Model design and analysis improvement of CNC Lathe Based on Ergonomics

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ABSTRACT: As a typical mechatronics numerical control equipment, CNC lathes are widely used in various processing industries. To obtain better machining accuracy and effect of parts, there is a direct relationship between the structural configuration of the CNC lathe, the input and output mode of the machining information, the arrangement of the operating mechanism, the difficulty of the operation of the equipment, and the accuracy of the operator's operation. When designing a CNC lathe, we must consider the relationship between the human-machine-environment and apply the ergonomic methods and principles to the product design. This paper is based on the individual components of the appearance of the CY-PTC5655 CNC lathe. It proposes the ergonomic design points based on the appearance, creates a good human-computer interaction relationship, and effectively improves the operator's working environment. Reduce the operator's fatigue and improve the production efficiency of the product. The main contents and analysis methods of the thesis have certain reference for the designers of related majors.

1. Forword

CNC lathe is a typical mechatronic product and one of the most widely used CNC machine tools. The numerical control technology adopted by it is the core content of advanced manufacturing technology, and it is the basis for realizing China's "smart manufacturing" and "Made in China 2025". The performance of CNC lathes is not only reflected in the machining accuracy, production efficiency, processing capacity, reliability, etc., but also directly related to the operability, accuracy, ease of operation and comfort of the equipment. In order to obtain better processing results, it has a direct relationship with the structural configuration of the CNC lathe, the input and output mode of the processing information, the arrangement of the operating mechanism, the difficulty of the operation of the equipment, and the accuracy of the operator's operation of the equipment. Ergonomics is a discipline that studies the characteristics of human beings and the matching of working conditions with machines. At present, there are problems in the shape of CNC lathes that are not easy to operate, the display device is not easy to observe, the working space is limited, the color is not properly matched, and the body is indifferent. The use of ergonomics to guide the design of CNC lathes body can create a good human-computer interaction relationship, effectively improve the operator's working environment, and achieve the purpose of reducing operator fatigue and improve product production efficiency. This research has important practical significance and research value in the context of the current vigorous promotion of intelligent manufacturing in the country.
2. The development status of ergonomics in the design of CNC lathes.

The competitiveness of CNC lathe products depends and foremost on their own mechanical properties and processing accuracy. All major enterprises attach importance to the promotion of technology, for products whose performance and core technologies are not very different from each other, the convenience of their use and the comfort of operators have become the key to winning the market competition. The rapid development of CNC technology in China has also led to the improvement of the technology of CNC lathes. The automation level and user-friendly design of machine tools have gradually been applied to machine tool design, but compared with the application of CNC technology of similar foreign machine tools, there is still a large gap. As the operator of the CNC lathe, Not only should it have good physical strength, but also require the operator to have certain operational experience and familiarity with the equipment. The unreasonable design of the structure, shape and man-machine interface of CNC lathes will lead to lower operator's work efficiency, bad feelings to the operator's physiology and psychology, prone to fatigue and even cause operational accidents. Therefore, when designing a CNC lathe, we must consider the relationship between the human-machine-environment, apply the ergonomic methods and principles to the product design, and use the machine operator as the starting point for product design. The appearance, structure, performance and functions achieved are designed around the user's physical and mental experience. At present, China's machine tool equipment lacks in-depth research on the application and humanized design of ergonomics. The humanized design of the CNC lathe shape must be studied from the design elements of the machine's appearance, color, operational amenity, materials and so on.

3. The necessity and significance of ergonomics in the design of CNC lathes.

In the design of CNC machine tools, the relevant principles and methods of ergonomics will play an important role in the function, reliability and performance of machine tool design. The significance is mainly reflected in the following aspects:

- According to relevant data such as human body size and activity range provided by ergonomics, the relevant design can adapt to the physiological and psychological needs of human beings in design, and Meet the physiological and psychological emotional needs of the operator in long-term work; Applying the knowledge of ergonomics to the design of CNC machine tools can also improve the aptitude, convenience and safety of the equipment, reduce errors in the operator's operation, and improve processing efficiency and processing quality.

