Industry Science and Engineering Vol. 2 No. 2, 2025

Design and Development of Human-Machine Interface for Siemens 840D CNC Gear Grinding Machine

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Abstract: Based on the OEM software design method of Siemens 840D CNC system, using the development environment provided by 840D CNC system, taking gear grinding control of CNC grinder as the research object, using object-oriented programming language VB, a specialized human-machine interface, and using VC to create a language dynamic link library, a dedicated operating interface for CNC gear grinding machine tool was developed. By inputting parameters through the human-machine interface, parameterized automatic machining is achieved, meeting the special needs of CNC grinding machine gear machining and greatly improving machining efficiency.

Keywords: Siemens 840D CNC System; Dynamic Link Library; Interface; Gear Machining

1. Introduction

Siemens CNC systems are widely used in China's machine tool industry, but mainly limited to simple use of Siemens standard CNC systems and shallow applications. The application of standard CNC systems not only fails to fully utilize the performance of Siemens CNC systems. In CNC machining, due to the standard G-code programming and standard operating interface used in standard CNC systems, most users can only use linear and circular interpolation instructions to develop machining programs, and machine tool manufacturers can only edit some text such as alarm messages. For the grinding of non-circular parts composed of complex curves or surfaces, special curve interpolation, error compensation, and real-time adjustment of process parameters are required [1]. The implementation of these functions places high demands on the technical level and operational experience of operators; In addition, similar complex parts are often encountered during processing. If traditional programming is used, it will result in a large workload, easy errors, and low production efficiency. In response to these issues, the secondary development of open CNC systems for specialized equipment such as grinding machines can meet the needs of personalized markets and has great practical significance.

Developing the secondary interface of the CNC system according to user requirements, achieving various parameter compensation or parameterized automatic programming, has become the key to improving production efficiency. The secondary development function of Siemens 840D CNC system provides a platform for implementing parameterized programming and parameter compensation. This article studies the OEM development software and environment of Siemens CNC system, mainly focusing on the user interface requirements of CNC gear grinding machine. The secondary interface design and embedding are carried out to achieve parameterized programming and error compensation of CNC gear grinding.

2. Technical Support for Siemens 840D CNC System and Its Secondary Development

2.1 Hardware Structure of Numerical Control System

The SINUMERIK 840D motion control system is built on a comprehensive system platform and is applicable to almost all control systems through system setting functions. Its CNC is divided into five parts, consisting of three parts: human-machine interface CPU (MMC-CPU), digital control CPU (NCK-CPU), and programmable logic controller CPU (PLC-CPU), as well as servo drive control and intermediate communication. In terms of physical structure, NC-CPU and PLC-CPU are integrated and synthesized in NCU (Numerical Control Unit),

but they are logically independent of each other. The human-machine interface is responsible for the input and display of NC data, realizing functions such as machine operation, monitoring, programming, and parameter setting. It consists of three parts: OP unit, MMC unit (human-machine communication), and MCP (machine operation panel), and completes the control function of the entire CNC system through the coordinated work of the three. The programmable logic controller (PLC) has functions such as machine logic control, machine operation, and PLC data management; NCK has functions such as NC code execution, code preprocessing, interpolation calculation, servo control, and NC data management. SINUMERIK 840D is an open CNC system. Users can purchase the development software package to call various built-in functions of the system through APIs, customize the window interface, and develop it using graphical software such as VB and VC on a general PC's WINDOWS platform.

2.2 OEM Development Software for 840D CNC System

The development software for the 840D CNC system is an OEM software package that can be used for secondary development of various machine tool interfaces above MMC103. Install the OEM development software on the computer. In the HMI Advanced file, the OEM, along with the data management file DH, header file HD, temporary folder ALTMP, user modification information USER, MMC2 standard user interface, and other information ADD ON folders, form the SINUMERIK840D system file structure. The main functions of the OEM software package include defining various software on the human-machine interface; By utilizing the DDE interface provided by OEM, it is possible to manage files in NCU, access various variables and parameters, access R parameters, access various variables in PLC, and manage files in MMC [3].

