DESIGN AND POSITIONING OF CONTROLS: THE OLD AND THE NEW INDUSTRIAL APPROACHES (Review Paper)

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ABSTRACT

While copious amounts of research exist with regard to positioning of controls, very little research covers the design shape of the controls. This paper demonstrates the importance of control positioning and design within industrial settings. Furthermore it aims to highlight the changes in industries with regard to control design and positioning. This paper is a review paper and thus much is based on findings by other authors. However, the changes in the industrial practices referred to by the author are from knowledge gained while visiting numerous industries in South Africa.

INTRODUCTION

Controls are designed (and less obviously, often poorly designed) to serve a specific function. Large controls are consistent with strength demands while smaller controls will be used for fine manipulative functions (Fransson and Winkel, 1991; Milerad and Ericson, 1994; Drury, 1995; Oborne, 1995; Fleming **et al.**, 1997; Macduff **et al.**, 1997). The problem with controls serving a specific function is that the worker now has to be fitted to the task and not the task to the worker as proposed by Grandjean (1998). On June 29, 1971, three Russian Cosmonauts were killed on re-entry into the earth's atmosphere. After investigating the accident, it was found that the valve securing the pressure inside the capsule had opened and let precious oxygen escape. One of the cosmonauts tried to close the valve but ran out of oxygen and the investigators would later determine that the valve would have required a further full minute of rapid turning to stop the escape of oxygen (Casey, 1993). Casey (1993) stipulates that the precise conditions under which the control would be used had not been considered during the design and construction. Although industries rarely have fatalities due to control design error, numerous musculoskeletal injuries are prevalent. One reason for this is that interactions between engineers and ergonomists are rare and ergonomics is often seen as a frill in the world of engineering design (Burns and Vincente, 2000). A second reason is the ability that human beings have to adapt to a situation. Unknowingly this ability to adapt may be the cause of numerous injuries, especially when working with hand tools or manipulating hand controls.

Working posture is a vital component of ergonomic design. However, postural assessments are hardly ever carried out at the worksite and on the rare occasion when these do occur, the work durations are usually insufficiently assessed (Oborne, 1995). This lack of workplace assessments makes it difficult to determine optimal working postures or to prevent hazardous working postures (Salvendy and Smith, 1981). In all working postures there is an interaction between the operator and the machine. Humans and machines are generally adequate when seen as separate entities, but it is the interface between the two that is of vital importance to industry (Oborne, 1989). In the working environment, where the operator is associated directly or indirectly with a range of technologies, it is important to realise that output and productivity will be enhanced if the man-machine interface is compatible (Drury, 1985; Bridger and Poluta, 1998). In the cases where the interface is not compatible, manual work can be emotionally and physically exhausting. Bridger and Jaros (1986) advanced the concept of an Ergosystem; that which emphasises the crucial interaction between the human operator, the machine and the environment. The level of compatibility between operator and machine is often influenced by the design of the machine as it influences the working posture of the operator. Kroemer and Grandjean (1997) emphasised the need for "natural" working postures:

> *Since natural postures – attitudes of the trunk, arms, and legs which do not involve static effort – and natural movements are a necessary part of efficient work, it is essential that the workplace should be suited to the body size and mobility of the operator.*
>
> (Kroemer and Grandjean, 1997; p135)

Therefore it is clear that the task and working posture need to complement the characteristics of the operator in such a way that optimum working conditions exist. Under these circumstances, worker safety and ultimately efficiency should be achieved.

REVIEW OF LITERATURE

The human operator may be seen as a system that generates purposeful muscular activity by converting chemical energy into mechanical energy (Bonjer, 1973). Some muscular work is encountered in almost all types of human endeavour, even in sedentary occupations. In Western societies the trend has been to attempt to eliminate all physically demanding activities from the working environment. This may be plausible in a First World situation, but would definitely not work in poorly mechanised occupational settings. For example, in Mexico it has been reported that manual controls are sometimes preferred over automation as manufacturing costs are kept to a minimum (Lara-Lopez **et al.**, 1999). Therefore it is imperative that the design of these manual controls affords the worker the most optimum working conditions, those which promote safety and efficiency.

