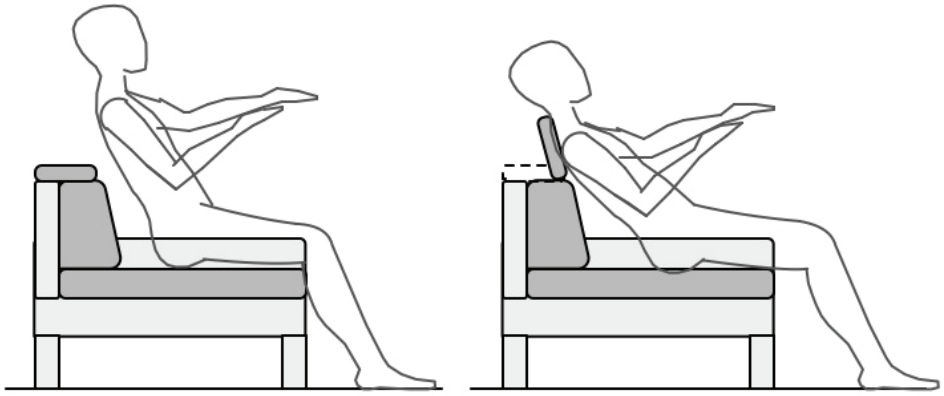
3: *Scheme of inclining back wrest*



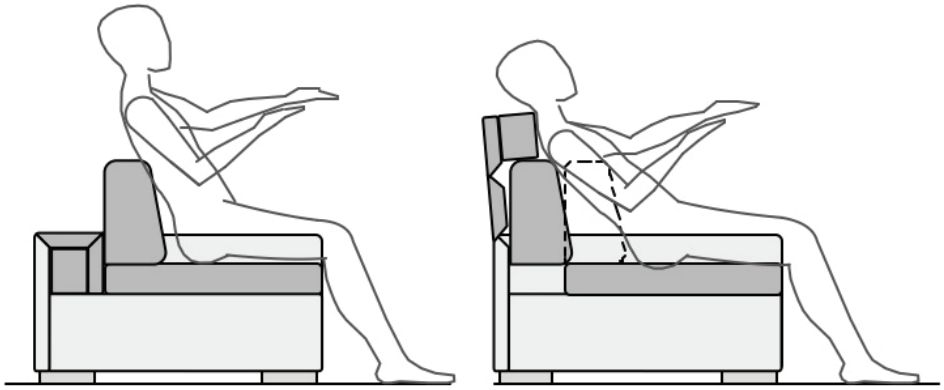
4: *Sceme of folding backwrest*



5: *Scheme of telescopic headrest*



6: *Scheme of tilt headrest*



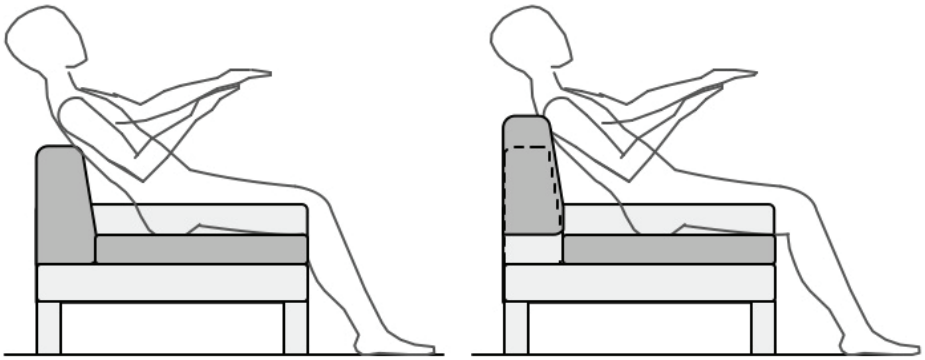
7: *Scheme of folding backwrest*

Height Adjustment of a Backrest

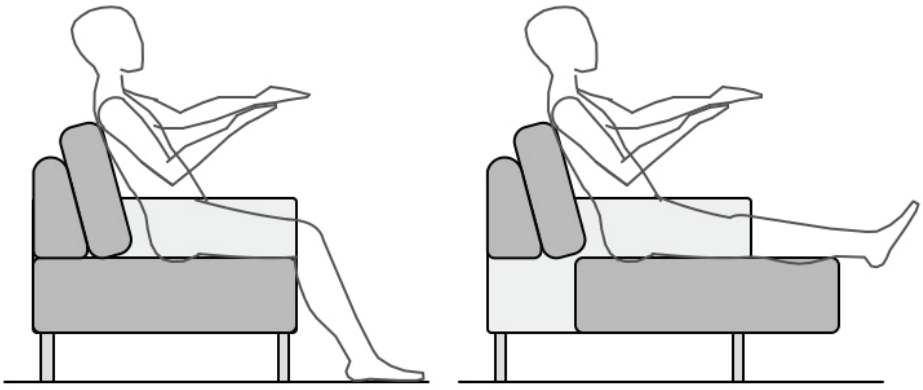
The height adjustment of a backrest by positioning the entire backrest part is seemingly simple at first sight. International furniture fairs showcased seating furniture models testing height adjustment options of entire back parts. The mechanical control of backrests with adjustable height is, however, problematic if they are wider. See Fig. 8.

