USING HFE TO DESIGN A USER-FRIENDLY CNC CONTROL PANEL

Term Paper

QAS 515

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Presented to

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Introduction and Statement of the Problem

For this class term paper, each student is instructed to choose a project with topic that is related HFE in his or her workplace. Then the student uses HFE knowledge to design, redesign or evaluate the chosen project. The project can be piece of equipment or system to have three different forms of displays, visual, tactual, and auditory. Examples

of these are a control panel of an industrial machine, an instrument panel of a car, the inside cabin of a fire truck, or workplace environment. The writer of this project chose the existing control penal of a Computer Numeric Control (CNC) machine for the study. . This CNC mill has the capability of milling or cutting very intricate and accurate shapes and angles from a piece of material called stock. An operator enters a program he or she has made into the CNC mill via a control panel located to the right and in front of the machine. This control panel houses all of the controls and functions of the mill that enables an operator to interact with the machine. A monitor is housed in this panel that displays the input from the operator and the status/output of the mill when in operation. For example, the monitor can display information regarding the milling or cutter speed of the spindle, or the location of the spindle or cutter relative to the x, y, and z axis/coordinates. A keyboard located below the monitor, allows an operator to input any information directly into the CNC mill. Various other controls an operator uses while performing a job are also located on this panel.

This control panel is nonadjustable; meaning the height of it relative to the floor or a user is fixed. The keyboard sits flat on the surface of the panel, i.e. the keyboard is perpendicular with the floor, or the hands of a user, and is parallel with the surface of the panel. The monitor displays information in orange/yellowish characters against a black background for the operator to see.

Stock or pieces of billet are loaded into the CNC mill through two clear sliding doors to the left of the control panel and in front of the machine. The piece(s) of stock are held in place by either a vise that clamps down on the stock, or are attached to a fixture or jig on a table inside the machine.

To the left and above the table, a tool holder holds various mills, drills, and other tools that are needed to perform a job. The operator decides what tools are necessary for a job and places them into the tool holder. From the tool holder, a spindle selects the necessary tool to perform the task that the operator has programmed into the mill. The spindle can spin at various RPM's (revolutions per minute) in order to "mill" the shape into the stock following the program from the operator. Once the CNC mill completes a job, the operator can inspect the part that is produced, and make any adjustments and changes if necessary. For example if there is too much chatter along the surface of a part, the operator may want to reduce the spindle speed. Using this CNC mill correctly will allow an increase in speed and accuracy of a product, which would prove extremely beneficial to mass produced parts by bringing an operation under statistical control versus a conventional, manually operated milling machine. The hypothesis of this study is to discover whether or not the use of HFE to evaluate and redesigns the control panel can improve and or maximize the human machine interface (HMI).

Purpose of the Study

The purpose of this project is to apply HFE concepts and theories discussed in lecture into the real world of design of objects that would benefit a user if it were redesigned. Once the writer decides on a particular product or equipment, he uses HFE to evaluate what are the good and bad points of its design. Then, he is to apply concepts of anthropometry in order to maximize the performance/interaction between a human and machine/system

Equipment Used

The apparatus chosen to conduct the experiment is a CNC (Computer Numeric Control) mill.

Procedure

To conduct this experiment the writer decided to redesign the control panel of CNC milling machine because he had direct access to it and he felt several improvements could be made to maximize the interaction of a user and the machine. This mill has all three types of displays including visual, tactual, and auditory.

The control panel that allows a user/operator to communicate or talk to the machine and also provides feedback by displaying information that is relevant to the operator. This panel consists of a monitor (visual), a keyboard and several other buttons and dials (tactual), that control a numerous number of functions of the mill. An operator can also directly watch as a job is being performed by the mill through windows located on the doors of the machine.

There is one audio display an operator may and should use when operating the mill and that is the sound that is produced while the machine is performing a job. When the machine is milling out the program into the stock it emits noise. An operator should become familiar and recognize if the noise produced sounds correct. For example, if the mill is milling a shape into a piece of aluminum stock, the operator should be able to recognize if the operation is performing smoothly based on the noise that is being produced from the cutter and aluminum. If the noise does not sound correct, the operator should check to see if there are any problems, like is the cutter speed or feed rate too fast

or too slow? An operator may also be required to minimize the time required to finish a job, but he or she may also be asked to maximize the tool life which can be done by becoming familiar with the noise produced and recognizing what cutter/spindle speed will provide the maximum tool life with the maximum amount of stock removal.

