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Adaptive Hand Controls for Agricultural Machinery

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INTRODUCTION

This Plowshares Technical Report attempts to address the numerous aspects with regard to the issue of hand-activated controls that can assist agricultural producers with physical disabilities to operate their tractors, combines, forage harvesters, and other self-propelled equipment safely and efficiently. The topics to be dealt with here include the following— (1) those disabilities most likely requiring such controls, (2) the various types of controls, (3) their appropriate locations, (4) levels of force needed to operate them, (5) specific suggestions for their proper design and construction, and (6) a suggested system for their visual identification. This report's focus is not only on converting of foot-operated controls (e.g., brakes, clutch, foot throttle) to hand-operated ones, but also on modifying hard-to-reach controls (e.g., differential lock, MFWD, PTO, throttle) so they can be safely manipulated by an operator with limited mobility or reach. Due to the low demand for adaptive hand controls and the diversity of control designs used on agricultural equipment there are no known commercially available control modification kits. Historically, most control modifications have been made by the operator or a local fabricator.[5]

What Are Adaptive Hand Controls?

They are 'non-standard' hand-operated controls added to a vehicle or piece of equipment to replace or supplement those designed to be operated by other parts of one's body (generally, the lower limbs and feet). As an interface between the operator and the machine function, such controls may be entirely mechanical and actuated using only the force applied by the operator, or they may involve components (e.g., pneumatic, electrical, hydraulic) that reduce the amount of force needed to actuate. Adaptive hand control devices include levers, push-buttons, joysticks, wheels, and rotary or linear switches.

TYPES OF DISABILITIES LIKELY TO REQUIRE HAND CONTROLS

There is a range of physical disabilities likely to require adaptations with various hand controls. A thorough assessment is needed to identify the adaptive equipment best suited to each individual's needs, or functional limitations, associated with various physical disabilities, in order to get the person back to performing the task they desire as quickly and safely as possible (VA, 1978). The following common types of disabilities are the most frequent to utilize adaptive hand controls.

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[5] See also the appendix for brief discussions on (a) the early efforts at Purdue University with regard to machinery operating control modifications for agricultural producers with disabilities, and (b) a summary of why there is a lack of comprehensive control-conversion standards or adaptive aids manufacturers' design and construction guidelines.

Spinal Cord-Related Disabilities

Of all the various physical disabilities, spinal cord injuries are the most common that necessitate use of modified controls. The degree of paralysis depends on what portions of the spinal cord are affected and how severely. Paraplegia is paralysis of the lower body and both legs; quadriplegia is paralysis affecting all four limbs.

The types of hand controls needed by a paraplegic and by a quadriplegic will depend on the severity of their condition. For instance, one who has good upper-body strength and mobility can likely use adaptive hand controls consisting of mechanical lever assemblies, whereas one with restricted upper body strength and mobility will probably require very conveniently located hand controls with small activation forces, such as toggle switches or joysticks.

For a person having little or no lower-limb impairments, the amount of force sufficient for the pushing and pulling of controls is often derived from bracing the body with the legs and feet (Chaffin et.al., 2006). In a standing posture, the legs can provide maximum horizontal force if the feet do not slip on the floor. However, if such bracing is not possible, some or all of the push-pull force normally exerted by the lower limbs may transfer to the upper body. Such would be the case for the seated operator, although other forms of bracing (e.g., the seat's backrest during pushing actions or wearing a seat belt when pulling) also come into play. For this reason, pushing hand-operated controls may be easier than pulling them, since the backrest helps stabilize, or prevent the operator from moving back during the action. In pulling of hand controls, the operator may lack proper stabilization of the upper body if the required forces exceed the reactive force of the body to maintain an upright position (Chaffin et.al., 2006). In this case, the use of a seat or lap/shoulder belt can reduce the forward motion.

It is important to consider whether a push-pull task otherwise deemed 'safe' for a seated but fully ambulant operator might exceed their capacity following impairment of their lower limbs (Chaffin et.al., 2006). The lack of reaction force from those limbs during pulling or pushing may also create instability in the torso, thus increasing the risk of falls and further injury.

