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The design of a motion controller for educational purposes based on ergonomics

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ABSTRACT: The motion controller is widely used and various models are available. The challenge in design is to realise the connection between the person who needs it and the functions of the model. So, the design of a modern motion controller should be based on the characteristics of the activities of people, whether working or at leisure. This can demonstrate a new and novel human-computer interaction. In the study presented here, the physiological characteristics of human body posture are analysed, to determine the design of a motion controller for educational purposes based on ergonomics. In most circumstances, the ergonomic approach to the design appears successful and optimal.

INTRODUCTION

The applied science of ergonomics makes use of human physiology and psychology as the basis by which to improve people's working conditions and, hence, their quality of life. System engineering is used to examine the interaction between humans and machines, humans and the environment, and machines and the environment. This is applied to production, so as to ensure the optimisation of the overall performance of a man-machine system, as shown in Figure 1. This provides the basis for a *human-machine-environment* system that is simple in operation, labour-saving, safe, efficient and comfortable to use [1-3].

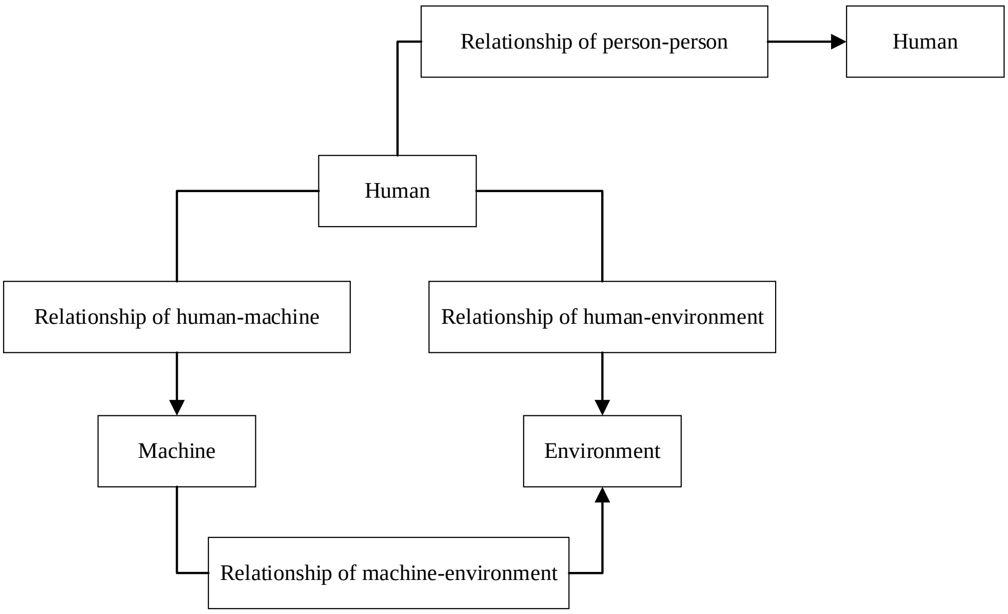

Figure 1: The relationship of the human-machine-environment.

In product development, attention must be paid to ensuring the product has the correct functionality, but at the same time is comfortable to use. Introducing ergonomics into the modern motion controller enables the user interface of the human-machine-environment system to be optimised [4].

APPLICATION OF ERGONOMICS TO THE DESIGN OF A MOTION CONTROLLER

Motion Controller based on Ergonomics

The design of a motion controller for educational purposes must take account of human body dimensions. There are six aspects to consider, viz.

Motion controller height: this refers to the vertical distance between the surface of the motion controller and the ground. The height should be such as to make the thigh approximately horizontal and the calf vertical, with the feet on the floor. Since motion controllers are often tilted backwards, the height of the motion controller is usually taken as the height at the front of the motion controller. Normally, motion controller height would be between 380 mm and 450 mm.

Motion controller surface depth: the motion controller surface depth has a great influence on comfort and body posture. It should satisfy three conditions, viz. it provides full support for hips; the lumbar is supported by the backrest; there should be a proper distance between the front of the motion controller and the calf [5].

The motion controller surface depth should be moderate. If the surface depth is more than the length of a thigh, there will be a large inclination forward hence losing lumbar support. This will exacerbate the use of muscles and cause fatigue. Usually the motion controller surface depth should be between 350 and 430 mm.

Motion controller surface width: the width of the motion controller surface is governed by the sitting posture and movements of people. As a result, the shape is often a wide front and narrow back. The width of the front is called the front motion controller width, and the width of the back is called the back motion controller width. The width should support the hips and leave room for other activities. Generally, 400 mm to 450 mm is appropriate. The arms and shoulders of people holding on to the handrail must be considered. Taking this into account, the width generally is not less than 500 mm.