DESIGN AND POSITIONING OF CONTROLS

It is essential that in the design and positioning of a control one has to take cognisance of many factors in order to optimise the interface between the equipment and the human (Grandjean, 1998; Bridger and Poluta, 1997; Kroemer and Grandjean, 1997). Control characteristics and positioning need to be compatible with the abilities and characteristics of the human operator and with the task requirements. These characteristics include size, shape, texture and function. A control with inappropriate physical dimensions or characteristics may result in undue stresses on the worker, and may lead to cumulative trauma disorders (CTDs) or even acute injuries (Oborne, 1995; Psacarelli, 1997).

Control Design

Size

The dimensions of a control should be related to the anthropometric dimensions of the pertinent limbs of the operator (Haselgrave, 1994; Oborne, 1995). Grip size should be related to the function for which it is required. For instance, a delicate manipulative function would require a smaller fine tuning control-type, while a forceful action requires a larger control with the necessary mechanical advantages (Fransson and Winkel, 1991; Milerad and Ericson, 1994; Fleming **et al.**, 1997). The problem is that often many controls are situated in awkward positions and require the operator to adopt awkward positions to generate the necessary forces. Having to exert force beyond safe limits increases the risk of physical strain (Van Wely, 1970; Anderson, 1971; Westgaard and Aaras, 1984). This increased risk is also related to the control diameter which also influences the amount of force an operator must produce (see Figure 1).

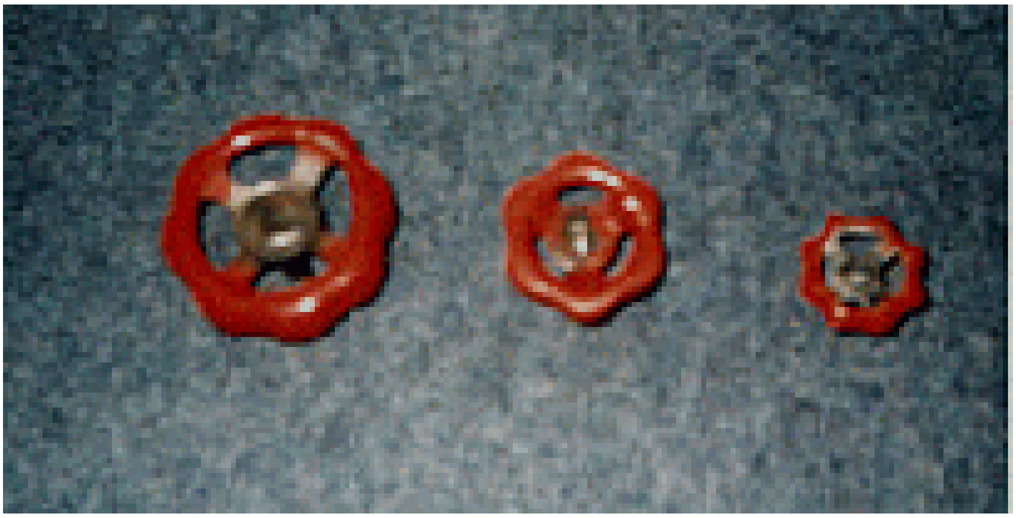

Figure 1: Variously sized circular type controls - reminiscent of the old industries.

Shape

Surprisingly little research has been done to determine the role which control shape affects the performance of the operator. In one study it was reported that circular grips are more advantageous as these allow the little and ring fingers to contribute to the total force exerted (Kinoshita **et al.**, 1996). Other studies have reported that large wheel controls that allowed the operator to use two hands as opposed to one were more efficient in tasks requiring high degrees of force (Drury, 1983; Fransson and Winkel, 1991; Woldstad **et al.**, 1995). The same applies if the control allows a worker to employ the whole upper extremity in the exertion. However, recent visits into industries, by the author, has revealed trends towards changes in the size and shape of controls. Newer or re-structured industries have moved from using the conventional circular controls (see Figure 2) to using the new lever-type controls (see Figure 3). The reason is that lever-type controls are easier to manipulate and that a quarter circular turn generally opens/closes the valve. Therefore, a more diverse population can manipulate the controls, which is particularly advantageous for those industries that employ females or persons of diverse morphologies and strength abilities. Furthermore, the fact that lever controls only require a quarter circular turn means that the extent of repetitive motions have been minimised and thus less strain should be experienced by the forearm.