- In the design of CNC machine tools, the design of human-machine interface is an important part of the human-machine-environment design. It can guarantee the reliable transmission of processing information during processing. The man-machine interface of the CNC machine tool can not only provide timely information such as the position, speed and spindle speed of the machine tool, but also accurately transmit the information to the machine operator to provide the operation basis for the machine operator. In the design process, the relevant knowledge of ergonomics is fully considered and integrated into the design, which will effectively ensure the processing data of the CNC machine tool is accurately transmitted to the operator, Meet the operator's visual and tactile feel, ensuring the accuracy and convenience of the operation.

- Combined with the standard operating button graphic design features in the human-machine interface design, it satisfies the operator's operating habits and ensures that the CNC machine tool processing can be carried out accurately. According to mechanical design, electrical design features and standardization requirements, important buttons such as emergency stop switch, power start, stop button, cycle start of machining program, stop button, etc. must be selected according to its function. This is also the ergonomic design application of ergonomics in the design of CNC machine tool panel.

- In the design of CNC machine tools, combined with the psychological factors of ergonomics, optimize the shape, color, material and working space of CNC machine tools to improve the working environment and ensure the operator's good work mood and Convenience and comfort of operation to achieve the purpose of ensuring processing quality and improving work efficiency.
4. Ergonomic design of the appearance of CNC lathes.

CNC lathe is a metal cutting processing equipment. From the clamping of parts, the installation of tools, the preparation of machining programs, the setting of workpiece coordinate system, the operation of tool setting, every operation step requires the participation of machine operators to complete the machine tool. Every step of the machine requires the participation of the machine operator. The machine operator's vision, body size, hearing, touch, etc. are the main sources of reliable information during machine operation. Based on the principles and methods of ergonomics, using the knowledge of vision, human body size and hearing in ergonomics, the design of the appearance design of CNC lathe is completed to ensure the operator's pleasantness, safety and comfort in manipulating the numerical control equipment, it has a good practical value. The appearance of the CNC lathe is composed of multiple units protected by the CNC lathe, mainly including the surrounding panels, sliding doors, fixed covers, side panels, observation windows, CNC control boxes and other components. The appearance design of the CNC lathe should be based on the ergonomics theory from the appearance of the machine tool, from the observation window, handle, sliding door, CNC control box, machine tool color, each unit material and other parts of the analysis and research.

4.1. Problems in the appearance and design of CNC lathe CY-PTC5655

As shown in Figure 1, it is the appearance of the CY-PTC5655 CNC lathe. The sliding door is divided into a left sliding door and a right sliding door, and the left sliding door has an observation window; The CNC operation box consisting of the numerical control system, the numerical control system operation panel and the machine operation panel is mounted on the right sliding door of the machine tool. As shown in Figure 2, it is the size display of some unit parts related to operation in the design of CNC lathe. The height of the bottom of the CRT box from the ground is 1272mm, and the height of the top from the ground is 1706mm. The operation panel on the CRT control box is the operator's eye and manual operation are based. In the design, the humanized design of the unit such as the processing observation window and the numerical control operation panel is the key content of the appearance design of the CNC lathe. The performance of this part of ergonomic design will directly affect the user's evaluation of the performance of the equipment.

![Fig. 1. Original appearance of CY-PTC5655 CNC lathe](image1)

![Fig. 2. CY-PTC5655 CNC lathe part size](image2)

Through the functional units such as the left sliding door, the right sliding door, the left door observation window, the door handle and the CNC control box on the right door of the CY-PTC5655 CNC lathe, the ergonomics analysis was carried out, and the appearance of the equipment was found. The following problems exist:

- The observation window on the left sliding door is viewed from a horizontal angle. The angle of inclination is too small, 63 degrees, and the size of the observation window is 540mm * 220mm. It is difficult for the operator to observe the workpiece processing under normal standing position, and it is necessary to close the observation window. It is very insecure and inconvenient to see the processing.
- The position of the numerical control system operation box on the right sliding door is 1272mm-1750mm from the ground. According to the human body height dimension analysis of the 50th percentile of Chinese adult males, the height position of the control box does not meet the requirements of human body height; meanwhile, The tilt angle of the CNC control box operation panel
is too small, 72 degrees from the horizontal direction, which is not convenient for the operator to operate and observe.