Inclination angles: there are two inclination angles, viz. the inclination angle of motion controller surface and the inclination angle of the backrest. The inclination angle of motion controller surface refers to the angle between the motion controller surface and the horizontal plane. The motion controller surface should be tilted slightly backward, to avoid hips sliding forwards during a long period of time sitting. It should be comfortable for the back to lean backwards naturally under the influence of gravity, and be affixed to the backrest to provide back support. When working, 5° is desirable, while 14° to 24° is appropriate when at rest. The angle of backrest refers to the angle between the backrest and the motion controller surface, with backrest [6]. For comfort keeping the spine in a natural position the most suitable angle is 95° to 115°.

Width and height of backrest: this is related to the width and height of the shoulder. There should be no interference with the operation of arms. The desirable width is between 320 mm and 360 mm. The height of the backrest should be between 350 mm and 480 mm.

Height of handrails: the main function of handrails is to support the weight of arms, so as to reduce the burden on the shoulders and increase comfort. During the change of posture between sitting, standing up or changing sitting posture, arms can use the handrails to support the body. In a swinging or erratic motion, the handrails can help the body to maintain balance and stability. Depending on the size of the body, the vertical distance between handrails on the surface to the base surface should be 200 mm and 230 mm. The front of the handrails can be slightly elevated, with the change of the inclination angle of motion controller surface and basic tilting of the backrest. The inclination of the armrests is generally ±10°, while the angle of the backrest in the horizontal direction is about ±10°.

STRUCTURAL DESIGN

A motion controller machine is composed of two parts, viz. the heading and workbench. The motion controller making machine co-ordinate system is defined as shown in Figure 2.

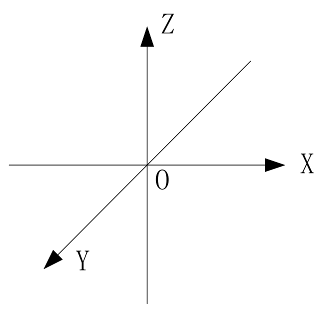

Figure 2: Co-ordinate system for the machine that makes the motion controller.

Forge Heading

The function of the forge heading is the non-manual forging of sheet metal. Movement of the forge heading is an up and down motion along the Z direction. The motion controller making machine must have good reliability and adapt to a high intensity of impact. The heading of the motion controller making machine described in this article is realised through a slider crank mechanism, as shown in Figure 3.

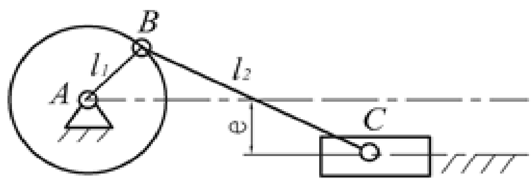

Figure 3: The slider crank mechanism.

The crank slider mechanism is widely used in various pressure machines. It has the advantages of being a simple structure, is convenient to use and has a good level of reliability.

The crank is driven by a motor to rotate, which drives the slider block in a reciprocating motion. The forging head is connected on the sliding block to realise the forged heading reciprocating motion in the Z direction. The rotation speed of the servo motor can be adjusted to control forging head reciprocating frequency, in order to adapt to different metals.

Workbench

The workbench is the carrier of the sheet metal. The workbench moves in the X and Y direction in the XOY plane [7]. The workbench is driven by a servo motor. In order to achieve the required motion, the rotation of the servo motor must be transformed into the linear motion of the workbench. During transmission, in the motion controller making machine, a screw nut is used to transform the rotary motion of the motor into linear motion of the workbench.

In order that the two vertical motions in the X and Y directions do not interfere with each other, the workbench is designed with two layers, as shown in Figure 4. Each layer consists of a servo motor operating through a screw. The workbench is driven by the servo motors to move in the X and Y directions. The workbench movement speed can be controlled by the speed of the servo motor. The workbench will move on a path according to the control system.

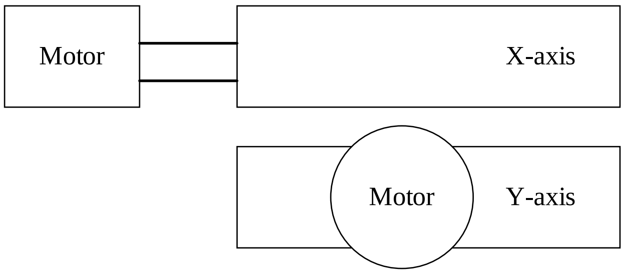

Figure 4. Workbench design.

CONTROL DESIGN OF THE MOTION CONTROLLER MAKING MACHINE

Principle of the Control System

The motion controller has the advantages of high precision; a fast response, a good level of reliability and wide used in recent years [8]. The core of a control system of motion controller making machine described in this article is the motor controller. The motor controller will control movements in the X, Y and Z directions. The detection device produces feedback, causing the motion to be adjusted according to the feedback [9].