Depth Adjustment of a Seat – a Sliding Seat, a Sliding Backrest

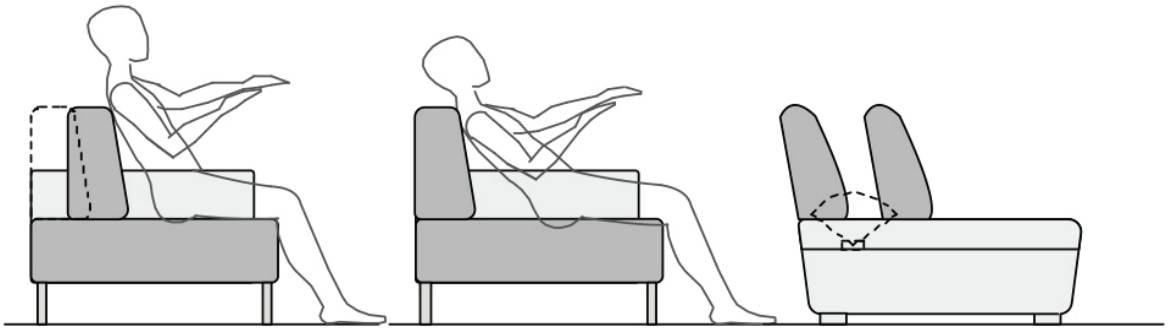
Contemporary modern lounge sets are intended not only for sitting but also for reclining with stretched-out legs. The depth of the seat is often too deep for normal upright sitting and it is frequently compensated by additional pillows placed in front of the backrest. The required depth of a seat can be adjusted by means of a sliding seat. See Fig. 9. The depth of a seat can be also adjusted by sliding the backrest part or by turning it on its swing support. See Fig. 10.



8: *Schema of adjustable hight of backwrest*



9: *Adjustment od seat depth by sliding seat*



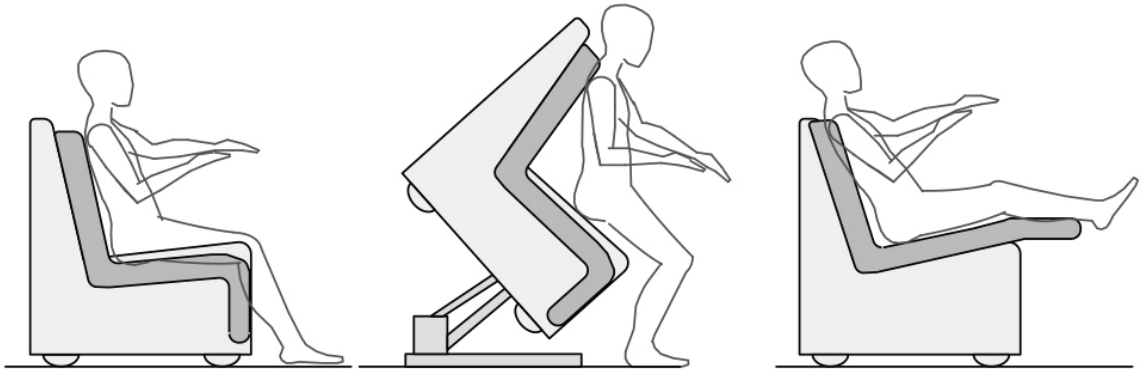
10: *Seat depth adjustment by sliding or overturing backwrest*

