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Evaluation of operational systems on combine harvester

In most cases the use of electronics in agricultural tractors and self-propelled machines make their operation easier. But the complexity of the machines and of their operation is increased by improved capacity, new functionalities by electronics and the diversity of variants. The manufacturer pursues different strategies in the designing of display and control units. To evaluate these systems in terms of ergonomics methods have been developed especially for passenger cars. In this study, they are applied exemplary to the operation of combine harvesters.

Keywords
Combine harvester, operation, ergonomics

Abstract
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The manufacturers of combine harvester meet the trend to more comprehensive operations by further developed multifunction handles and monitor based display and operation systems. Their complexity may need a longer time to get into. But by the frequency of use the operators are learning often very good how to use these systems. These systems distinguish noticeable between the different manufacturers. E.g. the displays can be focused on a screen near by the multifunctional handle or distributed on several screens and alphanumerical displays in the cabin. All systems have in common, that they were developed in accordance with technical, ergonomical and design criteria. For this the principal international standards for operation systems are used. The most important standards will be explained hereinafter. Based on that one of the evaluation systems for passenger cars will be copied and tested.

Normative fundamentals for the design and the evaluation of control systems

For the ergonomic design of control systems for mobile working machines several standards have to be used. They can be divided in process oriented and in product oriented standards. In the first group methods and processes for the development are described. In the second group required features of user interfaces are defined.

The DIN EN ISO 6385 can be seen as basic standard for ergonomics [1]. The ergonomic principles in the design of work systems are described. This standard divides the design process into the phases: analysis of requirements, analysis of functionality, conception and design, realization, introduction, validation and evaluation. By validation it is investigated if the functionality of the system works as intended. The evaluation consists also of a long-term supervision of the system and provides parameters for criteria like performance, safety, health and well-being of the operator.

The DIN EN ISO 13407 describes a guideline for the human oriented design process of interactive systems [2]. This process is characterized by four aspects: by an active participation of the users, a clear understanding of the requirements of users and of tasks will be achieved. The functional division between user and technique (e.g. by automation) should maintain a meaningful job for the operator. Due to feedback from the operators an iterative process leads to the solution for the design of user interfaces. The solution itself concerns several disciplines and will be developed by a multidisciplinary group. This standard also intends an assessment of the target achievement as well as the assessment of the system. Additionally, systematical long term observations of user feedback will identify implications which arise for example by unforeseen changes in working behavior.

DIN CEN/TR 614 is part of the product oriented standards and is published as Technical Report. Their part 3 is a design guideline for the ergonomical aspects of mobile working machines [3]. In several details this report refers to DIN EN 894 [4]. In this standard the ergonomical requirements for the design of displays and control actuators on machines are stated under the safety aspect. This standard put the requirements of the new EU Machinery Directive 2006/42/EG into concrete terms.

In part 1 of the DIN EN 894 the general principles for interaction between users and displays and control actuators are defined. By this it is secured that faults of the user are reduced to a minimum and an effective interaction between human and machine is ensured. For that different design guidelines are set up. Beside requirements on the user interface like reduction of complexity and self-explanatory of all parts, also these points are stated: a) the principle of grouping, b) the conformity with expectations and c) the demand for adaptability and learnability.

- a) Control actuators and displays should be grouped in order of their use. If no defined order is used, then they should be grouped in accordance with their importance and their frequency of use.
- b) The conformity with expectations describes how operators use stereotypes. This can be for example the expectation that with an upward actuation of a control actuator or to the right the value of an adjustment or of a display increases. It is expected that under situations of stress an operator acts in accordance of such stereotypes and not in the learned manner for this specific machine.
- c) Display and control systems should not be static. Adaptability and learnability means here, that these systems adapt themselves to the requirements, the abilities and the learnability of the operators.

In part 2 of DIN EN 894 recommendations were given for selection, design and arrangement of indicators on machines. For optical indicators detailed requirements for perception and readability are listed. For acoustic indicators the requirements for detection and identification are specified. Beside the signal-to-noise ratio of the volume and the recommended frequency range, the possibility for identification of an acoustic signal is pointed out. This can be done via pattern, sound and repetition. The character of acoustic alarm signals is very important for their perception according to their priority. Tactile indicators are described in accordance to their shape and position so that their state can also be felled.