- The material used for the observation door on the right side is iron sheet. It is necessary to open it completely to observe the machining condition of the workpiece from the side. It is unsafe to open the door during the processing, which also causes inconvenience to observe the processing.
- As can be seen from Figure 1, there are no handles installed on the left and right sliding doors. The handle is a functional component that facilitates the operator's operation of the machine tool, and plays an important role in improving the operator's work efficiency and operational comfort. Without a handle, it is inconvenient for the operator to operate normally.

4.2 Ergonomic analysis and design modification of some unit parts of CY-PTC5655 CNC lathe

The ergonomic performance of the CNC lathe unit components will directly affect the operator's operational performance. Based on the problems found in the above-mentioned on-site investigation, the solution to the problem is given.

- Left sliding door.

  The left sliding door is equipped with an observation window and a left door handle. In the process of machining parts, the operator stands in front of the left sliding door and observes the machining process of the workpiece through the observation window on the left sliding door. Therefore, the observer’s observation line in front of the left sliding door is the main source of design parameters for the design of the lathe viewing windows. The design of the left sliding door should be matched with the fixed cover on the left side, and it must be ensured that after opening the sliding door, the opening distance is larger than the maximum workpiece size that can be processed by the lathe, and a certain margin is left, so that the operator can easy to install and disassemble workpieces. In order to ensure the smooth development of the above work, the distance dimension after the sliding door is opened is more than 100mm larger than the workpiece size. At the same time, the left sliding door should also cooperate with the right sliding door. When the workpiece is machined, the workpiece can be processed after locking each other. During processing, the operator observes the machining of the workpiece through the observation window. The optimal field of view of the operator in the horizontal direction is 15 degrees in the left and right direction, and the optimal field of view in the vertical direction is 25 degrees upward and 30 degrees downward. The height of the observation window should be designed according to the human body's apparent height dimension of the 50th percentile of Chinese adult men. Therefore, the observation window should be designed based on the two elements of the field of view and the height of the human body, ensuring that the height and size of the observation window on the left sliding door conform to the optimal field of view of the operator, ensuring the convenience of observation. The material of the observation window is made of plexiglass, and the window strength should be able to withstand the throwing of workpieces rotating at high speed.

  After analysis, in order to facilitate the observation, in the improved design of the observation window on the left sliding door of the machine tool, the size of the observation window is increased to 580mm * 450mm, which satisfies the operator's optimal field of view range, and the inclination angle of the observation window is also observed. It is 73 degrees from the horizontal direction and meets the ergonomic design requirements, making it easy for operators to observe the machining process. The specific design is shown in Figure 3.
The CNC control box is mounted on the right sliding door. From the ergonomic point of view, in order to facilitate the operator to install and disassemble the workpiece, the knife and other operations, the left and right sliding doors should be locked to each other when machining the workpiece to ensure the safety of the machining process. The CNC control box on the door can be moved a distance with the right sliding door, which is convenient for the operator to clearly observe the condition of the tool and the workpiece when the knife is placed, and successfully complete the tool setting. As shown in Figure 4, it is the right side view of the CNC control box. The position of the CNC control box of the CNC lathe should be installed in the optimal field of view of the operator to meet the operator's eyes and manual operation to complete parameter setting, program entry, and operation during processing. Therefore, the optimal height of the CNC control box of the CNC lathe should be lower than the eye height in the standing position, higher than the elbow height in the standing position. When determining the design size and position of the operation panel of the CNC lathe, it is necessary to fully consider the compensation value of the eye height, elbow height and human body wearing shoes under the standing state of the operator. To ensure the comfort of the operator during the operation, it is necessary to design according to the 50-percent human body height of Chinese adult males. To adapt to different heights and genders of operators. As shown in Figure 5, the optimal size position of the operation panel on the CNC operation box should be lower than the eye height of the standing position and higher than the elbow height in the standing position. When designing, according to the size of the human body, consider the factors such as the eye height, elbow height, and the amount of correction of the human body wearing shoes in the standing position of the operator. During the operation, the operator's line of sight is required. The optimal field of view is about 10 degrees below the horizontal line of sight to ensure the convenience and comfort of the operator during operation. The modified CNC control box is 1090mm-1570mm away from the ground, which is in line with the optimal height range of the CNC panel. When the operator observes the CRT screen, the line of sight is slightly downward; the manipulator operation panel on the CNC control box is modified from the horizontal direction. It is 78 degrees to ensure the best operating condition and meet the operational requirements of the operation panel on the CRT control box during ergonomic design. The specific design is shown in Figure 6.
• Handle.