Height of Seat Adjustment

The height of a seat on home seating furniture constitutes a fundamental ergonomic parameter. Home seating furniture uses seat heights in the range from 35 to 50 cm. Elderly persons, in particular, will prefer a higher seat not only for easy standing up but also for sitting down on a lounge set or an armchair. Younger users, on the other hand, can find significantly low lounge sets attractive because this type of seating allows reclining with stretched out legs due to deeper seats and at the same time allows its users to keep their feet on the floor. Adjustable height of a chair is traditionally used in the case of a piano stool. The option of adjusting the individual height of a seat in relation to one's body height (or rather the length of one's legs) is essential for piano players because they need to operate the piano pedals. Optionally adjustable seat height – as it is known, for example, in the case of a piano stool – is not used in home seating furniture.

Sofa Beds, Sofas With Storage

Sofa beds and armchair beds constitute a separate category of seating furniture. This seating furniture aims not only at providing the seating function but also at offering the option of sleeping on an unfolded sleeping bed. The unfolding is provided by simple and sophisticated unfolding mechanisms which have various degrees of user-friendly control.



11: *Utilization of Lift Up chair*

Similarly, the market has been for a long time offering home seating furniture with storage which is accessible by means of tilting fittings.

Electromechanical Positioning Systems

The existing reclining furniture with electric motors can be classified in the category of electromechatronic application in seating furniture. The following principles can be noted in the market:

Reclining Relaxation Armchairs – TV Armchairs

The reclining principle of relaxation armchairs with electric motors is similar to the one in mechanical models of reclining armchairs. After a backward inclination of the backwrest, the seat is partially inclined backward and a footrest is extended out. An electric motor does not only increase the user-friendliness but it also eliminates any possible risk of a problematic return from the reclined position, which exists in the case of mechanical reclining armchairs.

Reclining Segment of Sofas and Armchairs – Lounge Sets

Similarly to electrically controlled reclining armchairs, lounge sets with optional electrically controlled reclining segments are offered in the framework of a seating furniture set without the corner part.

Massage Armchairs

Massage armchairs have constituted a separate group of seating furniture for a long time. Apart from an electrically controlled reclining mechanism, these armchairs are equipped with vibration and massage mechanisms.

Lift Up Armchairs

Armchairs which help persons with reduced mobility to stand up represent an independent group of seating furniture. The so-called "Lift Up" armchairs have been for a long time equipped with electric motors, which enable the required lift of the armchair or the seat. See Fig. 11.

Adjustment of Seat Depth – a Sliding Seat, a Sliding Backrest

Seating furniture with sliding seats for adjusting the optimum depth of the seat has been offered with electric motors in recent years. Versions with a sliding seat are used in majority of cases; versions with a sliding backrest represent a minority.

Adjustment of Seat Hight

Apart from the depth of the seat, the height of the seat is also one of the fundamental ergonomic parameters of seating furniture. Seating furniture with an adjustable height of a seat by means of electric motors is presented very rarely. If it is presented, it is rather in the form of development studies checking the meaningfulness of these solutions and the commercial interest in them[1].