Back-Related Disabilities

Back disorders can restrict trunk flexibility or range of spinal rotation. On some machines, (especially older ones), the hydraulic, three-point hitch, and PTO control levers are often located in such a way that the operator must either position himself or herself awkwardly or strain to reach them. Oftentimes, these levers are on the operator station floor and not high enough to allow manipulation without excessive bending and/or rotating of the upper body. Having to push or pull while the spine is laterally bent or rotated or where force must be applied awkwardly increases the risk of musculoskeletal injury, the antidote of which could be to relocate the levers, provide lever extensions, and/or adopt more ergonomically-friendly working postures.

Arthritis/Neuromuscular- and Amputation-Related Disabilities

Arthritis and neuromuscular disorders limit one's strength and mobility, thus making standard controls difficult and/or painful to use. Also, persons with foot or leg amputations often need hand control assemblies that allow operation of controls normally actuated by the feet. In both cases (i.e., arthritis/neuromuscular disorder and amputation), such hand controls may have to be built and/or relocated, extensions provided, and, again, proper working postures maintained. If the barrier relates to the inability to adequately grasp the hand control due to impaired grip strength, the handle may need to be modified through increasing the grip surface or changing the shape.

TYPES OF ADAPTIVE HAND CONTROLS

Most existing adaptive hand controls for the brakes, clutch, foot throttle, and differential lock are mechanical lever assemblies, which primarily consist of lever extensions or mechanical linkages (including cable-pulley assemblies). The other type of hand controls involves electric, pneumatic, or hydraulic actuators. Following is brief discussion of each, including their advantages/drawbacks and example applications.

Lever Extensions

Lever extensions are usually constructed of either flat-bar steel, steel tubing, or steel rods that are clamped, bolted, or welded to the factory control. Clamped or bolted assemblies with brackets that allow the extension to be easily removed are preferred because they provide the greatest measure of accommodation for users with and without impairments. Although they're simple and low-cost, sometimes it's not possible to gain sufficient leverage with only a lever extension. They may require excessive force to operate the control, which may, in turn, increase the risk of secondary injury. Cases have been noted in which the excessive force required to activate hand controls has resulted in shoulder injuries due to repetitive use, or in more severe cases, the loss of control of the machine. Figures 1, 2, and 3 show lever extensions either clamped or bolted onto a clutch pedal, brake pedals, and a pedal-controlled hydrostat transmission, respectively. Quick-attach style of lever extensions (not shown) can be used on older types of foot-operated pedals without the use of clamps or bolts. However, they only function with pull force, as a push force will dismount the lever from the pedal (thus, the pedal pivot point must be above the operator station platform).

Figure 1. Lever extension bolted to clutch pedal.

Figure 2. Removable pedal extensions constructed of barstock, clamped to the pedal with above platform pedal pivot.

Figure 3. Hand control mounted to hydrostatic transmission control pedal. Factory-linkage allows for a single hand control lever to actuate both the forward and reverse pedals.

Mechanical Linkages

Mechanical linkages can range from simple, relatively low-cost actuation systems to more complex ones. Those that are designed in accordance with ergonomic principles and positioned to allow actuation with minimal exertion can significantly improve leverage, whereas poorly designed and incorrectly positioned linkages may actually increase injury risk (Kroemer,1999; Prather, 2002). Figure 4 provides two views of a low-cost but effective mechanical linkage system mounted on an UTV.

Figure 4. Modified UTV foot controls using horizontal lever connected to the pedals with adjustable mechanical linkages. (Source: SureGrip HVL)

Electric, Pneumatic, and Hydraulic Actuators

Adaptive hand controls sometimes incorporate electric, pneumatic, or hydraulic actuators that act upon the pedal linkages and require relatively low force to move toggle switches or other control devices. Although more expensive than mechanical controls, such hand controls are often the only alternative for one who does not have sufficient strength and mobility to operate a mechanical lever assembly. Also keep in mind that if a particular piece of equipment is shared among several users, the safe (not maximum) pushing/pulling capacity of the weakest user should determine whether a purely mechanical adaptation would suffice without risk of causing injury. Further, it is recommended that all actuators be installed with the default or neutral position for the disengaged clutch position so that, in event of malfunction, the machine defaults to a stopped position. Electric- and pneumatic-actuated hand control modifications for agricultural equipment, though doable, have not been widely documented due expenses of designing and fabricating, as well as concerns over their safety in the event of electrical or hydraulic system failure.