Texture

The texture (feel) of the control serves as the interface between the machine and the operator and forms part of the feedback loop (Oborne, 1995). Texture relays information about the control to the operator and influences the outcome of the final action. Mismatched textures have been implicated in the etiologies of various injuries, especially those related to repetitive use (Drury, 1986; Frievalds, 1987). In other instances injuries may take the form of abrasions, blisters or cuts from the sharp or rough edges on the controls (Frievalds, 1987). Ergosense,

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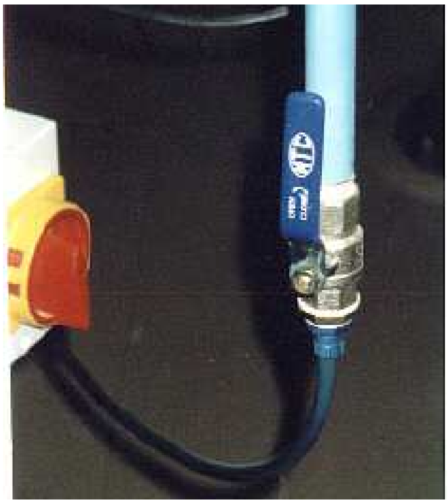

Figure 2: Circular type controls observed in
Figure 3: Lever control situated in
older industries.
newer industries.

computer software program developed by the Biomechanics Corporation of America (1995), has advocated that smooth surfaces tend to cause people to over-grip in order to obtain the same pressure or force as they would with a control with a rough surface (compare Figures 4 and 5). These seemingly contradictory statements illustrate the difficulties that ergonomists and engineers face when they try to design a control to meet all operator and processing criterias.

Figure 4: Older Industrial types: sharp metal circular control.

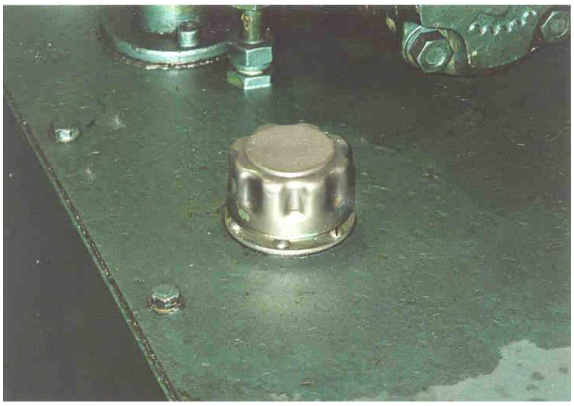

Figure 5: Old Industrial types: Smooth metal control.

Function

Fortunately for the modern human operator the function of a control is seen as crucial for its design. In the past all controls were of very similar size, texture, shape and colour (see Figure 6). This increased the level of confusion in emergencies or when new operators were introduced. Due to automation many of the problems relating to function have been minimised. Often large, multi-coloured control boards ensure that each control's function is clearly labelled and coloured in accordance with the specific task (see Figure 7).

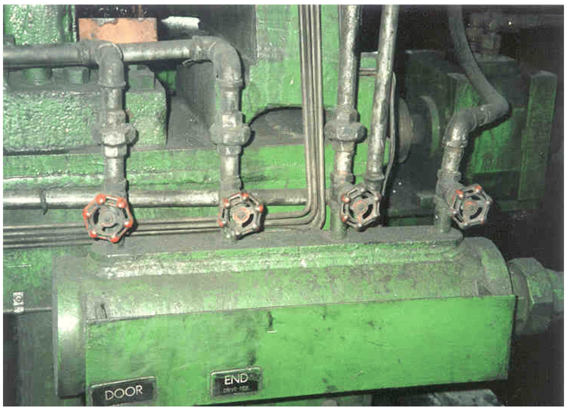

Figure 6:Older Industry: Mistaken identify and function.