Electrically Controlled Sofa Beds, Sofas With Storage

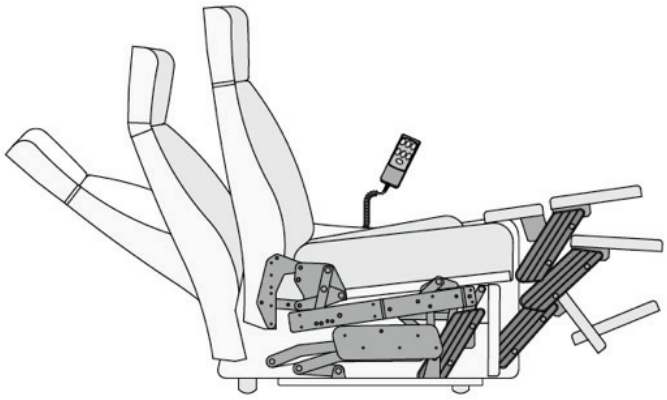
Recently, sofa beds and sofas with storage and electric motors which improve user comfort have also been presented.

Functional Parts of an Electromechanical Positioning System

In order to better understand the functioning of reclining furniture, it is advisable to define the functional parts of positioning mechanisms with electric motors in seating furniture. Reclining mechanisms of seating furniture with electric motors can be divided into the following functional parts:

- guiding system,
- electric motors,
- control system,
- safety elements.

1 Experimental electrical adjustable seating was presented on trade fair Orgatec 2008 by Nurus company

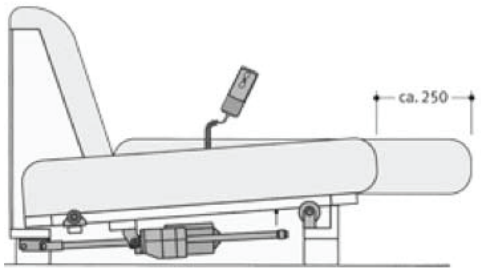


12: *Positioning mechanism Lusch ClassicCline.*

Guiding System

The path and range of a movement of adjustable elements in seating furniture with regard to a fixed frame or base of seating furniture is defined by a guiding system – a positioning mechanism. The adjustable parts of seating furniture are attached to moving parts of the mechanism. The final movement of a moving seat, a backrest and a footrest in a reclining armchair is the result of a sophisticated combination of lever and scissor mechanisms. Apart from achieving the required movement, correct dimensioning of the mechanism for the required weight load of the moving parts is also important. See Fig. 12.

Contemporary seating furniture with sliding seats uses significantly less complicated movements – very often it is sliding along a direct path. Complicated positioning mechanisms are no longer needed for ensuring these movements, simple guiding systems or the use of standard furniture fittings – castors, slides, etc. – suffice.See Fig. 13. Ensuring a stable position of a reclining part – preventing possible jamming of a reclining part against a fixed part in the case of uneven loading or differing resistance to sliding in various parts of the reclining part – constitutes an import part of guiding mechanisms.



13: *Slide out of seat using mechanism Lusch BH11*

Motors

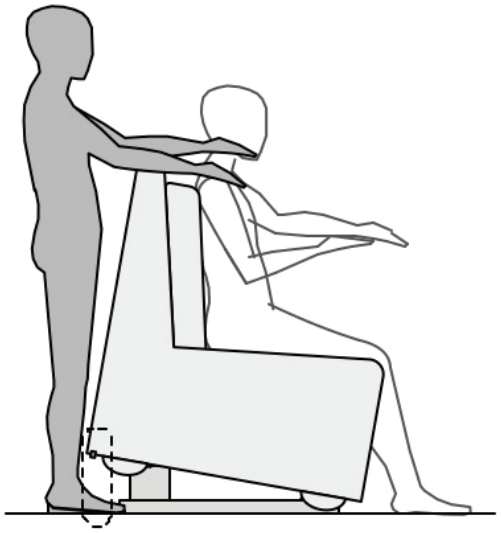
Electric motors – actuators – are used for movement initiation. Positioning mechanisms, which have been used up to now in seating furniture, use mostly rotation actuators which transfer forces to moving parts by means of levers located on rotating axes. Linear motors are used in contemporary modern applications for simpler movements of moving parts of seating furniture on a direct path.