The requirements for manually operated actuators are listed in part 3. A procedure for their selection is presented. First all requirements have to be detailed. This can be for example the intended precision and speed of actuation. Also the control of the actual position of the actuator via view and/or touch, the eventually requirement for an actuation with cloves and also eventually required type or direction of actuation has to be detailed. In the next steps of this procedure the suitable types of actuators will be chosen in accordance with these defined requirements.

In part 4 of the DIN EN 894 position and arrangement of indicators and actuators in the range of view and actuation are described. Also for the distances between the actuators and for the arrangement of indicators and actuators in relation to each other specifications were given. Hereby one important point is the so called compatibility. It describes the expectation of the user, that by actuation of a controller the system and the indicators are acting correspondingly. This means for example, the movements and the arrangements of control units are similar to the reactions of the corresponding indicators. A high compatibility between the displacement of the control units and the working elements of a machine is one goal in the development of control systems.

Additionally the DIN EN ISO 9241 [5] has to be mentioned. Originally this group of standards was intended for the ergonomical requirements and evaluations of monitor based office work. But their field of application was expanded to the “ergonomics of human-system interaction” including software interfaces, user oriented design, general optical displays on screens and the according physical input devices. This group of standards is not finished yet and many parts are in preparation.

Process for the evaluation of ergonomic systems

Beside the roughly described evaluation processes in the standards, for passenger cars appropriate processes are developed and published [6]. A further approach for the evaluation of control systems of cars describes the use of a product with the relations between indicators, actuators, active components and operator [7]. Starting with a neutral description of the vehicle´s cockpit an objective evaluation, the so called usability-factor, is derived. For this the cockpit is divided into primary, secondary and tertiary ranges for viewing and actuation. The whole vehicle cockpit as interface system consists of interface modules, e.g. the adjustment of a seat, and these consists of interface elements, e.g. the single switches for the adjustment of a seat. For the investigation of the usability factors appropriate criteria, as for example the operability or the compatibility of motion, has to be worked on. Each control element of a module is investigated with respect to these criteria and its degree of fulfillment (range of 0 to 4) has to be found out. The usability factor is achieved by the total number of points with relation to the maximal possible number. A very good operation system achieves values > 80 %. Between 60 and 80 % it can be named as a good system.

Application of the evaluation on operation systems of combine harvesters

As example for the transfer to operation systems of combine harvesters three cockpits of Claas, John Deere and New Holland were investigated. The technical stand of these at the University of Hohenheim available cockpits of the series Claas Lexion 600, John Deere WTS 9000 and New Holland CX 8000 do not comply with the most actual and best equipped models of these manufacturers.

All examined combines have multifunctional handles. With them the most important changes of the machine adjustment will be done. Partly the push buttons there has by several pressure points double functions. Also partly different functions were achieved by different length of actuation. The controls and indicators are for Claas and New Holland arranged on two main areas, for John Deere on three areas. Nearly all elements are positioned in the panel on the right of the operator´s seat. Claas has located there their central display screen with its control keys and a rotary switch. The monitor of New Holland can be positioned freely and is in front of the panel. Further control units are grouped according to functions. All manufacturers have integrated the control units for view and lighting in the panel of the roof. Typically for John Deere´s combine harvesters are the four control and display units in the a-post of the cabin. New Holland has integrated one smaller display and

Fig. 1

Comparison of the sequence of operation to activate the cutterbar control (left to right: Claas, John Deere, New Holland), acc. [6])

monitoring unit in the a-post. A similar function has the unit with indicator lights in the roof panel of John Deere.

