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Key Technology of CADDCAM Integration for Complex Parts of Marine Diesel Engine

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Abstract. The cam system takes machining features as the basic unit, realizes the rapid reuse of NC process through feature recognition. To address the issue of backward NC programming and low efficiency of complex parts of marine diesel engine in the actual production of enterprises. The process is carried out on the basis of full investigation and analysis of CADDCAM integration status of diesel engine manufacturing enterprises. This paper integrates feature recognition technology and MBD technology, improves the internal traditional production mode, and improves the overall manufacturing technology level of marine diesel engine. The cam system for design and manufacturing integration is designed and developed. Research on Feature-based machining technology. The structure and content of reusable NC process set are designed and constructed. According to the feature definition and feature recognition, the automatic matching of reusable feature NC process is realized, and the automatic tool path planning of machining feature is realized. The simulation results show that, by using CADDCAM technology, this paper has completed the development of an integrated system for automatic machining of diesel engine structural parts, which improves the machining efficiency and accuracy of marine diesel engine structural parts.

Keywords: Marine diesel engine; machining feature; feature recognition.
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1 INTRODUCTION

With the rapid development of China's shipbuilding industry, the share of China's shipbuilding industry in the international market occupies the forefront of the world. At the same time, the potential risks and huge challenges faced by the industry cannot be ignored. The main reason is that the productivity of marine diesel engine in China cannot keep up with the market development demand, and it still needs to import to make up for the short board of productivity; the independent research and development mainly focuses on the manufacturing process, and the design and development depends on foreign license technology, so the independent research and development ability is poor [1].

A large number of NC machining knowledge has not been fully summarized and reused. The continuous updating of key parts products has accumulated a large number of NC machining knowledge resources for enterprises [2]. The reuse of these knowledge can effectively shorten the production cycle of new products. However, the current NC knowledge reuse is still in a relatively simple stage, the actual experience and knowledge accumulated in the process of product processing have not been fully explored, the degree of knowledge extraction is not enough, and it is unable to realize deep-seated and wide-ranging knowledge reuse [3].

With the rise of model-based definition (MBD) technology, MBD model, which can be used to carry semantic information such as material, dimension and tolerance, has become an ideal information carrier, providing technical support for the design and manufacturing integration of complex parts [4]. At present, MBD technology has been widely used in aircraft industry and achieved certain results, but it has not been further promoted in marine diesel engine industry. As an engineering concept containing manufacturing information, machining features reflect the geometry of parts and machining constraints [5]. At present, the application of machining features and its recognition technology is still in the primary stage, and more research objects are still simple application examples, and the achievements are limited. In the specific field of diesel engine manufacturing research and application is still to be in-depth [6].

In this paper, the marine diesel engine key parts as the research object, to solve some existing problems of diesel engine manufacturing enterprises, to meet the actual needs of CNC technologists. The research and application of this project has important practical value for improving the production efficiency and quality of marine diesel engine and promoting the further development of marine diesel engine manufacturing industry.

The rest of the manuscript is organized as the recent work in the marine diesel engine by the integration of CADCAM technology is described in Section 2. The proposed methodology includes structure design of cam is presented in Section 3. The experimental analysis of the proposed design for feature recognition is described in Section 4. Section 5 describes the conclusion drawn from the present study.

2 LITERATURE REVIEW

In CADDCAM integration, Kuang et al. proposed CADDCAM system integration scheme based on machining features. The geometric model is transformed into feature model, which is convenient for machining process planning, NC code generation and clamping analysis. The machining features are mapped to the machining methods in NX reasonably, so as to realize the automatic tool path planning of features and improve the efficiency of NC code generation [7].