There is a wide range of driving aids developed for the motor vehicle industry with high-tech electronic controls, such as: push-pull breaking, acceleration and electronic driving systems, and acceleration, braking and steering with sophisticated drive-by-wire systems. In only a few cases have these systems been applied to agricultural equipment.

Some machinery, such as skid-steer loaders, allow the operator to manipulate the function/movement of the attachment using foot controls. If these controls are not accommodating to the user, an electronic valve assembly may be preferred. To allow the operator to control the movement of the attachment, a hand-controlled joystick combined with electric over hydraulic valves are utilized, in contrast to direct-linkage mechanical foot controllers with mechanical valves. Advancements in electronic valves and actuators, machinery components, and other technology enable the control of entire machines via wired or wireless remote control (Figure 5). These allow operators to obtain proper placement of controllers within the machine, or the ability to control additional machinery remotely without the need for the operator to enter and exit the machine multiple times. It is recommended that such technology possess redundant fail safes, and resort to a neutral/de-energized state in the occurrence of malfunction.

Figure 5: Wireless controller allows operator to control machinery from remote location without repositioning from one machine to another.

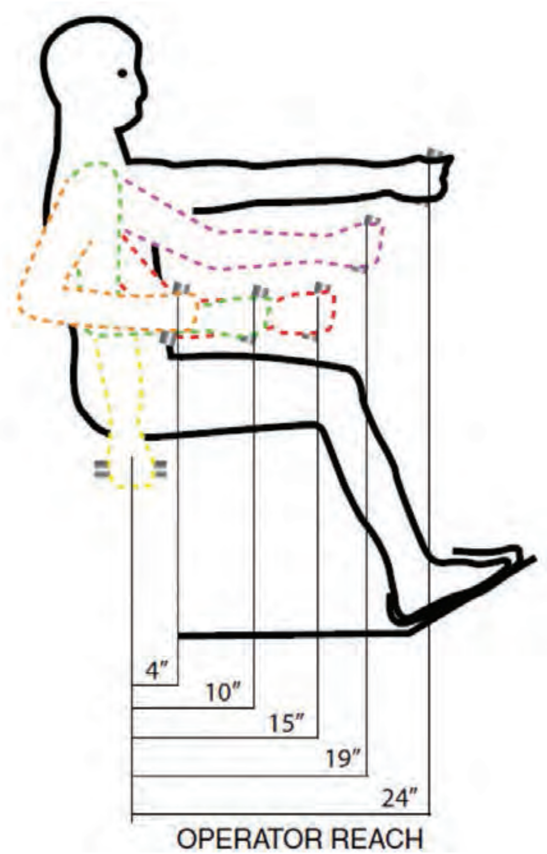

Figure 6. Frequently used controls need to be placed such that the operator can reach/use them without undue exertion or fatigue.

LOCATION OF ADAPTIVE HAND CONTROLS

To the extent possible, all hand controls (whether original or modified) should be located where the operator can easily reach them and apply maximum force. Usually, that 'best' location is between elbow and shoulder height, directly in front of the shoulders, and 16- 28 inches from a vertical plane of the back, as shown in Figure 6 (Imrhan, 1999). As a rule, pushing actions are most efficient when starting closer to the torso, pulling actions when further from the torso. In either case, operating the control should not induce flexed or rotated trunk postures (as occurs when it is located too far away) or shoulder hyperextension where the elbow projects to the rear of the trunk (as occurs when it is too close). Undue strain and fatigue are likely to result when one has to exert this reach to the limit.

If other persons will also be operating the piece of equipment, tables of anthropometric data are valuable in determining the optimum location of the controls. However, care should be taken to ensure that the correct dimensions are applied in each case. For example, the horizontal reach to a control is usually based on the forward reach of the 5th percentile woman, rather than on that of the 'average' (i.e., 50th percentile) man. And the precise distance to the control should take into account the operating action required. For instance, a lever that's to be gripped should be based on forward grip reach, which is significantly less than fingertip reach, such as might be used to determine the location of a push-button or a toggle-switch type control. Also, relative to determining precise distance, keep in mind:(1) that if hand controls are shared, maximum distance should accommodate the user who has the shortest grip reach, (2) that the operator's seat may adjust fore and aft; and (3) that some machines have seats which automatically adjust in height when the engine is started and have steering columns which tilt and/or telescope.