3. OEM Software Development for Gear Grinding Machines

The sequential structure control in OEM software provides a standard application framework for Siemens programs, as well as many standard modules and forms. The OEM development program written according to user requirements must be embedded into the standard sequential control framework provided by Siemens, using complete sequential control, in order for the HMI software package to support the program. Otherwise, the program cannot be run [4]. In order to quickly develop and design OEM software, we can use the OEM Samples instance in HMI Programming Package to select one instance such as OEMBSP0 for interface design and dynamic link library creation.

3.1 Design of Multi Form Operating Interface

The types and shapes of non-circular gears processed by gear grinding machines are different, but due to the regularity of the contour formation of the workpiece, its shape can be described by a limited number of characteristic parameters such as tooth number, modulus, pressure angle, and helix angle [4]. According to the functional requirements of CNC gear grinding machines, the parameters required for gear CNC programming can be divided into five groups: gear type parameters, gear parameters, tool parameters, process parameters, and machine installation parameters [5]. The overall diagram of the developed user interface is as follows:

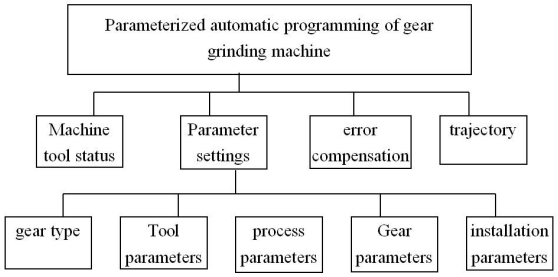

Figure 1. Parametric Programming Software of CNC Gear Grinder

Using VB to design the user interface, the content in each box is an interface, which includes forms and modules. There are a total of ten windows in this design, and each window is called as a separate sub function in the form of a sub window. Multiple forms together form the entire interface function. The relevant properties of the form are set as follows: caption, name, and tag are all set as one content, usually according to the sequence of the form (OEMFRAM0 to OEMFRAM9) or the name of the form, which facilitates the application and calling of the program.

In the VB environment, generate gearwheel.exe execution program for the window and module of the designed CNC gear grinding machine software interface control program, in order to

embed it into the standard sequential control provided by Siemens [6].

3.2 Creation of Dynamic Language Link Library

The menu text of the horizontal soft keys in the standard control interface provided by Siemens cannot be edited in VB environment, and can only be written by creating a dynamic link library in VC language. Creating a sequence controlled dynamic language DLL requires using VC++based on the corresponding RC file. Before creating a dynamic link library, first create an RC source file, which is an RC text edited using a clipboard. The partial content of the RC source file in this project is as follows：

```
STRINGTABLE DISCARDABLE
BEGIN
0 "10"//The starting address of the horizontal soft key
1 "100"//The starting address of the vertical soft key
2 "200"//The starting address of the dialog box or text
10 "Machine Status"//Text of the first horizontal soft key on the first interface
11 "Parameter Settings"//Text of the second horizontal soft key on the first interface
12 "Error Compensation"//Text of the third horizontal soft key on the first interface
13 "Running Trajectory"//Text of the fourth horizontal soft key on the first interface
16 "Exit"//Text of the seventh horizontal soft key on the first interface
END
```

The content in the text refers to the software tags and dialog boxes, as well as the text to be implemented on the tags. Therefore, the text in the RC file has a one-to-one correspondence with controls such as soft keys [7]. After creating the RC file, use VC++to generate the dynamic link library G_UK.DLL, and ensure that the file is "release" instead of "debug".

3.3 Interface Embedding

The OEM software sequence control mainly consists of the following six files: initialization file REGIE.INI, execution program files GEARWHEEL.EXE, MMC.INI, state management files GEARWHEEL.ZUS, GEARWHEEL.INI, window management file GEARWHEEL.MDI, and language file LangUAGE. DLL. Its structure is shown in the figure 2:

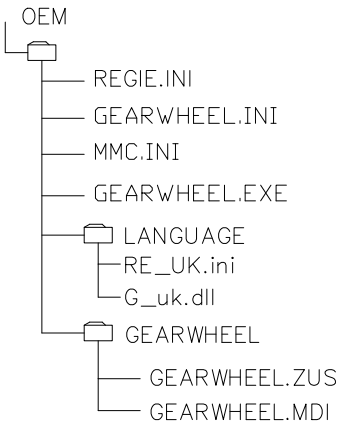

Figure 2. OEM Sequence Control Structure

The following illustrates the structure of sequential control and the functions and relationships between various files through the embedding process of the fully CNC grinding machine control interface.