Han et al. through the establishment of CADDCAM integrated system based on agent distributed network manufacturing mode, the process integration of automobile longitudinal beam plate design, programming, NC cutting and NC punching has been realized, and good practical application effect has been achieved [8]. Hengyuan et al. constructed the machining process planning mode and technology system for 3D digital manufacturing, proposed the process MBD model driven 3D digital machining process planning mode, transferred the manufacturing basis to the MBD process model, and constructed the CAD DCAM integration-oriented machining process planning architecture [9]. The automatic balancing method is advanced, scientific and effective. Starting from the actual production, through the analysis of single plane dynamic balance and double-sided dynamic balance, the life of the ring hammer can be prolonged by more than one time by using this method, the cost of replacing the ring hammer is greatly saved, and the economic benefit is very obvious. Use the Menu Script tool to generate your own menu, replace the UG menu, and also realize the editing of a UG menu and generate your own menu. The special dialog box design tool Block UI Styler owned by NX can almost meet all the interfaces required by

NX secondary development, and after the dialog box design is completed, code templates can be automatically generated to facilitate users to write programs.

As for the feature definition technology, Hong et al. proposed the feature definition for NC machining, and used the NC feature unit (NCFU) to define the geometric information and tool path control parameters of the machining object [10]. Chen et al. used hierarchical method to describe the geometric topology of features. The feature definition method proposed by Dejan, L. is easy to provide complete feature information [11]. Dejan et al. defines a feature as a set of surfaces satisfying specific manufacturing attributes, and constructs an information model of multi-attribute fusion to represent them [12]. Krimpenis et al. proposed a definition method of machining features based on holographic attribute surface edge graph and engineering semantics, and gave the structural representation of machining features [13].

This paper will integrate feature recognition technology and MBD technology, improve the traditional production mode inside the enterprise, improve the overall manufacturing technology level of marine diesel engine, design and develop a cam system for design and manufacturing integration.

3 RESEARCH METHODS

3.1 Structure Design of CAM System

CAM system is divided into user layer, function module layer, data storage layer and system support layer. User layer: the user layer is at the top of the system architecture, providing users with operation interface, including a series of operation navigation, system maintenance interface and so on. The user layer deals with the interaction between the user and the system. Through the UI interface in the user layer, users can easily call the system functions and manage and maintain the system resources.

3.1.1 Function module layer

This layer provides various utility services and application functions, including: information processing module, tool path planning module, post-processing module, simulation verification module, and system maintenance module. Data storage layer: the data storage layer is the data support of cam system operation, including Team center database and data files. Team center database realizes the underlying physical storage of predefined feature library, NC process knowledge base, process resource library, post processor library, simulation environment library and so on. The data file saves the basic configuration of the system or serves as an intermediate file for data transmission.

3.1.2 System support layer

The system support layer is located at the bottom of the system architecture, which provides the underlying functions of the system and the basic environment of the system operation, and is the bottom support of the cam system. Including basic CADDCAM platform NX, PLM data management platform Team center and operating system. The system realizes data storage and transmission through PLM.

PLM manages all kinds of data files in the form of structure tree, manages process resources in the form of Classification Library, supports version backtracking, workflow and process management, and comprehensively manages all data resources of the enterprise, as shown in Figure 1.