Control System

A control system enables controlling of the individual movements of reclining furniture. A cable or wireless control device is fitted with necessary buttons for individual movements. The impulses from the control device are evaluated by a control unit which controls the movements of individual motors. Individual motors can be operated by individual buttons for a given movement, or possibly the buttons can be used for a combination of several movements. If more motors are grouped together for a movement of a common moving part, the control unit has the important function of controlling the simultaneous movement of these drives even in the case of a differing load on the individual motors which is caused by uneven loading of the moving part. The control unit thus prevents possible crossing of a moving part in the guiding system. The control unit is also responsible for preventing an inappropriate combination of movements of moving parts which could damage the mechanism or the reclining seating furniture.

Safety Elements

The aim of a safety element is to prevent injury to persons or possibly damage to things during the use of reclining seating furniture with electric motors. Reclining seating furniture can have various danger levels of injury to persons or damage to objects. For example, in the case of a motorized sliding of a seat, the risk of injury to a person standing in front of the sliding seat is not significant. The force of the motor corresponds to the demand of the horizontal movement of the loaded seat and it does not pose a significant risk of injury. Lounge sets



14: *Safety edge protects risk area in rear part of Lift Up chair*

with a sliding seat fitted with an electric motor are therefore not equipped with a safety system.

By contrast, a Lift Up armchair must have the performance of its motors dimensioned for lifting a seated person and the armchair itself. During the downward movement of the armchair the motors use the same force to pull the armchair down. The space under the armchair is therefore an area with a significant risk and a person standing behind the armchair or a pet lying within this space may get injured (a squeezed foot) or a thing which is located in this space may get damaged. See Fig. 14. Contemporary Lift Up armchairs tend to be equipped with a contact safety system which uses a Safety Edge[2]. The elastic profile of the edge contains two parallel conductors. When the edge is squeezed, the conductors touch each other and the signal is evaluated by the control unit which performs programmed tasks. After the safety edge comes into contact, the control unit will stop the movement of the motor, or possibly return the movement several centimetres backward. If, for example, a foot is squeezed between the descending armchair and the floor, it is not enough to stop the movement, the armchair has to be moved backward so that the foot can be released.

Application of Mechatronics in RecliningSeating Furniture

In order for a positioning system to be classified in the category of mechatronics it is necessary that the electromechanical system cooperates with a logical element. It is exactly the presence of this logical function which upgrades an electromechanical system to a mechatronic one. The following elements or principles can represent this fundamental logical element:

- motor control unit,
- safety system – contact, motor protection, contactless,
- wireless control – Bluetooth, Wi-Fi,
- integrated audio technology,
- variable intensity of assistance with standing up in a Lift Up armchair,
- electronic initiation of rocking.

Control Unit

If one or more electric motors – actuators – are used in seating furniture, a control unit, which performs simultaneously several tasks, is used for their control. Apart from the task of switching on and off the movement of a motor in the required direction, the control unit is able to control the simultaneous even movement of several motors with different loads. It thus prevents the moving part from getting jammed and prevents any damage to the positioning mechanism. The control unit therefore performs a logical function. The reclining mechanisms of seating furniture which are equipped with a control unit for controlling the movement of more electric motors can be therefore, from this point of view, designated as mechatronic.

Safety System

A safety system in contemporary seating furniture with electric motors has been used only in the case of Lift Up armchairs. The risk area is fitted with a contact Safety Edge. The contact edge itself does not have a logical function. A signal – contact – in the safety edge is evaluated by the control unit. Its presence thus ranks a positioning system with a contact safety edge and a control unit among mechatronic systems.

Anti-collision system for office desks using a control of the increased motor load Piezo Linak (2013) represents another principle of a safety element. A sensor is integrated in the body of the column. When the load increases, the sensor evaluates the situation and communicates with the control unit. If a situation poses a risk, the movement is automatically stopped and returned back by several centimetres. The safety system functioning on the basis of controlling the increased motor load ranks the positioning system in the category of mechatronic systems. The actual effectiveness of this safety system is questionable.