Based on these three forms of displays, the monitor for visual, keyboard for tactual, and noise for audio, the writer felt redesigning all three will increase and benefit an operator using this specific machine. He also felt a new design will reduce the stress on a user and at the same time maximize the performance of an individual based on concepts he have learned from lecture.

. There are four strategies that should be considered when designing an object: 1. Design for the extremes 2. Design for the average 3. Design for adjustability 4. Custom-making. The writer should decide what strategy or strategies would increase the interaction/performance of an individual(s) interacting with their particular system. Also, he should consider any stressors a user may encounter when interacting with the system and consider if the stressors can be minimized and or eliminated. Once he redesigns the system incorporating all of the concepts discussed in lecture, he is to explain what changes he felt were needed in the "system" and hypothetically build the new "system." Once the new system is "built" he is to analyze if the changes either increased or decreased the interaction between a user and "system."

Result

From the existing control panel as shown in Figure 1, the height from center of monitor to ground is 65" and the height from the center keyboard to ground it 46". Assume that the machine operator is a man standing on the ground as shown in Figure 2

to operate the machine via the control panel. He feels les eyes strain when His eyes are 20” away from the monitor and looks down at 15^0 from the line of sight. He also feels the most comfort when typing at his elbow height and his arm is parallel to his eyes’ direction as shown in Figure 3. From this assumption, the offset height from line of sight to center of monitor and keyboard is 5.36”.