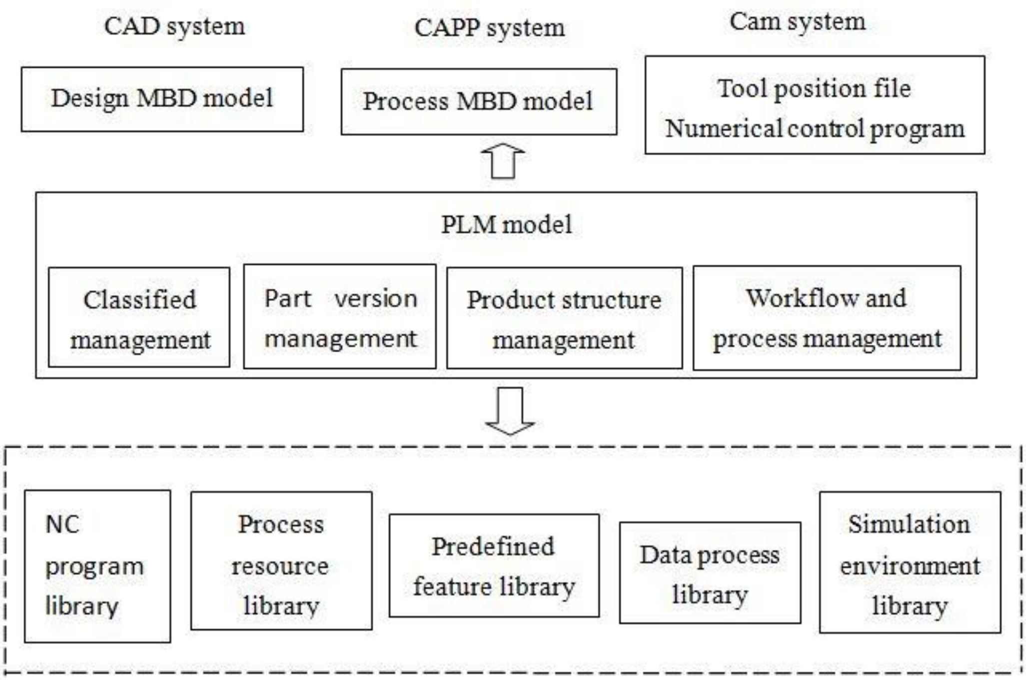

Figure 1: CAM information management.

The development process of the system is mainly divided into: customer demand analysis, system solution analysis and design, detailed design and other stages [14].

- First of all, through the communication with customers, understand the needs of customers, clear the objectives of the system, and analyze the feasibility of system development;
- After the feasibility study is passed, the system solution is initially drawn up, and the scheme is modified according to the reasonable feedback of the customer after the customer's consideration;
- After the preliminary scheme meets the requirements, the company conducts a detailed investigation to collect the original supporting data and detailed requirements of the system development, such as process preparation specifications, NC programming specifications, enterprise naming habits, parts digital simulation data, machine tool and CNC system data, etc;
- Build the overall system architecture, divide the subsystems according to the functional requirements, and design the functional modules;
- The coding realizes each function module and realizes the expected functions of the system;
- Enter the test phase, repair the operation errors, and further improve the system according to the feedback from customers;
- Finally, complete the system deployment, deliver it to customers, complete the system use training, and provide regular maintenance.

According to the functional requirements of cam system and the high cohesion requirements of modules, the system is divided into five modules: information processing, tool path planning, post-processing, simulation verification, system maintenance, covering all the functions of the integrated system as shown in Figure 2.