A contactless safety system which is used, for example, in the dining table Gorenje SmarTable (2009) represents yet another principle of a safety system. The activation of the safety system does not require any contact between a hand and the table,

2 Mayser Safety Edge

the presence of a hand in the risk area is enough to activate it. The contactless safety system contains a logical element – an evaluation software – which ranks the positioning system in the category of mechatronics.

Wireless Control

Current trends of smart households introduce new standards of controlling home appliances and interior elements (lighting, heating, shading, etc.) by means of wireless technologies – Bluetooth, Wi-Fi. Renowned companies in many furniture fields make use of the popularity and trendiness of Apple products (iPads, iPhones) and offer wireless control by means of these devices. Currently, there are availbale wireless technologies for controlling positioning systems in seating furniture by means of smartphones iPhone and Samsung and iPad[3]. The control unit of the positioning mechanism is equipped with a receiving unit which processes a Bluetooth or Wi-Fi signal. The positioning system with this method of control is classified in the category of mechatronic systems.

Integrated Audio Technology

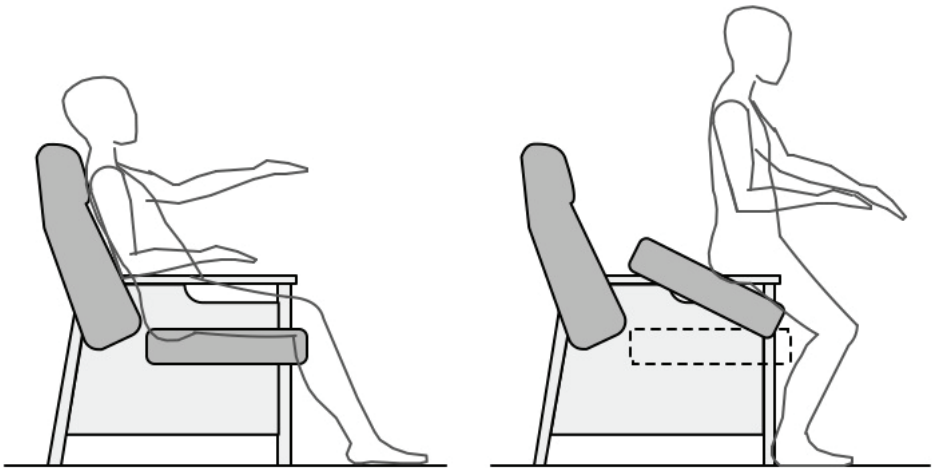
At present, various forms of audio technology are being integrated in seating furniture. Docks for iPods, iPhones or USB flash drives are fitted in seating furniture in order to play audio files. Seating furniture is equipped with a sound system or possibly only with vibration transducers which provide the low frequency band[4]. In addition, some applications are fitted with wireless transfer of a music signal from an audio centre into the seating element or an audio signal from the lounge set to a TV[5]. This wireless transfer of an audio and video signal cannot be classified as a technology in the category of mechatronic applications. The function of the transfer of an AV signal is completely separated from possible reclining properties of seating furniture, therefore there is no cooperation between electromechanical systems of the positioning mechanism and wireless transfer technologies.

Variable Intensity of Assistance With Standing up in a Lift Up Armchair

Lift Up armchairs make standing up easier for elderly persons with reduced mobility. It is a paradox, however, that when a user uses this aid, he stops exercising his relevant body parts and relatively soon his muscles become weak. This is in contrast to the situation when he was forced to exercise these muscles whenever he stood up from a normal armchair. If a Lift Up armchair were equipped with a technology which could regulate the force of the motor or the range of the lifting movement or tilting of the seat according to the weakness of the user's muscles, a continuous appropriate exercise of the user's muscles would be achieved and the process of their weakening would be slowed down. This principle would constitute an application of mechatronics which provides reclining seating furniture with a new functional value. See Fig. 15.

