The Computer Numerical Control System Design for the Saddle Surface of the Flange Connection Processing Plant

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Abstract. It is required to construct huge hydrocracking units in order to boost the revenue from refined goods. The barrel welding receiver skirt has a saddle-shaped surface in the reactor processing of the barrel welding receiver skirt, and the processing process is getting increasingly complex. In order to enhance the welding quality of the skirt to the actual shape of the receiver as the size and wall thickness of the receiver grow, it is important to develop the CNC system for welding the skirt to the actual shape of receiver. It talked about the manufacturing plan, the hardware circuit, and the software flowchart, to name a few subjects. Finally, the C programming language and the assembles programming language are utilized to implement the manufacturing flowchart in uVision3. Protues8 is responsible for the implementation of the hardware circuit. It is demonstrated by the simulation results that the proposed design plan for the CNC system is technically possible.

1. Introduction
When it comes to oil refinery operations, a hydrogen reaction chamber is an absolute must-have piece of equipment[1]. At the moment, the reasoning has arisen as a result of the increasing volume of the reaction chamber in relation to the wall thickness, the mechanism dimensions, and the weight of the reaction chamber[2-3]. As a result, a new need for the reaction vessel's manufacturing process has been established; in addition, the welded pipe, which is critical to the vessel's operation, has proven to be more difficult to manufacture than previously thought.

It was found in China that square turning and hand polishing were employed in the undersurface preparation of the saddle surface of the flange connection[4-5]. For the upper surface of the saddle surface, a planner or a numerically controlled lathe was employed to prepare the material. Those technologies were available options for processing flanges with thin wall thicknesses because of their availability. However, due to the rising size and wall thickness, the current processing methods were unable to complete the machining[6].

In order to reduce the design cycle time and cost savings, the saddle surface of the flange connection processing plant has been transformed in accordance with the C5116A-type lathe, the vertical lathe has been converted into a horizontal miller, and the cutter has been installed, connecting the vertical slide that was previously used to fix the lathe tool[7-8]. It was a single-developer project. An affordable CNC System design was presented in this research in order to improve the precision of the welding process that connects the flange surface and the cylinder's inside.
2. The synopsis of the saddle surface of flange connection processing
The saddle surface is an intersectional surface that is formed by joining a horizontal column with a vertical column and a column. Figure 1 depicts the situation.

![Figure 1. The saddle surface.](image)

The heavy-duty planner was largely responsible for the processing of the saddle surface, the inner surface of the flange edge, and specifically the curved surface of the flange edge itself (1). Mold was used to create the shape of the surface after it was moved. After the template had created the correct tracks, the copying cufing of the inner face was completed using a continuous movement planner in accordance with the template. The plant next began processing the external surface, specifically the curved surface, which was the next step (2).

3. The processing scheme of the saddle surface of flange connection
When the saddle surface is being machined, the work piece is rotated, and the milling cutter begins to process by adjusting the radial motion to the axial movement of the work piece. When this is done, we need to know the coordinate direction of the milling machine. For example, the Y-axis of the milling machine is the direction of the rotary movement of the worktable, while the Z-axis is the direction of the tool lifting movement and the X-axis is the direction of the horizontal movements [1, 2]. Figure 2 depicts the situation. To maintain symmetry in the design, the roughcast will be processed at the same time as the other roughcast is completed. The processing system for the outside surface is being redesigned in conjunction with roughing and finishing machining to get a more efficient result.

![Figure 2. The coordinate direction of the milling machine.](image)
3.1. Rough machining

During this stage, the outline will be completed by the cutter's dispersed two-axis combined movement of the saddle surface of the flange roughcast, which will be completed by the flange roughcast. The rough machining will make use of the even-depth processing technique. In addition, Figure 3 depicts the cutter path used in the processing.

Figure 3. The cutter path of the processing.