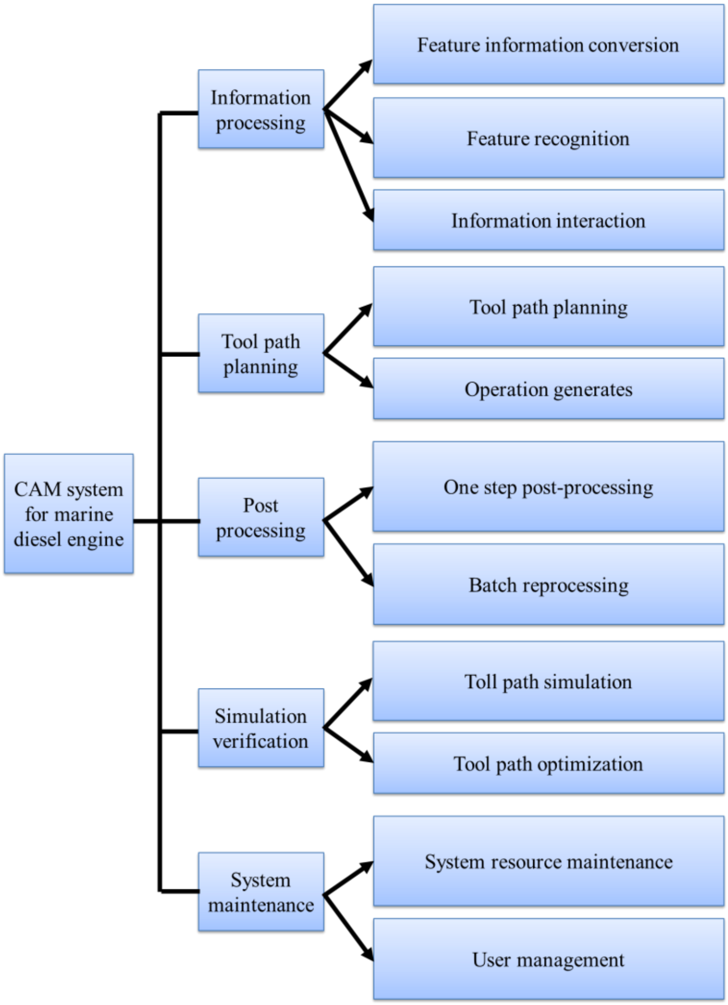

Figure 2: Module design of cam system.

One of the most important aspects of programming is that it is easier to modify the basic rules of programming. Therefore, using the idea of modularization, the program to realize complex functions is divided into several routines. Each routine implements a specific operation, and the routine that implements the same operation is only written once, and there is a calling relationship between routines.

3.2 Machining Feature Recognition of Marine Diesel Engine Key Parts

In this paper, a method of machining feature recognition based on subgraph isomorphism is proposed. The feature recognition process takes each element in the predefined machining feature library as the search target, and searches the specific machining object matching with it in the process model. The recognition process uses graph structure to express the topological relationship of features, which can deal with the complex situation of feature intersection. The pre-defined feature library can be expanded and maintained separately, and the application scope of recognition is easy to adjust. Figure 3 represents the block diagram of proposed design of marine engine analysis using CAD platform. The first stage is the reading of a file into new model which is traversed to dimensional information by utilizing the information from dimension collection pointer.

In the next stage dimension information is extracted and if the process meets the requirement of extraction then it is followed otherwise the process subjected to the file reading stage. After the extraction of dimensional features, the next edge as the end of feature extraction. The process is then continued for the next type of information extraction.