Electronic Initiation of Rocking

Sitting in a rocking chair should bring about a state of ease and relaxation. Rocking is initiated by pushing one's legs off the ground; from time to time it is necessary to maintain the rocking movement by repeated pushing. Without these impulses the rocking movement soon stops. Electrical initiation of rocking would increase the user's



15: *Scheme of chair with tilt seat for help by stand up of disabled person*

3 Bluetooth application I-CTRL (2014)
4 "Silent subwoofer" ButtKicker (2012)
5 Sound transmitter TV aRound (2014)

comfort characteristic for a rocking chair. In addition, if a rocking chair with electrical initiation of rocking were equipped with a technology which selects an optimum rocking intensity depending on whether the user is awake or sleeping, a completely new principle of a mechatronic rocking chair with a new functional value could be developed. See Fig. 16.

DISCUSSION

Use of mechatronics in home seating furniture has not been a discussed or published subject up to now. The general aim of further development of seating furniture is the improvement of ergonomic parameters of seating furniture, improvement of user comfort in controlling and using seating furniture and providing new additional functions of seating furniture. In this connection it is necessary to state that apart from mechatronic and electromechanical principles these aims can be achieved also by means of using mechanical principles. The use of mechatronics should not be an end in itself.

The use of electric motors itself in seating furniture brings up new questions which need to be solved; in particular there is the need to formulate new safety aspects, to address the obsoleteness or absence of technical standards describing the required properties of seating furniture with electric motors and introduce methods of testing this furniture in accredited test rooms. The use of electric motors in reclining seating furniture usually increases the price of a product significantly which narrows down the potential customer segment and also the probability of its marketability. The dependency of electric motors in seating furniture on a source of electric energy can have a negative psychological effect on certain customer groups. In fact, electric motors of seating furniture will introduce new requirements in the way electricity is distributed in residential areas (installation of seating furniture in spaces).

Apart from these problematic aspects, the potential of electromechanical and mechatronic applications in seating furniture is unequivocal and it is a challenge for further development. Applications of mechatronics in home seating furniture can be beneficial in the following fields:

- more comfortable controlling,
- higher safety of use,
- new functions of reclining seating furniture which are inaccessible without mechatronics.

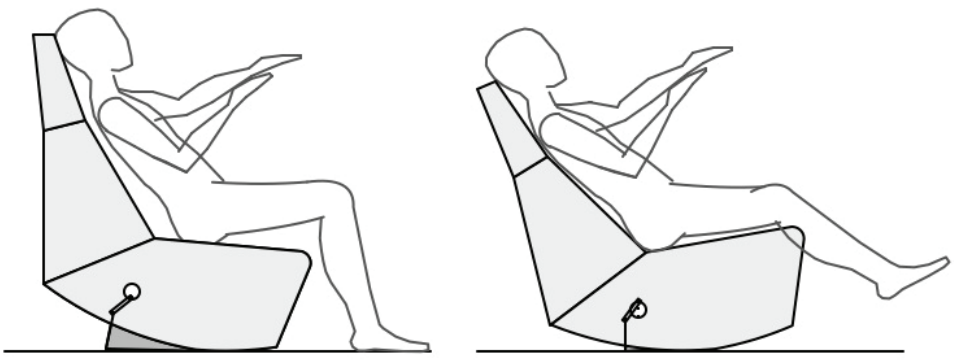
More Comfortable Controlling

Mechatronic applications can bring more comfortable controlling. Example: seating furniture with an adjustable depth of the seating part by sliding the seat forward and backward exists at present on the market either with a manual mechanical control or with an electric motor. While mechanical control presupposes the handling of an unloaded seat by a standing person, an electric motor enables to change the position of the seat with the user sitting directly on the controlled seat. In addition, the electric motor fixates the seat in any position in the range of sliding while in the case of mechanical control using the seat in-between positions can be problematic. If a wireless control by means of Bluetooth of Wi-Fi is considered to be an application of mechatronics, it is already at present possible to note all 3 levels of positioning mechanism in this type of reclining seating furniture: mechanical, electromechanical and mechatronic. All three types fulfil the same ergonomic function in reclining furniture. The fundamental difference is in the comfort of controlling.