In order to establish the coordinate figures of cutting tool penetration and retraction, it will be necessary to take into consideration the unique structure of the flange edge. Furthermore, the moving trajectories of the milling cutter, as depicted in Figure 3, represent the rotational locus of the workpiece when the tool incises the radius of the flange connection to a specific depth. Aside from that, the dotted line represents the machining marks on the workpiece, which are created when the tool begins to process and the workpiece rotates. The cutter started working at the bottom of the roughcast and worked his way up. In the following stage, the roughcast will be developed in a bottom-up manner into a specific shape with stepped sides and armillary conformation, which is the semi-finished result of the flange edge. As soon as the cutter travels to the next point after completing one phase of processing, the process begins all over again by changing the axial movement to match the radial motion. As previously stated, the CNC system is primarily responsible for calculating the number of cutting feeds and for determining the coordinates of the X-axis and the Y-axis of the machine.

The steps involved in roughing the CNC system's calculations are detailed in the next section. Consider the following parameters: \( R \) is the radius of the welded cylinder, which corresponds to the flange connection; \( r \) is the radius of the loop curve; \( A \) is the initial point; and \( L \) is the horizontal distance between the initial point and the lowest point of the loop curve. The rotation of the workpiece will then be in a clockwise direction. Figure 4 depicts the position relationship of the cutter, with the (a) representing the front view, the (b) representing parts of the cutaway view, and the (c) representing the right elevation.

Consider the following: when the work-piece rotates from point A (the lowest point) to point B, where \( a \) is the rotation angle and \( H \) is the ascending distance of confronting cutting axes, the angle of rotation is. It will be necessary to derive the equations in accordance with the geometrical relationship indicated in Figure 4.

In accordance with Figure 4(a), the ascending distance between two facing cutter axes will be

\[
H = R - \sqrt{R^2 - E^2}
\]

Furthermore, according to Figure 4(b), the horizontal distance between the initial point and the lowest point will be

\[
L = r \sin a
\]

The simultaneous equations will then be determined by applying Formula (1) and Formula (2).
\[
\begin{aligned}
L &= r \sin \alpha \\
H &= R - \sqrt{R^2 - L^2}
\end{aligned}
\]  \hspace{1cm} (3)

Thus, the ascending distance between facing cutter axes will be

\[
H = R - \sqrt{R^2 - (r \sin \alpha)^2}
\]  \hspace{1cm} (4)

It is possible to draw two inferences from the equation presented above. One is that when the invariable number of \( r \) is supplied, the numerical value of \( H \) is periodically variable, as opposed to a constant. When the invariable number of \( R \) is supplied, the other is that the greater the number of \( r \), the greater the number of \( H \).

![Diagram of bowl and semi-finished products contour](image)

**Figure 4.** The position relationship of the cutter.

We suppose that \( h \) is the depth of processing for each process, \((\theta_i, H_i)\) is the coordinates of the starting-tool point for each \( i \)-th process, \( H_i \) is the total milling depth in the Z direction after the \( i \)-th process is completed. Also, we consider that \( \theta_i \) is the revolving angle, which is the differential angle between position of the work-piece and the maximum point, and \( \theta_i \in (0, \pi) \) are all positive integers.

As a result, the decision \( H_i \) will be

\[
H_i = i h, \quad H_i = R - \sqrt{R^2 - (r \sin \theta_i)^2}
\]  \hspace{1cm} (5)

To illustrate, consider the following: \((\theta_{i+1}, H_{i+1})\) is the coordinates of the starting-tool point of the \( i+1 \)-th process, \( H_{i+1} \) is the total milling depth (measured in Z direction) after the \( i \)-th process has been completed, and \( \theta_i \) is the revolving angle, which is the differential angle between the position of the work piece and that of the maximum point (measured in Z direction).