To limit the evaluation two exemplary sequences of operations were chosen. First the height control of the cutterbar has to be activated and then it has to be switched to the automatic ground pressure control. The notation of these automatic controls is different for these three manufacturers, but in principal the functionalities are comparable. For the second sequence the respective automatic feed rate control systems of the combine has to be activated. For the automatic control of the ground speed the manufacturers are using different measured quantities as signal for the load of the combine. This can be done by the load of the threshing system (Massey Ferguson, Fendt), by engine load and the thickness of material in the feed rake (Claas), by the load of cutterbar and feed rake (New Holland) or by load of threshing system and engine together with the grain loss level (John Deere). For this investigation there wasn´t an automatic control system for the ground speed installed on the combine of New Holland.

Comparing the motions of the driver during the operation of the header height control, the differences between the numbers of steps of operations and of the position of the control units relatively to each other is remarkable, **figure 1**. For Claas one step of operation less is necessary. For New Holland the used control units are mostly grouped together in a spatial sequence. John Deere integrates additional control units in the a-post. Due to this the driver has to change the position of his hand further times. The change between height control and automatic ground pressure control is done at the multifunctional handle for the combine of Claas, for John Deere at the a-post and for New Holland with a rocker switch beside their multifunctional handle. The activation of the automatic feed rate control is done for the combine of John Deere again at the a-post. Again for Claas one step less is necessary for this operation.

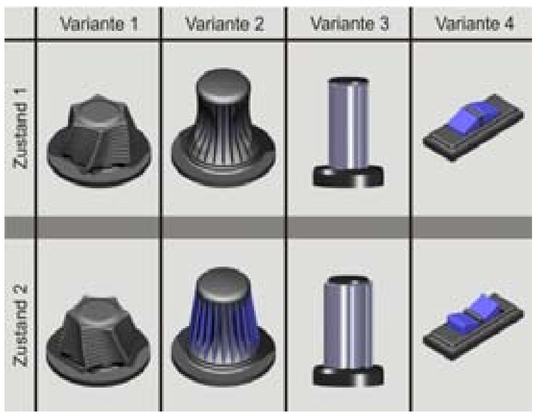
Analyzing these different display and control systems with regard to their usability factor, the total value results with 85,4 % for New Holland, 83,5 % for John Deere and 75,1 % for Claas. Deductions in the evaluation are mainly due to additional operation steps or due to incompatibilities between the moving sense of an actuator and the respective active element. For example with the multifunctional handle of Claas the operator has to press the actuator downwards to lift the cutterbar upwards. To lower the cutterbar the actuator has to be pressed upwards. Noticeable for John Deere is the numbering of the activation buttons on their multifunctional handle from right to left, contrary to the reading direction. As further example the fore and aft reel adjustment can be mentioned. All manufacturers are using for this actuators with left/right orientation. The left actuator is used by Claas for the function "backwards", John Deere and New Holland use it as "forward". Left/right oriented actuators have according to the used standards also the meaning of "plus/minus". With relation to the driving direction of a machine however the operator will link the direction "left" with "in driving direction".

Summary and outlook

The analysis of three operation systems of combine harvesters shows the individual operation concepts of the different manufacturers. The comparison with the operation at other models of these manufacturers demonstrates also, that consequently they maintain these concepts. Further developments can be seen at revised and at new models of the manufacturers. So Claas changed from cursor keys for the operation of their screen to rotary/push buttons and John Deere uses in their combine harvesters also screen for display and operation.

Today the demanded adaptability of operation systems to the needs, the capabilities and the learning ability of the users (DIN EN 894) is realized only in a small degree. It can be found at display monitors, where users partly can choose the presented information. Furthermore the user defines itself how deep he would go into the respective structure of the menu. An adaption on the mechanical level is available in upper class passenger cars for the operation of systems for comfort and entertainment with multifunctional actuators with rotation, pushing and sliding. Here the possible movements of the actuator adapt themself to the actual structure of the menu. Additional concepts for the adaptability of the operation are using actuators with variable shapes, **figure 2** [8]. Tactile perception enables

Fig. 2



Concepts of four variants of adaptive variable control units [8] the user to identify the possible directions of movement. Used for the strong varying situations of operation in agricultural machines and tractors could help to realize simple and adaptive operation systems.

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