Hand control extensions added to foot pedals operate by either push or pull force, the determination of which will be based on the pedals' pivot points. Figure 7 shows a pair of hand-control levers attached to brake pedals with above-platform-floor pivot points; this configuration requires the operator to pull the levers toward his body to apply braking forces. Figure 7 also shows a single hand-control lever mounted to a clutch pedal with a below-platform-floor pivot point; this configuration requires the operator to push the lever forward away from his body in order to disengage the clutch.

Figure 7. (Left) Pedal pivot point above platform floor requires pulling action to manipulate the pedals, (Right) Pedal pivot point below platform floor requires pushing action to manipulate the pedal.

Additional Recommendations Regarding Hand Control Location

- They should be located so as not to interfere with, obscure, or inadvertently actuate any other controls or components. There should be at least a 2-inch gap between adjacent lever handles to allow for the thickness of the 95th-percentile hand wearing gloves (ASABE, 1983). However, consideration needs to be given to the operation of braking controls on equipment where the brake pedals are separated between right and left. In these cases, the operator may choose to manually apply braking force to both sides simultaneously, thus requiring both hand controls to be grasped by one hand.
- They should be located so as not to interfere with the pathway to the seat to allow easy entry and exit for operators with disabilities. Also, SAE Standard J1194 requires two 'unrestricted' (i.e., unblocked) exits from the tractor cab (SAE, 2009). The ways to conform to this recommendation include using hand control lever extensions that are easily removable during cab entry/exit and addition of a removable steering wheel and/or tilting steering column.
- They should be located so as not to come into contact with one's legs during operation. Persons with spinal cord injuries or other neurological disorders may not have sensation in their legs and thus can suffer harm to these limbs without being aware of it. Adaptive hand controls should be positioned to allow for changes in body posture, such as slumping, stretching, or movement caused by the machine's acceleration and vibration.

FORCES REQUIRED TO OPERATE ADAPTIVE HAND CONTROLS

The level of force needed to operate these controls is optimized via their location and the proper design of their lever-arms/linkages. Controls requiring excessive force can cause fatigue and reduce alertness (even for young operators) (Fathallah et.al. 2008). On the other hand, those offering too little resistance can increase the risk of inadvertent actuation, which may result in injury to the operator and bystanders, and damage to the machine or the surrounding environment (Kelso, et.al., 2008., Purcell, 1980. ASABE 2014).

For most designs, the maximum acceptable push/pull force lasting up to 5 seconds is 29 pounds when seated (CCOHS, 2017). It is recommended that designs not test the limits of the individual operator's capability. Thus, injury risk can be minimized by reducing the requirement to operate controls to, at most, two thirds of these force limits (Imrhan, 1999).

The factors affecting force application include the following—(1) plane in which force is exerted relative to the body, (2) direction of the force, (3) degree of arm extension, (4) one's posture, (5) one's hand strength, (6) bracing of one's feet and back; (7) back angle of the seat; (8) length of time the force is applied, (9) surface interface between the person's hand and the hand control (i.e. material and shape of the control's surface), (10) how often the force must be applied (Hutchingson, 1981), and (11) distance from the mid-plane of the body to 8 inches to the right for right-handers or to the left for left-handers (see areas labeled 'Primary Control Zone' in Figure 8) (Purcell, 1980).