As a result, the overall milling depth \( H_{i+1} \) will be

\[
H_{i+1} = R - \sqrt{R^2 - (r \sin \theta_{i+1})^2}
\]  \hspace{1cm} (6)

\[
H_{i+1} = h + H_i = (i + 1)h
\]  \hspace{1cm} (7)
As a result, the spinning angel's name $\theta_{i,j}$ will be

$$\theta_{i,j} = \arcsin \frac{\sqrt{2} \sin \alpha - 2h \sqrt{R^2 - (r \sin \theta)^2} - h^2}{r}$$

(8)

In summary, the X-axis and Y-axis coordinate will be solved on the basis the Formula (3) to the Formula (8). And now let us consider $(\theta_i, H_i)$ is the first process's coordinate of the starting-tool point. Therefore, the coordinate will be

$$H_i = h; \quad \theta_i = \arcsin \frac{\sqrt{2} h R - h^2}{r}$$

(9)

3.2. Finishing machining.

The burr of the semi-finished items will be treated at this stage, which was created during the rough machining. Figure 1 depicts the shape of semi-finished objects, as well as their dimensions. Following that, the finishing machining will make use of the equidistant-line-processing technique. During the process of machining the semi-finished product, the workpiece is rotated, and the milling cutter begins to process in the regularly vertical-lift direction. Figure 5 depicts a schematic model of finishing machining, in which (a) represents the trajectory of a single tool path and (b) represents the contour line of the finishing machining process. It is necessary to utilize line interpolation in the processing because of the requirements for machining accuracy, which only serves to improve the precision of the weld surface precision. And the contour line is made up of a series of parallel curves that run down the edge of the flange.

In order to process semi-finished products in the finishing machining, we have adopted the sequence of processing from the outer edge to the inner edge. Following that, we'll figure out how far each step length rises above the ground. The poly-lines are used to create a contour line that fits the data. In addition, the Formula (4) is valid, in which the period of the numerical value of $H$ is $\pi$, and the symmetry axis is $\pi/2$.

Consider the following: the coordinate of $\alpha$ is the unit step, and $\alpha \in (0, 90^\circ)$, $\theta$ is the step length; $N$ is the number of coordinates of the poly-lines; and As a result, the coordinates' numbers will be as follows:

$$N = \frac{90^\circ}{\theta}.$$

It will be necessary to use the incremental approach in order to calculate the coordinates of the polyline.

In this example, let us consider that $(\Delta \theta_i = \theta, \ \Delta H_i)$ is the coordinates of the end point of the first poly-lines, $(\Delta \theta_i = \theta, \ \Delta H_i)$ is the coordinates of the end point of the second poly-lines, ..., $(\Delta \theta_i = \theta, \ \Delta H_i)$ is the coordinates of the end point of the N-th poly-lines.

Now consider that $\alpha = \theta$.

Note that
\[ \Delta H_1 = R - \sqrt{R^2 -(r \sin \theta)^2} \]  

Let \( \alpha_2 = 2\theta \).

And note that

\[ \Delta H_2 = \sqrt{R^2 -(r \sin \theta)^2} - \sqrt{R^2 -(r \sin 2\theta)^2} \]  

... ...

Let \( \alpha_i = i\theta \).

Also note that

\[ \Delta H_i = \sqrt{R^2 - [r \sin (i-1)\theta]^2} - \sqrt{R^2 -(r \sin i\theta)^2} \]  

Let \( \alpha_n = n\theta \).

And note that

\[ \Delta H_n = \sqrt{R^2 -(r \sin n\theta)^2} \]  

Whenever the work-piece is rotated, the milling cutter begins to process the material using line interpolation in the finishing machining process. In the processing of the junction of flange connecting and flange edge, the conterminous line of circular arc will be fitted by increasing the vertical distance of tooling, which will be accomplished by increasing the vertical distance of tooling.

4. The design proposal of hardware and software

Given the budget constraints of the project, a detailed design proposal for plant hardware, based on the MSC-51 SCM expanding I/O port, has been submitted for consideration. There are two critical implementations for this system: the design plan for the hardware and the importance of the module in the software design. The hardware design plan is the first, and the software design plan is the second.

4.1. The hardware design.

AT89S52 is the model number of the SCM; with a few slices of 8255a, the hardware system was able to add 8K of RAM and an I/O port. Figure 6 depicts a structure block in more detail.