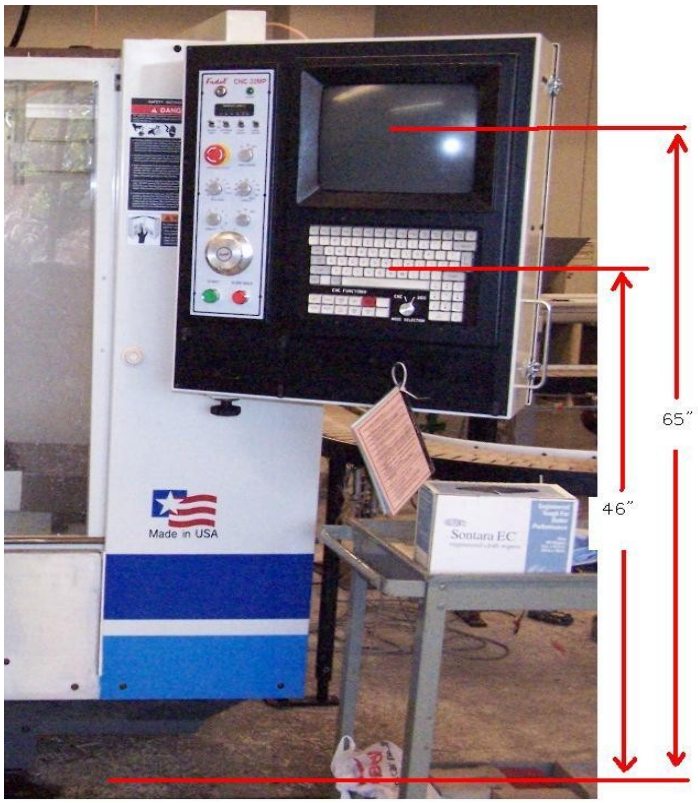

Figure 1. Fixed height of existing CNC control panel measured from ground

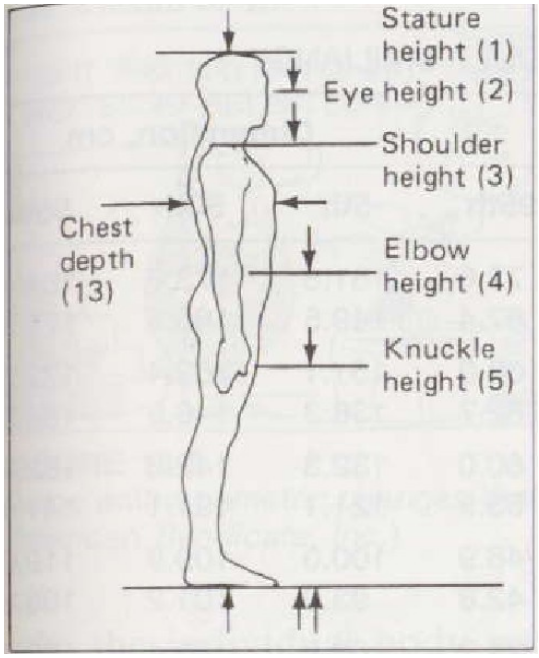

Figure 2 Diagram of structural (static body features
From Human Factors in Engineering and Design P.P 415

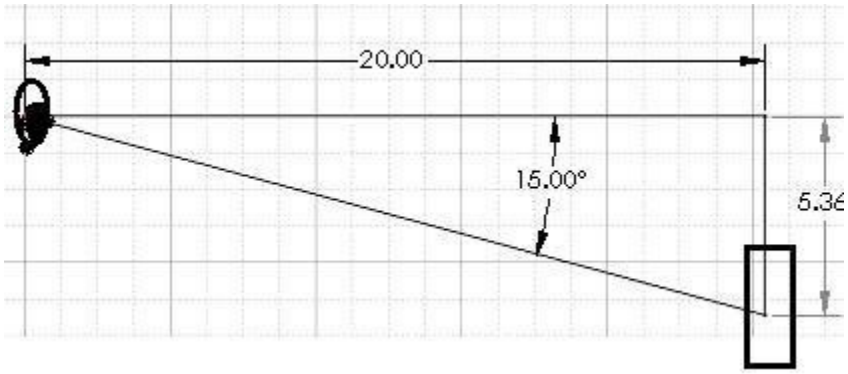

Figure 3. Height offset between eyes of sight to center of monitor and keyboard

Table 1 provides body dimensions of U.S adult civilians. Although most CNC machine operators are male, the redesign control panel also covers for female as well. In order to maximize the adjustable height of monitor (eye height) and keyboard (elbow height), the 5th percentile female and 95th percentile male is selected. From Table 1 the eye heights are 54.4" and 63.9" at 5th female percentile and 95th male percentile

respectively. From the same table the elbow height are 36.9" and 43.3" at 5th female percentile and 95th male percentile respectively.

To compensate 5.36" (the operator stands 20.00" away and looks down 15^0 from the line of sight or the arm inclines 15^0 from the line of sight), maximum monitor height is 58.54" (63.9" – 5.36"); minimum monitor height is 49.04" (54.4" – 5.36"); maximum keyboard height is 37.94" (43.3" – 5.36") and minimum keyboard height is 31.54" (36.9" – 5.36"). The redesign heights of monitor and keyboard are shown in Figure 4 and Table 2. The detail mechanical drawing for the redesign is shown is Figure 5. Note that the redesign also adds an alarm alert with color light.

Table 1

Selected Body Dimensions of U.S Adult Civilians

		Dimension (in)	
Body dimension	Sex	5 percentile	95 percentile
Stature height	Male	63.7	68.3
	Female	58.9	63.2
Eye height	Male	59.5	63.9
	Female	54.4	58.6
Shoulder height	Male	52.1	56.2
	Female	47.7	51.6
Elbow height	Male	39.4	43.3
	Female	36.9	39.8

From Human Factors in Engineering and Design P.P 418

Table 2

Comparison between Existing and Redesign Heights

	Dimensions (in)	
	Existing	Redesign
Eye Height	65	49.04 - 58.54
Elbow Height	46	31.54 - 37.94