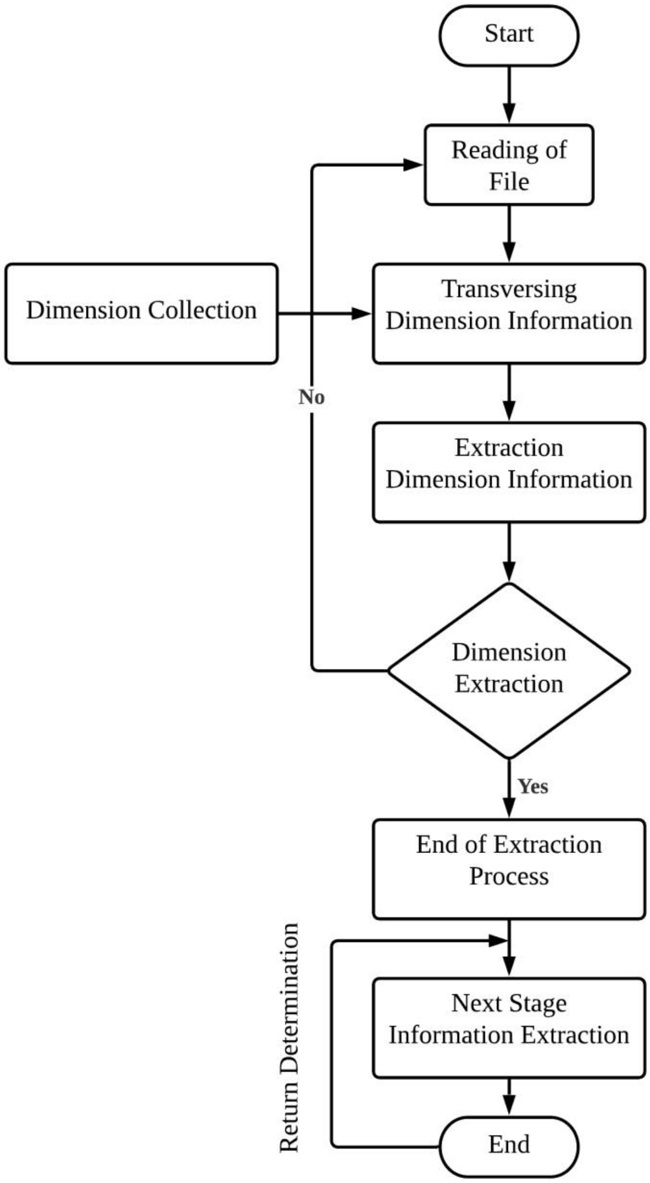

Figure 3: Block diagram of CAD based analysis.

The matching process integrates manufacturing semantic and geometric information, and the recognition result is accurate and reliable. The detailed process of feature recognition is described as follows:

Process of feature recognition
Input: Process model PAG, predefined feature atlas G
Output: Feature recognition results

Pmfag is obtained by deleting the vertex of PAG machining surface
For each FMFAG in PMFAG do
According to the feature category, find the predefined feature graph subset G '
For each FAG in G′ do
Feature information model matching fmfag and fag
If matches successfully then
Generate EFAG corresponding to fmfag
Call match (s) with EFAG as G1, FAG as G2 and S0 as input
Post processing of identification results
End if
End for each
End for each
End

The EFAG (extended feature adjacency graph) is an extended feature adjacency graph. It is generated by converting all machining face vertices except fmfag's machining face vertex into non machining face vertex in PAG based on the PAG where fmfag is located. The above match is a subgraph isomorphism method with vF2 algorithm as the core. Based on the matching results, the final similarity judgment is analyzed and obtained, and the association between the matching results and the predefined features is created according to the judgment results. The similarity between FMI and FMJ can be defined as follows:

$$SIM_{ij} = \begin{cases} 0, & \exists k \in \{T, M\}, s.t. SIM(FM_{ik}, FM_{jk}) = 0 \\ \sum_{k \in E} \omega_k SIM(FM_{ik}, FM_{jk}), & \forall k \in \{T, M\}, s.t. SIM(FM_{ik}, FM_{jk}) \neq 0 \end{cases} \tag{1}$$

where e is the set of all information elements, t and M represent the feature category and processing method respectively. Sim (fmik, fmjk) represents the similarity between FMI and FMJ in information element K.K ω is the weight of each information element in similarity comparison. From the above formula, when the key manufacturing semantic layer information is different, it can be considered that there is no similarity between the two feature information models, so the low-level information is no longer compared and the comparison process is simplified.

For the matching results which completely contain the vertices of G2 machining surface, the similarity between the two features FI and FJ of the matching results can be further calculated by the following formula:

$$SIM(F_i, F_j) = \frac{Num(G_R)}{N} \tag{2}$$

where num() function returns the number of vertices in the graph, GR is the matching result, and N is obtained from the following formula:

$$N = \max\{Num(G_2), N_{osn}\} \tag{3}$$

where nosn is all one-step neighbors of the working face vertex in GR in G1.

In other words, if the NC tool path library is not expanded, the designer will determine whether the feature library is complete or not. The post-processing of identification results is as follows:

Post-processing of identification

Input: Matching result m of single feature

Output: Relationship between features to be machined and predefined features

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For each MK in M (MK is the kth element in M)
The similarity between the two features FI and FJ of MK is further analyzed
    If SIM(Fi, Fj)>SIM(Fi-1, Fj-1) then
Create the relationship between feature FI and FJ
    End if
  End for each
End
```

After recognition, the matching results are analyzed and the phase between features is further analyzed. According to the analysis results, the relationship between the features with the greatest similarity is created. The so-called association relation is a binary formed by the key value relationship between the pending processing and the predefined feature index. Through the association relationship, the corresponding predefined features can be quickly found from the features to be processed [15].

4 EXPERIMENTAL RESULTS AND SIMULATION ANALYSIS

4.1 Examples of Feature Recognition

Taking the large end machining surface of connecting rod body as an example, the matching process of feature recognition is described. The feature to be matched is F0. The attributes of features F1 ~ F4, F0 and predefined features F1 ~ F4 in the feature library are taken as shown in Table 1 (the data in the table have been rounded).

	Feature type	*Processing method*	*Processing stage*	*Roughness (RA)*	*Tolerance class*
F0	Noodles	Milling	Crude	12.5	13
F1	Noodles	Milling	Essence	3.2	12
F2	Noodles	Milling	Semi semi seminal	6.3	13
F3	Noodles	Milling	Crude	12.5	12
F4	Hole	Drill	Crude	12.5	13
Weight	0.2	0.2	0.15	0.075	0.075

Table 1: F0 and parameters of each predefined feature attribute.

The geometric description of F0 ~ F4 is shown in Figure 4. Each feature takes 1000 pairs of points, which are equally divided into 20 equidistant intervals between 0 and the extreme value of distance (mm). The weight of each element is set as shown in the above table. Calculate the similarity of feature information model, as shown in Table 2.

According to the calculation results in Table 2, the similarity of feature F3 is greater than the threshold, and the next sub graph isomorphism process is carried out. The EFAG of F0 does not correspond to the label of non-machining vertex in fag of F3, and the same label does not necessarily refer to the same face.

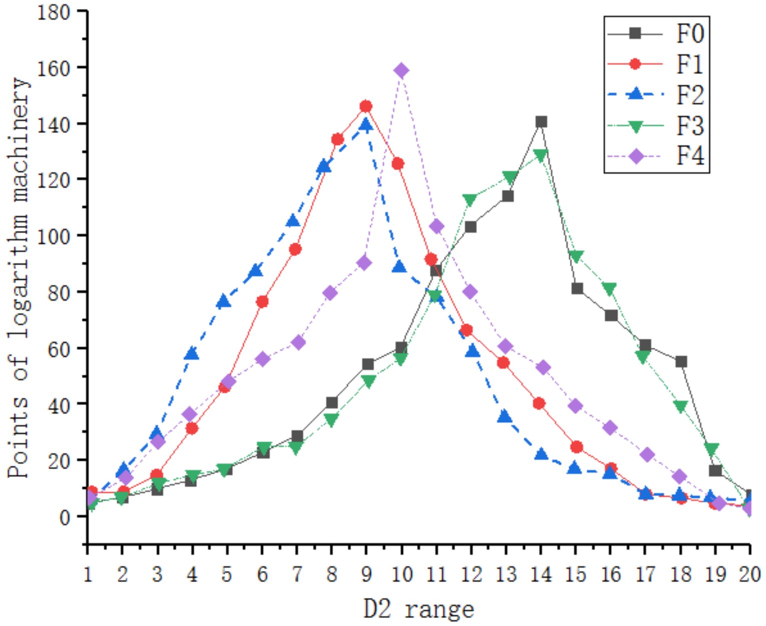

Figure 4: D2 shape distribution of features.

	F1	*F2*	*F3*	*F4*
F0	0.2	0.2	0.15	0.075

Table 2: Similarity calculation results of feature information model.

Further analysis of the similarity between F0 and F3, setting the threshold interval as (0.4, 0.8), the calculation results show that sim (F0, F3) = 0.857, which is beyond the upper limit of threshold. Therefore, there is a large similarity between F0 and F3. The feature F3 has high reuse value and can be used for processing large end F0.

4.2 Machining Simulation and Analysis