1) Establish program management file Regie. ini

Regie is a control program that can flexibly manage auxiliary programs (basic modules), regional applications, dynamic link libraries, and VBX files. It has functions such as system initialization, loading dynamic link libraries, launching applications, system configuration, and regional conversion. The start of sequential control is initiated by Regie pre starting auxiliary applications (DDL, VBX) to regional applications. After an application starts, Regie waits until prompted that initialization is complete. Regie has three types of regional applications: one is a standard OEM regional application created by VB and embedded into sequential control; The second type is PC user applications under WINDOWS; The third type is standard applications under WINDOWS such as EXCEL or EDIT. , Regie uses REGIE.INI, REGIE.DLL, Regie-language.INI, OEMFRAME.INI, MMC.INI files to implement these regional applications.

Regie. Ini can be edited with text, just like other initialization files in Windows,. Each application is managed and launched by regie, and its information is stored together in regie.ini to form the program management file. Therefore, all applications developed by users need to be configured in Regie.ini, and the programs need to be embedded into Siemens standard HMI systems through it.

In C: \ Siemens \ Sinnumerik \ HMI-Advanced \ mmc2, regie. ini has been standardized. To embed the designed application into the standard interface, simply modify some settings in regie.

In [TaskConfiguration], task0-7 corresponds to the eight horizontal soft keys on the standard interface. HSK0-HSK5 are the standard control interface keys for CNC systems, and are usually designed to be controlled by user developed OEM software from HSK6 and HSK7. In the OEM software design of CNC gear grinding machine tools, the standard interface framework can be basically used for control. The OEM application program of this design is called gearwheel, which is accessed through the HSK6 soft key and has a response limit time of 20 seconds. In the regie. ini under C: \ Siemens \ Cininerik \ HMI Advanced \ OEM, the following settings are made:

[TaskConfiguration]

Task6 = name := gearwheel, timeout := 20000,PreLoad := true

At system startup, it is necessary to directly enter and display the screen of the designed application program. The settings are as follows:

[Miscellaneous]

PoweronTaskIndex =6

In this way, simply press the seventh key of the horizontal soft key to enter the developed application. In the OEM software development of this gear grinding machine, the mmc. in and i in the standard user interface MMC2 will be used without any additional settings.

2) Create a new folder called GearWheel under.../OEM/, and create the sub window list file GearWheel.MDI and control file GearWheel.ZUS in text format within GearWheel.

MDIList is a list of sub windows developed for the secondary interface, and all sub window names are listed in GearWheel.MDI.

GearWheel.MDI is edited using a writing board and includes information such as the names, types, preprocessing measures, and annotations of each sub window [8]. In the secondary development control software of this grinder, after reasonable planning and design, the following settings have been made:

OEMFRAM0 "1//Main interface

OEMFRAM1 "1//Machine status

OEMFRAM2 "1//Parameter settings

OEMFRAM3 1//Error compensation

OEMFRAM4 "1//Motion trajectory

OEMFLAM5 "2//Gear type

OEMFRAM6 2//Gear parameters

OEMFLAM7 2//Tool parameters

OEMFLAM8 "2//Process parameters

OEMFLAM9 "2//Installation parameters

OEMFRAM0 "," OEMFRAM1 ", etc. represent the name of the sub form, the number" 1 "represents the first state," 2 "represents the second state,//followed by the annotation text. OEM0 is the main interface, which appears as the first interface during program execution, and the following windows appear sequentially when the corresponding soft keys are pressed.