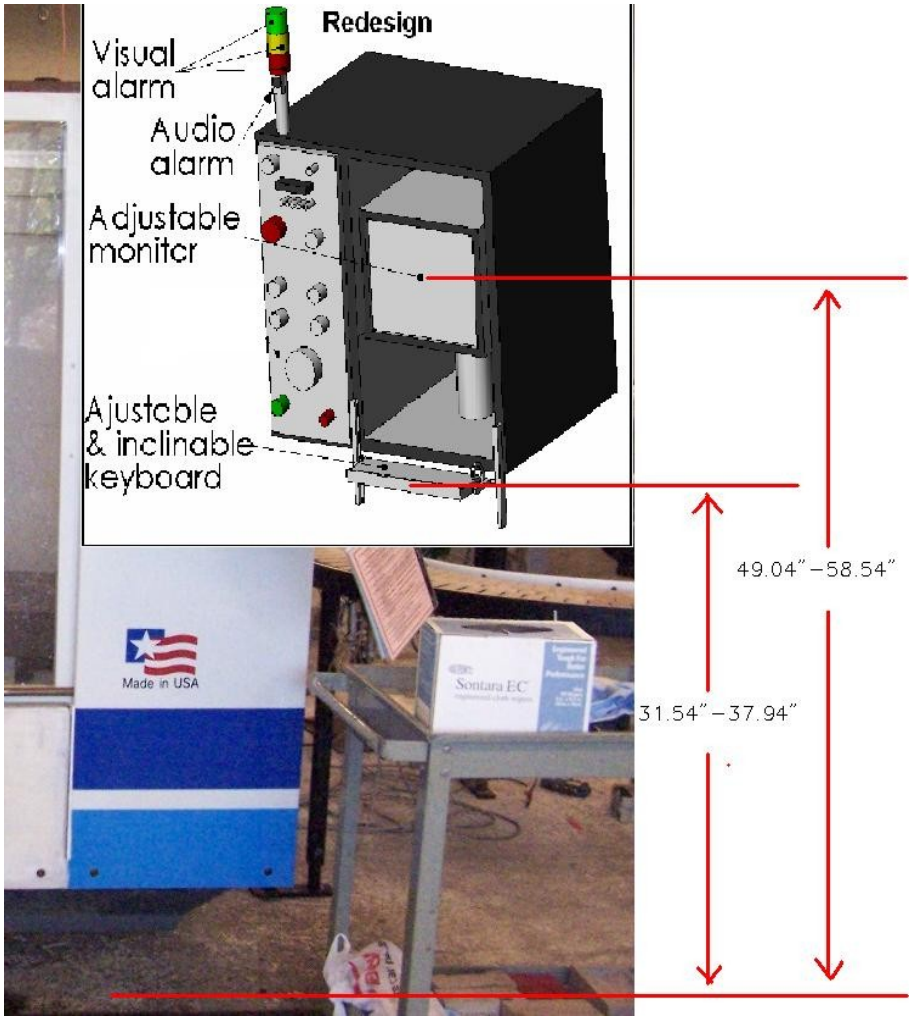

Figure 4. Adjustable height of redesign CNC control panel

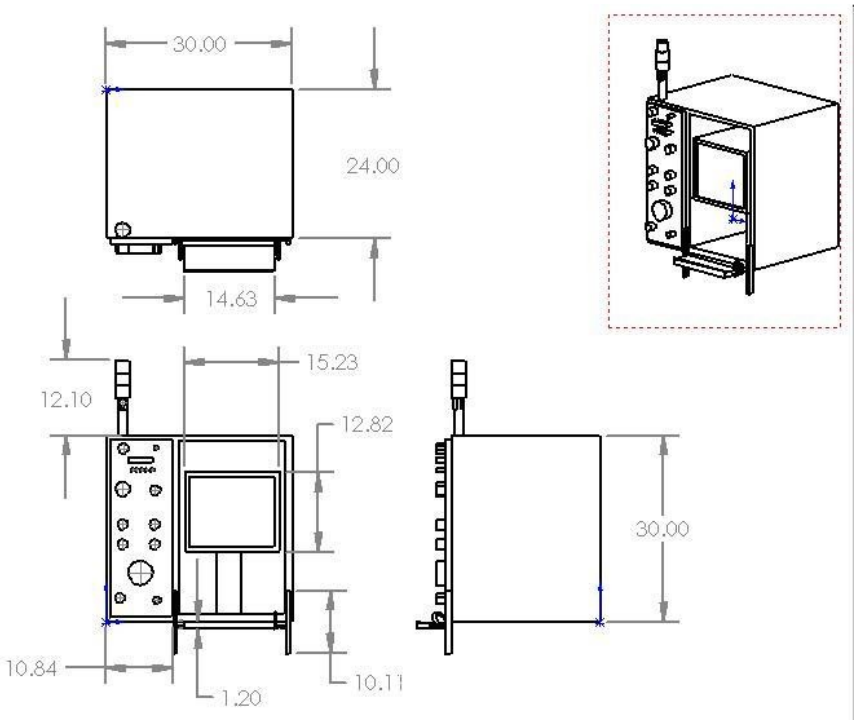

Figure 5. Drawing of redesign CNC control panel

Analysis and HFE Countermeasures

Taking several measurements and evaluating the design of the CNC mill, the redesigning the control panel, keyboard, and the addition of an alarm with a light will increase the performance of an operator.

By redesigning the monitor to be vertically adjustable from 49.04” to 58.54” and the keyboard adjustable from 31.54” to 37.94” vertically, an operator is then able to adjust both to a position where he or she feels the most comfort. It is also realized an operator will be frequently looking at the monitor in order to check the status of the machine, so it took into account the placement of the monitor on the panel. Taking into consideration for eye strain, the redesign for the monitor incorporates an angle of 15 degrees +/- 2 degrees below the line of horizon (in line with an operators sight) no matter where the panel is vertically adjusted to.

Next, the redesign in the placement of the keyboard will also benefit an operator. Having the keyboard in the position it is in with the original design, the keyboard is parallel with the face of the panel, which makes it perpendicular with an operator's hands. Having it placed this way may decrease any pressure/stress on an operator's wrist but it increases the time to perform a job. Stress on the wrist is reduced with the original design of the keyboard by having the wrist in a natural/neutral position when the operator is entering information using the keyboard. When entering or punching in data, the operator's wrist is in a straight line with your forearm, but this will lead to the operator to use only one finger from each hand or even just one finger from one hand to enter information. Since the operator cannot bend his wrist to a comfortable position to be able to use both hands and all fingers, like when he types using a conventional keyboard, the placement of the keyboard were redesigned.

The redesign of the keyboard makes it fully retractable from underneath the monitor, and is fully inclinable from 0 degrees to 45 degrees. By doing this, it gives an operator complete adjustability to be able to incline and place the keyboard in any position an operator would feel the most comfort.