The virtual machining simulation and optimization of NC program is realized in the process of machining simulation, and the simulation verification report and optimized NC file are output. The quality of the machining process is improved due to machining errors. The integrated system relies on VERICUT simulation platform to realize the simulation and verification process of tool path. Through the virtual simulation process of VERICUT, the interference and collision between tool and machine tool, accessories and workpiece are avoided; through the comparison of models before and after cutting, the cutting quality (whether there is over cutting or missing cutting) is analyzed; through the optimization of numerical control program, the cutting efficiency is improved, the tool wear is reduced, and the service life of cutter and machine tool is prolonged.

Through the integrated interface of VERICUT and NX cam, the setting of blank, fixture, coordinate system and cutter of parts to be processed is realized in NX machining environment. The settings of machine model, control system and simulation report format in simulation environment are uniformly loaded by simulation template. The simulation template is a VERICUT engineering file, which forms a mapping relationship with the machine tool number. Before the tool path simulation, the simulation template is obtained by matching the machine tool number in the simulation template library. When starting and entering VERICUT simulation environment through nx-v interface, the simulation template is called and the corresponding settings in the template are loaded in VERICUT. The information transmission between NX and VERICUT is shown in Figure 5.

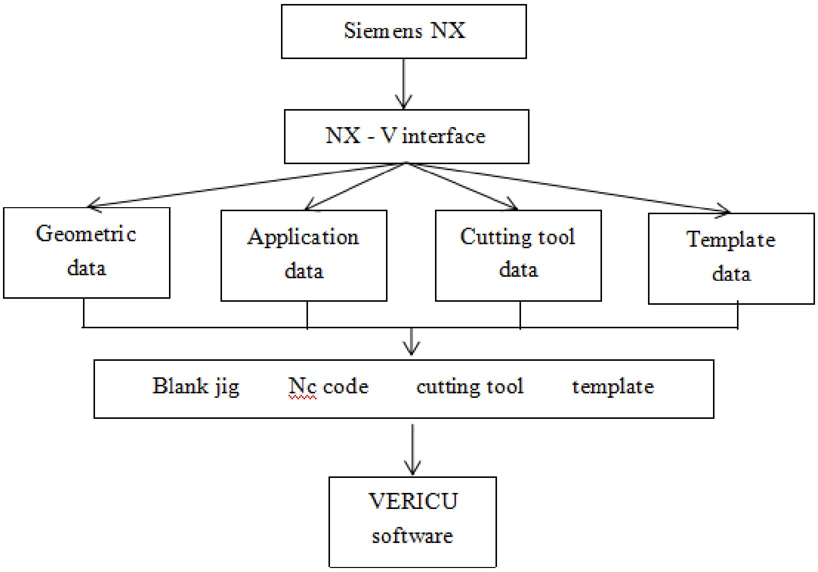

Figure 5: Information transfer between NX and VERICUT.

In order to avoid the z-axis movement exceeding the maximum stroke of the machine tool, the z-axis coordinate value is split. The limited value of z-axis is input by the compiler. The coordinate value exceeding the limit value is output by the W-axis, and the limited value mom of z-axis is transmitted by ZW splitting custom event_z_limit_Value to handle the ZW split event in post-processing.ZW splitting should be applied in both rapid move and linear move.

After the post-processing, open the nx-v interface for simulation related settings, such as machining zero point, blank, etc., the system automatically matches the simulation template. After setting the parameters, start VERICUT in the interface and output it to VERICUT for simulation.

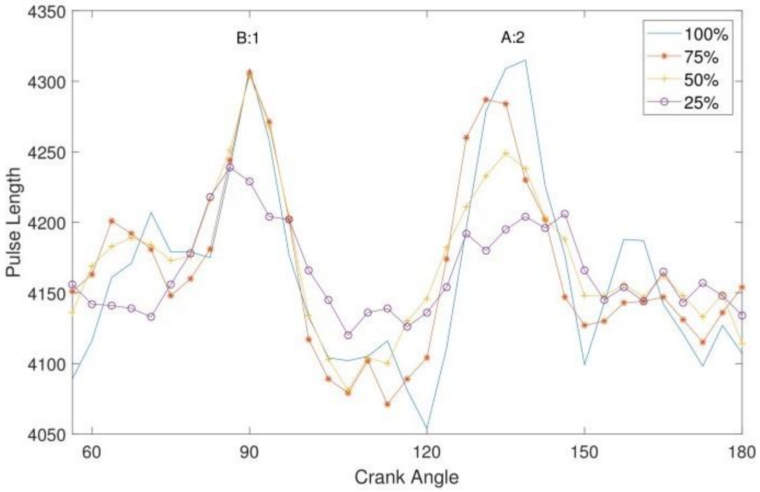

Figure 6: Combustion analysis of two cylinders through CAD signals.

Figure 6 represents different load of CAD signals that are corresponds to crankshaft. The cylinders of engine which are connected to the crankshaft ignites fuel sequentially. This figure represents the combustion stroke and the difference among the combustion stocks and the engine load can easily be observed. It is observed from the experimentation that ignition behavior of cylinder at load of 25% is not as accurate as of 100% load. It is also observed that the ignition behavior at the combustion stock time during higher loads at engine 75% and hundred percent which are observed as similar to lower loads