GearWheel.ZUS is also edited using a writing board, which records all the states and behaviors of the developed application, describing the soft key assignment tasks in the states. Due to space constraints, only one state matrix of the main interface is listed here [9].

```
999
"------------------------------------------------------------"
999 "Zustand  Htext Vtext  Childs  Return  Folgezustand  Flag  Kommentar "
999 main interface
[0]   0   0    "OEMFRAM0"   "0" 0
0    -1 -1     ""           "0" 1
1    -1 -1     ""           "1" 2
2    -1 -1     ""           "2" 3
3    -1 -1     ""           "3"  4
4    -1 -1     ""           "4"  -1
5    -1 -1     ""           "5"  -1
6    -1 -1     ""           "6"  -1
7    -1 -1     ""           "7"  -1
8    -1 -1     ""           "8"  -1
9    -1 -1     ""           "9"      -1
10   -1 -1     ""           "10" -1
11   -1 -1     ""           "11" -1
12   -1 -1     ""           "12" -1
13   -1 -1     ""           "13" -1
14   -1 -1     ""           "14" -1
15   -1 -1     ""           "15" -1
16   -1 -1     ""           "16"   0
```

The [0] in the first row of the first state matrix represents the number of states, indicating the first state. The page number is 0, and the first page is the main interface of the design; The [1] in the second matrix represents the second state, with page number 1, which is the processing display page. 0 and 0 respectively represent the starting addresses of the horizontal and vertical soft keys. "OEM0" represents the name of the main interface corresponding to the display window, "0" represents the return value, and the last 0 represents the flag, which represents the page number of each state control sub interface.

The first 0 in the second row represents the first horizontal soft key, 0~7 represents the 8 soft keys in the horizontal direction, 8~15 represents the 8 soft keys in the vertical direction, 16

represents the return key, and the number below the return value represents the state to be returned when the key is pressed. The parameters in the other lines correspond to the first line.

In the designed state matrix one, when the first button of the horizontal software is pressed on the main interface, it will switch to page [1], which is the "machine state". When the second horizontal soft key is pressed, it will switch to page [3], which is the parameter setting screen. When the third horizontal soft key is pressed, it will switch to [4], which is the motion trajectory screen. As long as these parameters in the state matrix are set, satisfactory soft key allocation and page control functions can be achieved.

3) Edit the initialization file GearWheel.ini for this project and move it to.../OEM/.

GearWheel.ini is a wizard file for OEM interface control, which controls the management of sub windows and control files. The file name is defined as a constant in the program module PRIMATE.BAS. Text can be used for editing, and its content is divided into two parts: Control and DEBUG:

[CONTROL]
MDIList=GearWheel\GearWheel.MDI
ControlFile=GearWheel\GearWheel.ZUS
[DEBUG]
i_Button=1
Stop_Button=1
Recall_Button=1

After setting up, copy the GearWheel.ini system initialization file to the OEM directory, otherwise the executable program can find the path at runtime.

4) Embed the VB multi form executable file gearwheel.exe generated in the first two steps, as well as the guk.dll and ini files generated in VC language in OEM.

Move the previously generated gearwheel.exe executable file to the.../OEM/folder, and move the guk.Dll files for multiple languages to the language folder. The RE-UK.ini initialization file in the language folder contains the soft key text. To make the display text of HSK6 (the 7th horizontal soft key) "gear grinding", open the RE-UK.ini file and make the following settings:

[HSoftkeyTexts]
[HSK6="Gear Grinding"]

3.4 Data Transfer Between NC/PLC/HMI

After embedding the designed interface, the coordinate values and feed rate of the axis should be displayed on the interface, and the corresponding parameter settings should be read into the system program to achieve monitoring and operation of the CNC machine tool. It is necessary to establish DDE links to achieve these data exchange functions, and OEM needs to provide us with DDE interfaces to access variables and files of NC, PLC, and MMC103. The communication between the NC/PLC program designed in this project is achieved through the OPC (OLE for process control) and Sinumerik COM interfaces provided by OEM software [10]. The NC-DDE service program provides three services: variable access (accessing data variables in NC, PLC, and Drives), area service (copying files between HMI and NCU), and PI instruction service (calling instructions in NCU). The NC-DDE service program is the only interface for accessing the underlying numerical control system, and any data transmitted to or received from the numerical control system must go through the NC-DDE service program. The user program calls the services in the NC-DDE service program through Dynamic Data Exchange Protocol (DDE) to achieve monitoring and operation of CNC machine tools. The NC current coordinate position of the designed grinder is dynamically obtained and displayed: the implementation method is as follows:

Automatic data update
Label1.LinkTopic = "ncdde|ncu840d"
Label1.LinkItem="/Channel/MachineAxis/actToolBasePos[u2,3]"
Label1.LinkMode = 1 'Hotlink
Writing of NC variable parameters:
Label1.LinkTopic = "ncdde|ncu840d"
Label1.LinkItem = "/Channel/Parameter/R[1]"
Label1.LinkMode = 2 'Manual
Label1.Caption = "4" ; Write value
Label1.LinkPoke
Execution of NC instructions:
Label1.LinkTopic = "ncdde|ncu840d"
Label1.LinkMode = 2
Label1.LinkExecute
"COPY_TO_NC(""C:\NC\test.mpf"",_/NC/_N_MPF_DIR/N_TEST_MPF,
Transfer files to NC

In the automatic data update, when the actual position of the third axis in the second channel changes, the system data is automatically updated, and the LinkMode must be set to 1 during automatic data update.

The writing of NC variable parameters is when

the user writes data 4 to R [1] in the first channel, Label1.LinkMode = 2, The manual and dynamic data exchange method must be LinkPoke.

The execution of the NC instruction is to transfer the TEST MPF file from MMC to NC. Label1. LinkMode=2, which means manual.

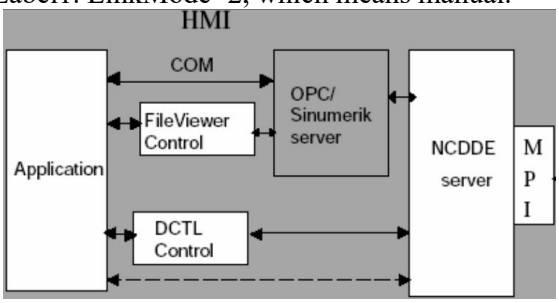

Figure 3. Communication Between HMI and 840D

4. Operation of OEM Software

At this point, the entire OEM design process has been completed. Start HMI startup, enter the HMI standard interface, click the "Gear Grinding" soft key to enter the OEM software user main interface, as shown in Figure 4. Click on the 'Parameter Settings' soft key to enter the OEM software user parameter settings screen and perform relevant parameter settings that meet processing requirements.

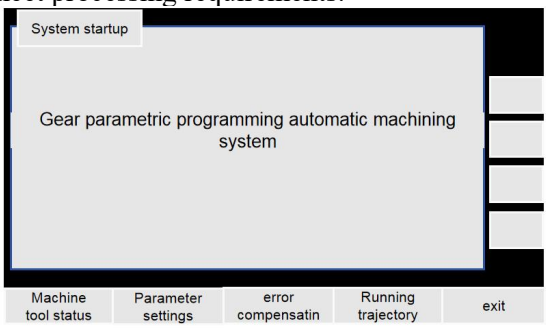

Figure 4. Main Interface

5. Summary

The demand for CNC specialized software is very high, but due to the technical complexity of the CNC system itself, the design difficulty is high and the efficiency is low. In response to the issue of user development for secondary interfaces, the research mainly studied the development method of OEM software for Siemens 840D CNC system. Taking CNC gear grinding parameterized automatic machining as the object, a dedicated control interface and a fully functional integration were proposed into the Siemens system, and the design and operation of the secondary interface were completed. The application of the designed secondary control interface greatly simplifies the programming of complex and similar parts, simplifies operations, saves processing time, improves productivity and product accuracy, and meets its own special needs.

Acknowledgements

This work was supported by Taizhou Key Laboratory of Robotics and Intelligent Equipment and 2023 Taizhou City Science and Technology Plan Project (Industrial) First Batch of Projects (23gya13).

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