The motor for the Z direction is used to drive the forge heading. The force and frequency of the heading is controlled by the motor speed and a power detection device is installed in the Z direction. The motors for the X and Y directions drive the metal sheet, with limit switches installed in the X and Y directions to avoid danger. The system control principle is shown in Figure 5, while Figure 6 shows the flow of control.

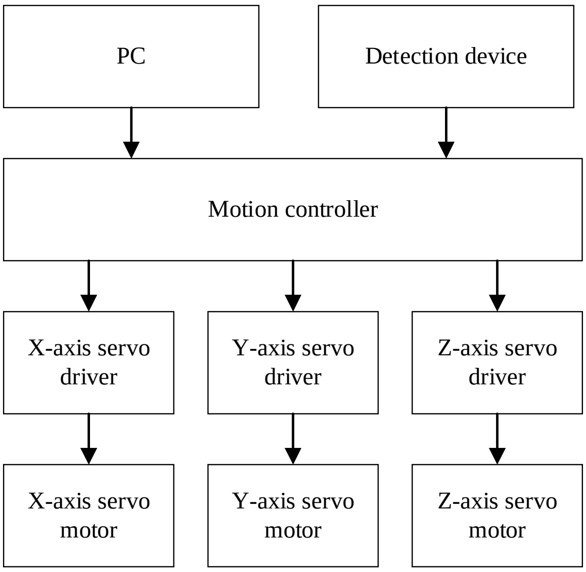

Figure 5: The system control principle.

Control System Design

First of all, the system is initialised. After initialisation, the model is selected and parameters set. The motion controller making machine has an automatic and manual mode. In the automatic mode, the workbench will be controlled by the control system program to follow the programmed trajectory. In the manual mode, the workbench is controlled by hand. The Z axis motor is started after the completion of the parameter settings. Then, the X and Y axis motors are started (Figure 6).

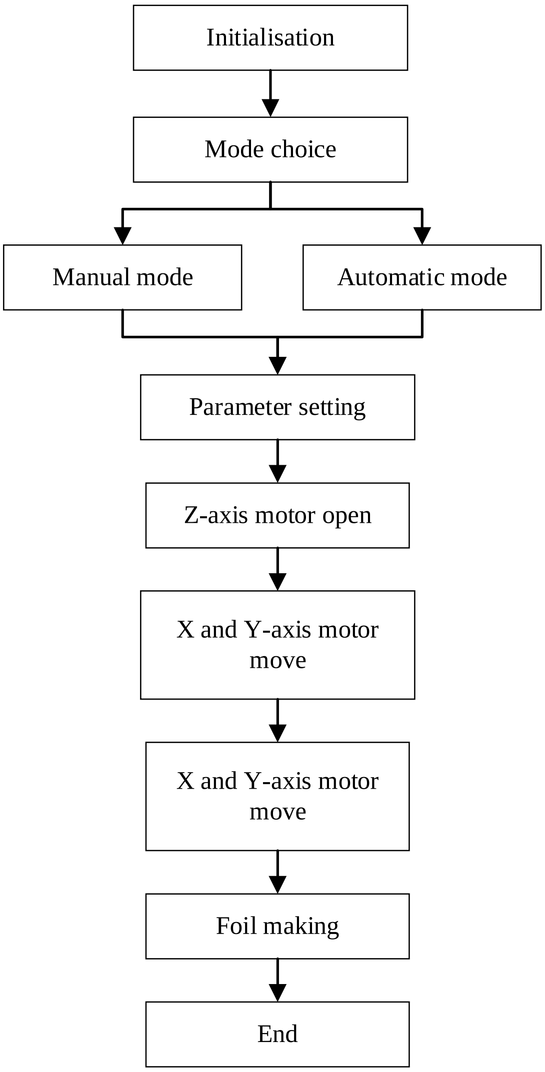

Figure 6: Control operation flow chart.

The input/output distribution of system is shown in Table 1. The motion controller programming language is based on Visual Basic. This has the advantages of simple structure and is easy to program. The programming completes the design of the control system.

Table 1: System I/O distribution.

Input		Output	
IN0	X-axis limit switch 1	OUT1	X-axis servo motor
IN1	X-axis limit switch 2	OUT2	Y-axis servo motor
IN2	Y-axis limit switch 1	OUT3	Z-axis servo motor
IN3	Y-axis limit switch 2		
IN4	Z-axis limit switch 1		
IN5	Z-axis limit switch 2		
IN6	Force sensor		
IN7	Temperature sensor		

CONCLUSIONS

There are many factors that can influence the design of a motion controller. Designers of these should consider the various factors that could be relevant, such as environmental impact, the controller surface material and also any psychological issues.

Through designing and evaluating motion controllers, the occurrence of occupational risks can be reduced, with an increase in comfort and efficiency. Hence, it can improve work efficiency, reduce labour costs, and ensure the safety of operators.

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