In the design of the handle, the installation size of the handle should be considered. The shape, size and material of the handle should be selected from the tactile feel to ensure the operator's grip comfort and ease of operation. Through ergonomic analysis, the handles on the left and right sliding doors are mounted in the lower position on the left and right sliding doors. The design of the handle is based on the optimal height of 1050 mm in human body operation. The cross-sectional area of the handle is rectangular with four corners and the length and width are 200 mm * 20 mm. CY-PTC5655 CNC lathe, because the observation window of the left sliding door increases, the right CNC control box moves down, Therefore, the handles on the left and right sliding doors are installed at a distance of 780 mm from the ground, and their design meets the requirements of ergonomic design. The specific design and modified effects are shown in Figure 6 and Figure 7.

• Observation door on the right side.

As shown in Figure 3, On the right side of the observation door, an observation window made of plexiglass is provided, and the size is 520 mm * 380 mm, which is convenient for observing the processing.

4.3. Color design of CNC lathe

Color is a very important visual information in addition to the appearance of CNC machine tools, the application of color must meet the physiological and psychological needs of the operator to operate the device for a long time, giving a comfortable psychological suggestion. Not only has the effect of increasing equipment aesthetics, reducing fatigue during operation etc., also ensure that the color of the CNC machine tool can comfort the operator's psychological feelings of working for a long time, played a role in function indication, regional division and improved observation accuracy. When the operator of the CNC machine tool faces the CNC machine tool for a long time in the processing process, the large-scale machine tool exterior color will largely affect the operator's mood and work efficiency. The appearance color of the machine tool is combined with different machine tool shapes and corporate culture, which will produce strong emotional color and performance characteristics, which will bring greater spiritual influence to the use of machine tools. The correct use of color will directly affect the processing quality and processing efficiency of the operator.

In the shape color design of CNC machine tools, the color configuration of the upper part of the lower part or the shallow part of the whole machine should be selected to give a stable and calm feeling. At the same time, because the machine tool is easy to produce a lot of chips, the chip removal device will transfer all kinds of chips downwards, and the bottom is designed to be darker to make the machine look cleaner and tidy. The upper part of the traditional CNC machine tool usually adopts white, but the operator is easy to produce a glare when facing a large area of white for a long time, so it is not suitable to select the white color of the whole machine shape. The CY-PTC5655 CNC lathe is entirely gray, which can calm people's minds and make people feel calm and meet the ergonomic color requirements of the equipment.

5. Conclusion

In order to better ensure the operator's convenience, comfort and safety, the ergonomic design principle should be applied to the product design of CNC machine tools to ensure a good man-machine relationship and effectively improve the operator's work. The environment achieves the goal of reducing the labor intensity of operators and increasing labor productivity. Starting from the appearance design of CNC lathe, based on the ergonomic design principle and method, the paper carries out the improved design of some functional components for the original equipment, which plays a certain role in promoting the appearance and appearance of CNC lathe.

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