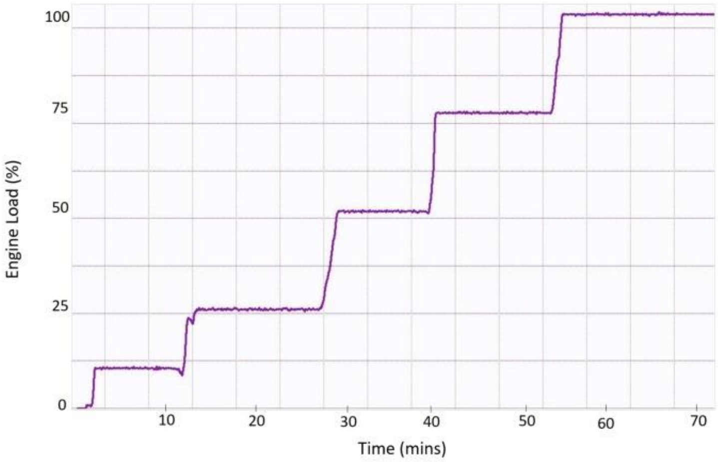

Figure 7: Performance analysis of load information in real time engine.

Figure 7 represents the load information at real-time which is measured fore operating engine where the load of engine varies from 0% to 100% in 75 minutes. It is observed that the classification of engine load helps for the optimisation of engine control parameters which further increases the engine efficiency.

After all the work is finished and saved, all kinds of files such as NC program will be returned to the corresponding process node and can be viewed in PLM platform.

Through the machining simulation experiment, we can see that using CADDCAM technology, this paper has completed the integrated system development of diesel engine structural parts automatic processing, which improves the processing efficiency and precision of marine diesel engine structural parts, and meets the practical application requirements.

5 CONCLUSION

Based on the MBD model, the only interface between the feature extraction and the information processing of the enterprise is realized based on the MBD model. The unified management of information is realized based on PLM platform. The valuable information in the process of cam operation is timely filed, and the information sharing of product design, manufacturing and other aspects is realized.

At the same time, the machining technology system of marine diesel engine key parts based on machining feature recognition is proposed, which can improve the efficiency of NC programming without losing accuracy. The cam system takes machining features as the basic unit, realizes the rapid reuse of NC process through feature recognition, and then realizes the automatic tool path planning of machining features. According to the actual requirements of the enterprise, the post processor is customized to generate NC programs that meet the enterprise specifications. Finally, the generated NC program is simulated to ensure the correctness of tool path and program, and further improve the cutting efficiency of the program. The simulation results show that sim (F0, F3) = 0.857, which is beyond the upper limit of threshold. Therefore, there is a great similarity between F0 and F3. The feature F3 has high reuse value and can be used for processing large end F0.

More than 50% of the efficiency of the NC system has been verified by the enterprise. The machining simulation experiment shows that CADDCAM system can improve the machining efficiency and accuracy of marine diesel engine structural parts, and meet the application requirements of practical enterprises.

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