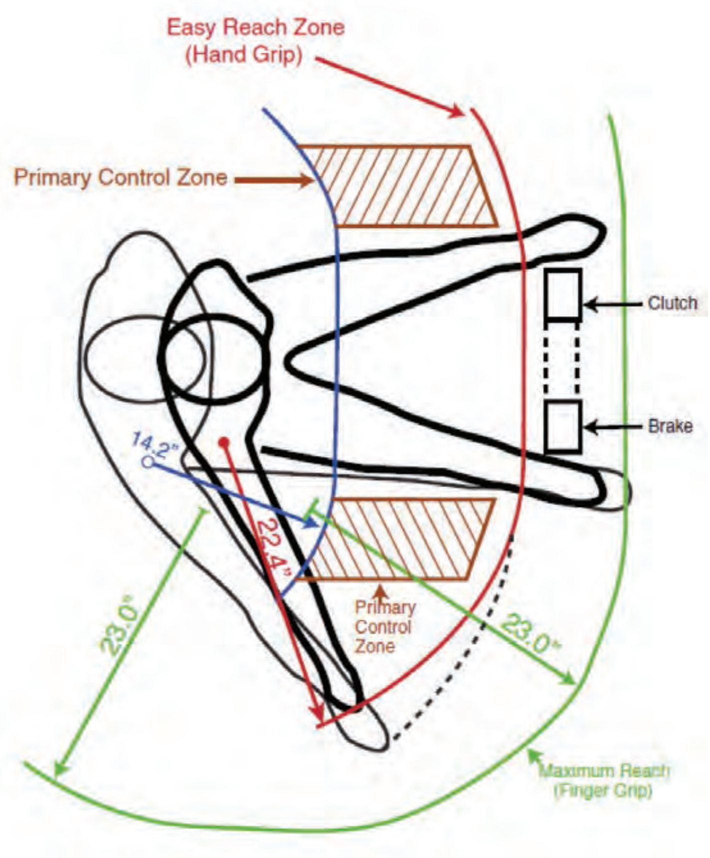

Figure 8. Optimum hand control positions.

CONSIDERATIONS IN DESIGNING AND CONSTRUCTING ADAPTIVE HAND CONTROLS

One of the first considerations to be made prior to installing adaptive hand controls is the selection of the machine that provides the greatest potential for use and offers the greatest potential for completing a successful modification. Some tractors, for example, lend themselves to easier or less costly modifications. Attempting to make the adaptions on older machines reduces the usable life of the adaption and fails to capitalize on newer design features that might better accommodate the operator's needs.

While adaptive hand controls can allow persons with physical impairments to operate their machinery safely and effectively, such controls are not to interfere with the operation of that machinery by others if shared use is anticipated. Based on years of evaluating 'homemade' hand controls at Purdue University plus in-depth reviews of government- and professional society-developed standards relative to vehicular adaptive equipment, the following guidelines are recommended for the design and construction of adaptive hand controls. (Note. Keep in mind that these guidelines are neither comprehensive nor universal; but rather each case must be examined individually, based on the operator's capabilities and specific piece of equipment being modified.)

- The materials used to construct adaptive hand controls should be strong and durable enough to stand up under the stress of normal operation (VA, 1978; Prather, 2002). It's highly recommended that a registered professional engineer be consulted to verify the design of such controls for their functionality and the appropriateness of their component parts.
- All sharp and jagged edges should be eliminated to prevent injury to the operator or damage to his clothing during operation and when entering/exiting. It should be remembered that some operators may have no or only limited feeling in their lower limbs, thus making them more susceptible to bruising or injury do to component contact.

- All components parts should be resistant to corrosion, which would otherwise weaken them and/or produce sharp edges.
- If at all possible, the controls should be of an 'add-on' nature. Permanent alterations (e.g., welding, boring holes, and cosmetic changes) could not only weaken the controls' structural rigidity, but also depreciate the equipment's resale value. Fasteners should be graded bolts, i.e. Grade 8, and secured with lock washers or lock nuts.
- Operating the controls during complex maneuvers (e.g., those performed at row ends and on hillsides) may be difficult to coordinate using only the hands. For example, in some cases, the operator will need to steer as well as operate the brake and clutch simultaneously. One way a number of operators have sought to address this is by designing their clutch hand-control linkage to lock the clutch in the 'disengaged' position in order to free the hand that normally operates the clutch to perform other tasks. Figure 9 shows such a clutch-locking mechanism. It's critical, however, that the linkage securely locks the clutch in that disengaged position until the operator re-engages the clutch. Warning: One must never leave the vehicle in gear while using the locking mechanism as a form of 'park.' Most such mechanisms, which function by either cam-over-center design or hand-controlled break/release design, can fail if bumped, possibly resulting in a run-over of the operator or a bystander if the transmission is "in gear".

Figure 9. Locking hand control lever with removable steering wheel for easier mounting/dismounting of the machine.

- Clutch hand controls should be designed to pull towards the operator (generally rearward) to disengage the clutch, as recommended by ASABE/ISO Standard 15077. However, in some cases, where the operator is less stable or secure, being able to push may prove easier.
- All two-wheel-drive tractors have two brakes. If the conventional brake-interlock between the two is made inoperable by attaching an adaptive hand control, a locking mechanism must be included in the control's design to allow for combined or equalized braking, as as seen in Figure 10.

Figure 10. Hand-brakes should be constructed to allow for independent and equalized braking.