The redesign of the control panel, keyboard, and monitor that incorporates a line of sight that is below the line of horizon for an operator, provides adjustability, added comfort, decrease time for a job/task, and an increase in performance of an operator. The redesign will be able to accommodate any user of varying heights and physiques, from the 5^{th} percentile female to the 95^{th} percentile male.

Lastly, the addition of a ringing alarm with a warning light will also improve the performance of an operator. Adding this alarm into the design can alert an operator if

something is wrong with the job, or a malfunction has occurred while operating the mill. This will be helpful in situations where an operator is in an environment where noise levels are high, especially if the operator is required to wear ear protection, or if the operator is hard of hearing or the extreme case is deaf. For example, imagine if this CNC mill was housed in a machine shop where the noise level was a consistent 120 dB (an extreme case). An operator is required to wear ear protection in order to protect his or her ears from this amount of noise exposure. In a situation like this, an operator will have a very difficult time in assessing the cutter/spindle speed of the CNC, and may realize something is wrong when it is too late. By having an alarm equipped with a light an operator will be able to hear and or see if his or her set up is correct. For example, if the operator enters in the wrong spindle speed for the machining of titanium stock the alarm and light will go off before the job proceeds. This will not only save set-up time, but will also save the operator from damaged tools, scraping the part, damage to the CNC, and most importantly increase the safety for himself.

Conclusion

The redesign of CNC control panel was done based on HFE. Specifically, the adjustable range of monitor's height (49.04" – 58.54") and keyboard's height (31.54" – 37.94") will give more flexible access for any user of varying heights and physiques, from the 5th percentile female to the 95th percentile male. Furthermore, the addition of ringing alarm with color light and adjustable noise level will improve performance of and operator. The writer of this term paper strongly believes that HFE can be used to improve performance of an operator in addition to increase safety at workplace.