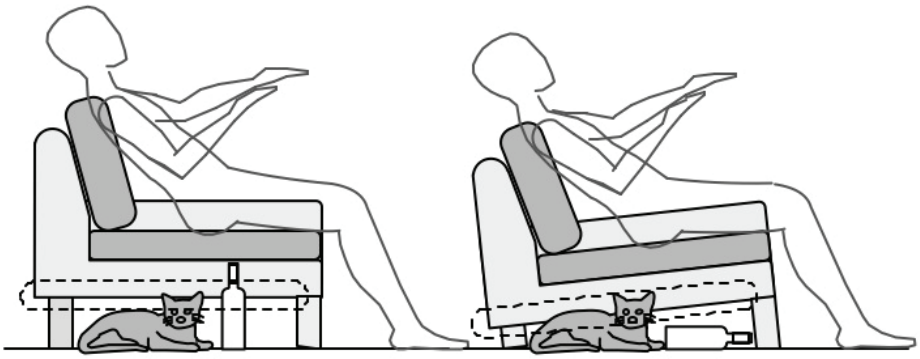
Higher Safety of Use

Mechatronic applications can bring higher safety of use. Example: an armchair helping the elderly with standing up, which is called a “Lift Up” armchair, poses a risk of injury to a second person or of damage to an object in the area of its rear edge. The use of a contact safety edge protects only the back edge of the armchair. The use of a contactless safety system can expand this controlled critical area also to the space under the armchair. See Fig. 17.

Mechatronic applications can increase the quality of safety systems of reclining furniture as well as expand the field of applications of reclining furniture by up-to-now unused principles,



16: *Rocking chair with eletronically controled initiation of rocking*



17: *Risk area below positioning seating furniture*

especially with regard to the possible dangers they pose when used.

The future development of reclining furniture is narrowly bound with the development of contactless safety systems using present and future technologies: for example, miniature cameras and evaluating software, optical, acoustic and other contactless sensors. Touch technologies used in mobile phones may be also available. The setting of required parameters – movement detection, presence of human or animal body parts, detection of inanimate objects in risk areas – will be crucial for the development of these new safety systems.

New Functions of Seating Furniture

The visions of future applications of mechatronics in seating furniture have indicated a potential area for new, still unknown functions of seating furniture – electrically controlled rocking in a rocking chair depending on whether the user is asleep, an electronically regulated force in a Lift Up armchair helping a person stand up according to his or her muscle weakness. These visions and hypotheses formulate fields for further development in the application of mechatronics in seating furniture.

SUMMARY

The aim of the article is to define the border area between electromechanical and mechatronic applications in home seating furniture. An analysis of the existing state of mechanical and electromechanical positioning principles in seating furniture defines individual ergonomic parameters which are influenced in reclining of seating furniture. The analysis includes specification of individual functional parts of a positioning system of seating furniture with an electric motor. Some principles of the present reclining seating furniture can be already classified in the category of mechatronic applications. In the framework of further development of seating furniture it is possible to presuppose that the current trend of using electric motors in reclining seating furniture will continue.

Apart from new properties, the designation of products as mechatronic may also help commercial promotion of these products. It can be assumed that certain producers or makers will use this designation purely formally or in a calculated manner to label their products as mechatronic. As the definition of mechatronics is still not absolutely unequivocal and it is still being developed, the classification of certain applications in mechatronic principles may be a subject of possible formal or ideological debate. The aim of the article is to initiate such a discussion.

Another aim of the article is to formulate potential fields for further development of mechatronic applications in home seating furniture. The author claims that further development of mechatronic applications in seating furniture will bring about improvements of user comfort, higher safety of use due to the use of new safety features, and it may also introduce new and as of yet unused additional functions of seating furniture. The author predicts fields with a potential of new additional functions of seating furniture.

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