- Hydraulic and pneumatic adaptive hand controls should be operable even when the machine's engine is off. If a cylinder is used as the actuator for a clutch hand control, the machine that stalls under load is difficult to get out of gear if the clutch cannot be disengaged. Thus, it's strongly recommended that the disengaged position be the actuator's default position. This can be accomplished by incorporating a spring to disengage the clutch, while the actuator is used to engage the clutch during operation.

- With clutch adaptive hand controls that use an electrical actuator, it's difficult to control clutch engagement/disengagement. The actuator must be slowed down enough to allow for smooth engagement ('feathering'), which is important for safe starts and ease in connecting to implements. However, the clutch must be able to disengage quickly if necessary but must not engage too slowly, because it might overheat under heavy loads due to excessive slippage. Electric, hydraulic, and pneumatic clutch adaptive hand controls should give the operator good control over engagement/disengagement.
- Adaptive hand controls should be properly designed to allow for safe operation when engine power fails or there is a failure in the hydraulic system. Power brakes and clutches are often designed to become fully mechanical when a machine stalls. Clutches on certain machinery models, for example, might require only a 15-pound pull on a mechanical lever assembly to disengage the clutch when the vehicle is running. Yet the force required to disengage the clutch with the same lever assembly when the machine is not running might be 90 pounds of pull, which exceeds both the capacity of many operators and the lever assembly. Some machinery models provide for limited power braking after the engine is stalled; however, power brakes on most are fully manual when the engine is not running.

Transmission Options and Clutching

Transmission options (e.g., hydrostatic, shift-on-the-go, hydraulic high-low, shuttle shift, constant velocity, and infinitely variable) require less—and in some cases even no—clutching, which frees the operator's hands for other tasks. For example, several manufacturers offer power shift transmissions that can be used with little clutching. Shuttle shifters allow one to shift from forward to reverse directions without the use of the clutch while maintaining the same gear. And hydrostatic, constant velocity, and infinitely variable transmissions, which are offered on many tractors and nearly all newer combines, have greatly reduced the need for extensive control modifications by allowing the operator the full speed range of the vehicle with no or minimal use of a floor-mounted pedal. In some cases, the hydrostatic transmission allows the operator to slow the machine to a stop without even using brakes. Care should be taken when using the transmission repetitively for breaking in some situations to avoid damage to the transmission.

VISUAL IDENTIFICATION OF ADAPTIVE HAND CONTROLS

Visual identification of controls can reduce the risk of error during the machine's operation. This may be important not only for the operator, but also for others nearby who could be injured by inadvertent actuation of the machine or any attachments. Two types of visual identification discussed here—color coding and labeling.

Figure 11. Color coding for operator controls.

Red: Single function stop engine controls

Yellow: Controls which involve the engagement of mechanisms (PTO, separators, cutterheads, etc.)

Orange: Machine ground motion controls (engine speed control, transmission control, parking brakes, park locks, etc.)

Black (or any color other than Red, Yellow or Orange): All controls not mentioned prior, (component lift, setting or adjustments, lights, cabin comfort, etc.)

Color Codes for Controls

Standardization of colors for controls increases the probability that those having a similar function fitted to different machines will be correctly identified. This could be critically important in an emergency, where a machine function must respond in predictable ways when someone unfamiliar with it operates the control. ASABE/ISO Standard 15077, "Tractors and Self-propelled Machinery for Agriculture – Operator Controls – Actuating Forces, Displacement, Location and Method of Operation" provides appropriate color coding dependent upon control function (ASABE, 2014). Paint suppliers should be able to provide colors that match the recommended color.

Labeling Symbols for Controls

Standard ANSI/ASABE AD11684, "Tractors. Machinery for Agriculture and Forestry, Powered Lawn and Garden Equipment: Safety Signs and Hazard Pictorials: General Principals" sets out the requirements for legibility, as well as the use of standardized graphical representations of control function with clear large text (ASABE, 2011). Graphical symbols should be designed with clear color patterns/symbols to transmit information independently of language, which is helpful to operators who do not have adequate English language skills, such as non-English speaking migrant laborers and English-speaking workers with limited reading ability.

When modifying factory control position or linkage, proper labeling should accompany the new design to allow for proper control function identification.

Figure 12. Graphical symbols for operator controls.