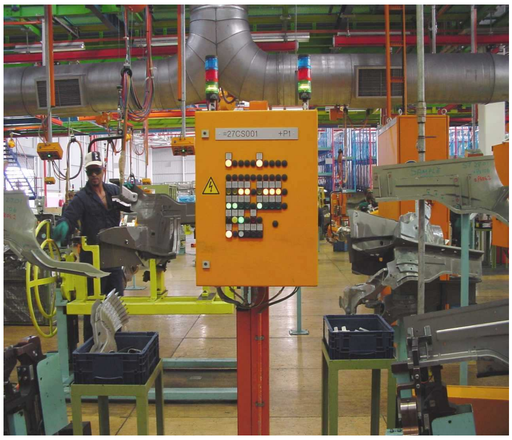

Figure 7: Newer Industry: automation.

Positioning of Controls

The position of a control is generally task specific and influences the working posture that the operator will adopt. The importance of understanding posture has long been at the forefront of ergonomics practices. In the early 1700's Ramazzini (1713) had already identified the need to develop a natural working posture to combat the "certain violent and irregular motions" experienced by an operator.

Haselgrave (1994) argued that a desirable posture cannot be clearly defined in ergonomics due to its ever-changing status. There are many functional aspects of posture and Corlett (1981) defines it as, "the position adopted because it is appropriate for the task being performed". Figures 8 and 9 illustrate cases where the positioning of the control has forced the operator to adopt awkward working postures. In most modern industries, controls above shoulder and below waist height have been eliminated. However, examples of poor postural demands in specific industries such as mining where workers are forced to work in a crawl space with very limited ranges of motion.

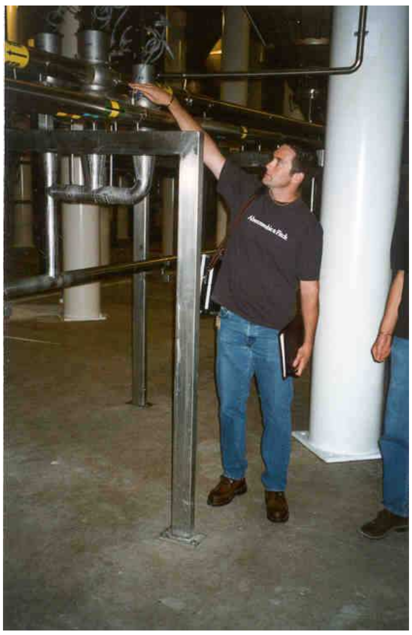

Figure 8: High reaches.

Figure 9: Restrictive crawl spaces.

In certain instances the placement of control(s) cannot be altered, the most common reason being the cost of alterations. From an economic and managerial point of view the cost of minimising the problem by replacing the control-type is often less than the costs associated with worker injury (see Figure 10).

Figure 10: Optimally positioned control.

HUMAN CHARACTERISTICS

Dimensions of the human body have always been a source of interest for ergonomists and there is substantial literature on the topic. Anthropometric measures have been made of almost every conceivable morphological attribute (refer to Pheasant, 1995). Ironically these data are hardly ever used in the design process due to the lack of communication between ergonomists and engineers. Design would be facilitated if anthropometric data were used in the design of machinery. In many instances the empirical data are used incorrectly. Vasu and Mital (2000) point out that it is incorrect to assume that if a person falls into a certain percentile for stature then their other anthropometric measures fall into the same percentile. Human variability creates problems, as a workstation designed exclusively for a person with all average anthropometric dimensions might still impose numerous awkward working postures for others (Vasu and Mital, 2000). Therefore anthropometric data in design should be used to cater for a range of people and consider this human diversity (Pheasant, 1995). Engineers need to take cognisance of the size, shape and proportions of the workers operating machinery (Haselgrave, 1994; Pheasant, 1995; Vasu and Mital, 2000).

CONCLUSION

The following conclusions have been made from the literature reviewed in this paper and from the experiences gained from various visits to industrial settings. Control design is a crucial aspect of all industries. In modernised industries there has been a definite shift from using the circular type control to the lever-type control. This shift is very important as it allows a more diverse population to operate these controls. Lever-type controls do not require as much force as the circular controls to operate, thus allowing “weaker” operators to handle the demands of the task. Secondly, the lever-type controls minimise the problems that are caused by human variability, accommodating a large diversity of hand sizes. In certain instances when the position of the control cannot be changed, then the type of control needs to be considered in order to minimise the negative impact upon the operator.

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