In this section, we will disassemble the CNC system into its three basic components: the control system, the driving system, and the electric motors. The motion commands for the coordinate axes will be calculated by the control system using the interpolation approach, which will be implemented using the processing scheme presented in this work. Once this is completed, the pulse sequence will be transmitted to the drive system. Finally, after receiving the motion commands supplied by the drive system, the motors will begin to work as a result.
The output interface is discussed in greater detail below. The servo-actuator was connected to the X-axis and Z-axis drives, which allowed it to control the movement direction and velocity of the cutter in the tool holder. The Y-axis drive was used to connect the servo-actuator to the workpiece, which allowed it to control the rotation of the piece. The speed of the cutter was controlled by the inverter, which was coupled to the spindle motor. Because of the varying size of the workpiece, the beam changes the location of the cutting axis. In addition, the cutter bracket is held in place by the hydraulic drive and the optical coupler.

The input interface is detailed in greater detail below. Set and reset the machine tool, as well as control the photoelectric switch, are all accomplished through the machine switch. In addition, the matrix keyboard is utilized to enter parameters.

The RAM is used for storing live programs and data, such as the user's debugging program, the interim result of a calculation, and the data and parameters of the I/O port, among other things. The convenience of reading and writing is a plus, but the disadvantage is that it is volatile. As a result, in the event of an unexpected power failure, the standby strategy is applied to the battery to ensure the integrity of the data stored inside.

Displaying the current processing status and selecting an interface are the primary functions of the display, while the operation panel is responsible for displaying and selecting the interface. They communicate with the microcontroller using the serial port on the microcontroller's board.

4.2. The software design
The modular design will be implemented, and the C language will be used to compile and assemble the code. The C programming language is used throughout the program's body. The feed pulse program of the servo system, which is a high-priority processing method and an important portion of the program, will be written in the assembles language, as will the rest of the program. There are several components to this software, including a compiler for the parts of finishing machining and rough machining, communication between a microcontroller and an operating panel and display via serial port, construction of a user interface, the auto zero function, and so on. It will be necessary to complete the flowchart of the program in uVision2, which is depicted in Figure 7.
A separate priority process is created for each functional module based on the real-time requirements of the various tasks. Each functional module is separated into many priority processes. They are assigned by the source of the interrupt. For example, a top-priority processing procedure will be loaded right now, even if a lower-priority processing procedure is now executing. At the same time, the software section displays the design considerations for each module and each subprogram flow, as illustrated in Figure 8.

An I/O port’s three control pins are used to regulate the uniaxial data transfer, and an addressing list stored in the ROM will be used to determine the accessible address. Furthermore, the feed data for the movement axis will be stored in a distinct portion of the RAM that has been specified. The physical circuit is implemented in the Protues7 programming language. As well as for program validation and debugging, the simulation will be utilized.

Figure 7. The program flow.

Figure 8. The subprogram flow of the rough and finishing machining.
5. Conclusion
This study offers the interpolation and machining scheme of the flange receiver based on the system analysis of the machining special machine. It also determines the hardware design scheme and software design scheme of the system, and it carries out the related application development work. A detailed machining strategy for the saddle surface of the flange receiver is proposed, and the overall structure scheme of the system, as well as the development environment, development tools, and design scheme of the system, are all determined.

Using simulation, it was discovered that the CNC system meets all machining criteria while also increasing productivity while simultaneously lowering costs and lowering the total cost of ownership. Furthermore, it addresses the difficulties of long-term machining as well as the severe physical harm given to employees as a result of the design of square turning and hand polishing, which were previously present. Due to the independent design and development of the CNC system, it was possible to greatly enhance machining precision while also accelerating the completion of the saddle edge machining process. This design solution significantly solves the productivity challenges associated with hydrogenation reactor machining while also significantly lowering expenses. In terms of functionality and human-machine interface development, however, this design approach still need improvement, particularly in terms of network connection and adaptability, both of which will be crucial components of later study.

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