SUMMARY

The information in this report is intended to assist farmers, rehabilitation professionals, and engineers as they attempt to design and construct safe, quality, adaptive hand controls for agricultural equipment. Evaluation of numerous such controls over the years at Purdue University indicates that many pieces of equipment can be successfully modified to meet the needs of most individuals with disabilities. Nevertheless, further assessment is warranted to identify all of the potential hazards involved in the modification of specific tractors and other farm machinery before it is released to the operator for use.

Because specialists involved in vehicle adaptations have already put time and effort into development of hand controls for automobiles, it is possible to learn from their successes. Cooperative efforts between rehabilitation professionals and agricultural equipment manufacturers in addressing the needs of farmers with disabilities would also likely yield valuable information. Designing safe, durable, and effective adaptive hand controls can best be achieved by sharing ideas, plans, and standards among those engaged in designing, constructing, and using such modifications.

APPENDIX

Early Efforts Regarding Ag Equipment Control Modifications

In 1979, the Breaking New Ground (BNG) Resource Center was established within Purdue University's Department of Agricultural and Biological Engineering to assist agricultural producers with physical disabilities who desired to remain actively involved in their farm or ranch operations. The Center's primary goal was to develop, identify, and compile practical alternative designs, modifications, and accessories to help these producers safely operate their equipment and complete other essential farm-related tasks.

Among the most frequent inquiries that BNG has continued to receive are ones that have to do with the modification of operating controls on large pieces of agricultural equipment. For example—(1) a farmer who is paraplegic cannot depress the conventional clutch and brake pedal on his/her tractor; (2) a one-arm amputee has problems operating controls located on the same side of the cab or its console as his missing limb; or (3) a person with a back or neck injury has trouble reaching the PTO or three-point-hitch control lever due to difficulty in turning or bending his/her upper torso or neck. These are just a few of many situations calling for modifications to existing controls.

Since its inception, BNG has had opportunity to evaluate numerous 'homemade' modifications to the original controls found on agricultural equipment, most of them having been made by the farmer, a farm family member, or a local mechanic or machinist. More recently, there is a small but growing number of fabricators, such as Life Essentials Inc. of Brookston, IN, (http://www.lifeessentialslifts.com), which specialize in providing custom-made modifications that have proven both safe and highly successful. For additional information on hand controls, visit the Toolbox at www.agrability.org/toolbox

Why a Lack of Ag Equipment Adaptive-Aids Standards/Guidelines

REGARDING DESIGN/CONSTRUCTION STANDARDS. Currently, no comprehensive standards exist specifically related to the design and construction of adaptive hand controls for agricultural equipment. Concern has been raised over the quality and safety of those controls that have been constructed by users and local fabricators (Gruver et. al, 1997; Willkomm, 1990). An extensive review of the standards for automotive hand controls or hand controls in general (published by various governmental agencies and professional entities) reveal that, although no standards applied directly to hand controls for individuals with disabilities who use agricultural equipment, standards do exist that address design parameters for controls intended to be used by the farming population. The concepts presented within such standards do provide a starting point for hand control evaluation and design.

REGARDING DESIGN/CONSTRUCTION GUIDELINES. Manufacturers of adaptive aids for automotive applications cite the following reasons as to why control conversion guidelines are not presently available for agricultural equipment:

- These manufacturers were unaware of the need for control modification in the agricultural workplace.
- Lack of high demand for adaptive hand controls prevented these manufacturers from profitably producing them for agricultural equipment. This may, in part, be a consequence of the tendency for farmers to make modifications themselves and, in part, the result of a relatively small number of agricultural vehicles in use compared with the number of automobiles and trucks in use (DOT, 2006). (Note: Added to these disincentives is the trend toward increased farm size, which fuels growth in the development and sale of high-capacity machines but reduces the overall number purchased and operated (CNH, 2007).)
- Because product liability issues associated with modifying agricultural equipment have not been clearly defined, the manufacturers believe production and sale of the controls would be a risky venture.
- Due to the diverse nature of agricultural equipment, it is difficult to design a set of controls that fit more than one make or model of machine. Unlike most automobiles, there are no common mounting points (e.g., the steering column) that allow design and manufacture of universal adapter sets. Location of controls, direction of pedal travel, and force required to activate controls differ among the various makes and models and render designing a universal set of controls very difficult.

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