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par

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THE REAL TIME PRODUCT QUALITY INTELLIGENT FORECASTING AND ANALYSIS SYSTEM

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ABSTRACT

Catalytic cracking fractional column is the most important production device for refining enterprises in China. Its main products are car gasoline and diesel fuel. The yield and quality of these two kinds of products decide directly the economic efficiency of enterprises. In order to increase the economic efficiency of enterprises, it is needed to better adjust and control the quality of cat gasoline and diesel fuel. Because fluidized catalytic cracking unit (FCCU) is in closed state, it is impossible to observe actual production process manually. But if people cannot timely master product quality condition, it is impossible to adjust effectively the technological parameters in order to control product quality. But at present, it takes four hours to obtain quality level of products if using the method of manual sampling testing. If it is as this, production process cannot, based on the analyzed results, be timely adjusted.

Therefore, developing the real-time product quality intellect forecasting and analysis system of fractional column and realizing forecasting and analysis on-line have important theoretic meaning and value in engineering application. This system can real-timely forecast product quality of fractional column, and can also real-timely analyze the factors affecting the products. So, the adjustment of technological parameters is more targeted, and shortens adjustment time, and increases efficiency. It is no doubt that the economic efficiency will increase.

The thesis, taking fractional column of fluidized catalytic cracking unit (FCCU) as research target, with the aim of forecasting product quality level of fractional column, establishes quality forecasting model through the method of neural network, and speculates the critical technological parameters that are hard to measure or impossible to measure at all through the technological parameters that are easy to measure.

The system first finishes interactive interface between control system and operator with the functions of dynamic display and real-time data acquisition through configuration software DCS(Distributed Control System), which can supervise, control, activate and manage the whole system. Then it will realize product quality forecasting of fractional column through the method of combining utility function based on average level and neural network. Finally it will realize the analysis of factors affecting product quality through the method of combining fuzzy technology and neural network.

The thesis, through system configuration and using neural network technology to forecast product quality of fractional column and analyze the factors affecting product quality, combines fuzzy technology and neural network which play their respective advantages to finish the display and control of operation state of fractionation system and realize real-time forecasting and analysis.

The online forecasting system of product quality of catalytic cracking fractional column based on the method mentioned above is developed for many small and medium petrochemical enterprises. The aim is to transform the equipments under the present condition of small and medium petrochemical enterprises with no change in the hardware of the original DCS (Distributed Control System) of refining enterprises. Therefore, this system has many advantages such as small investment, short transformation time and easy realization, etc.

Currently, this system has been tried on the fluidized catalytic cracking unit (FCCU) in Tianjin First Petrochemical Plant in China. The operating result shows that the value and laboratory value of dry point of cat gasoline and solidifying point of diesel fuel forecasted real-timely in this model have better goodness of fit, satisfying the requirements of product quality index. The test result shows that the technical path and method using neural network technology to forecast product quality put forward in the thesis is feasible.

Key words: Catalytic cracking; Fractional column; Neural network

PREFACE

In the small and medium petrochemical enterprises in our country, the main products of fluidized catalytic cracking unit (FCCU) are cat gasoline and diesel fuel. And the quality level of these two kinds of products is obtained by the method of manual sampling laboratory analysis. The disadvantage of this method is long analysis duration with four hours' lag. Therefore, it is not real-time to use results of analyzed quality to direct production of fluidized catalytic cracking unit (FCCU), which will affect economic efficiency of fluidized catalytic cracking unit (FCCU).

The thesis just begins to have a research under this background. Its purpose is to realize product quality online forecasting of fluidized catalytic cracking unit (FCCU), that is, obtaining information of product quality real-timely. Thus, it is possible to adjust operation parameter of fluidized catalytic cracking unit (FCCU), and optimize production process so that the economic efficiency of enterprise will increase.

The system developed in the thesis is for many small and medium oil refining plants. It is, under the present condition of small and medium enterprises, transforming the equipments, and applying this system widely on the basis of the original DCS(Distributed Control System). Therefore, this system has many advantages such as small investment, short transformation time and easy realization, etc. Meanwhile, it also has features of simple operation and easy installation and easy maintenance, etc.

In the whole process of the thesis design, my mentor Pro.Yang Shuying has given me enthusiastic and positive guidance and assistance. And also, Senior Engineer Ma Guohua in the First Tianjin Petroleum chemical Plant in China has given me great support and help. Here, I extend my sincere thanks to them. Meanwhile, I also give my thanks to Zhang Shenfeng for his guidance and help in the process of inspecting and adjusting the procedure. Here, I want to give my special thanks to Jinjuan for her help in the translation of the thesis. Finally, I would like to express my thanks to some of my friends and classmates for their positive and fair suggestion.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ANN	Artificial Neural Networks
APC	Advanced Process Control
API	Application Programming Interface
BP	Back-Propagation
CASE	Computer Aided Software Engineering
DCS	Distributed Control System
FCCU	Fluidized Catalytic Cracking Unit
GDI	Graphic Device Interface
I/O	Input and Output
MFC	Microsoft Foundation Class
MIMO	Multiple Input Multiple Output
NN	Neural Network
OOP	Object-Oriented Programming ,
PLC	Programmable Logic Controller

CHAPTER 1

INTRODUCTION

1.1 The Main Research Work of the Thesis

1.1.1 The Purpose of the Thesis

In the refining enterprises of our country, fluidized catalytic cracking unit (FCCU) is the most important production device which is composed of three systems.

- Reaction-reactivation System;
- Fractionation System;
- Absorption and Stability System.

Among them, fractionation system is the most important component, because the two main products of fluidized catalytic cracking unit (FCCU) are both produced in fractional system. The product quality of fractional column directly decides economic interest of fluidized catalytic cracking unit (FCCU). Therefore, optimizing operating state of fractional column and controlling over the product quality has great importance.

But each system of fluidized catalytic cracking unit (FCCU) have features of multivariate, nonlinearity and strong coupling and meanwhile technological parameters of fractional column have great relevance to other systems, so it is very hard to analyze correctly operating state of system and control effectively product quality.

In fluidized catalytic cracking unit (FCCU) of small and medium refining enterprises, fractional column is the main reactor and its main products are cat gasoline and diesel fuel. The operation state of fractional column directly decides the quality of these two kinds of products. Therefore, optimizing control of fractional column has great effect on product quality level.

At present, DCS(Distributed Control System)used in small and medium petrochemical enterprises only has functions of display and statement. It cannot optimize and control production process of fractional column and cannot forecast and analyze online product quality, either. In order to control the quality of cat gasoline and diesel fuel, the dry point of cat gasoline and the solidifying point of diesel fuel must be tested real-timely and effectively. At present, in most of small and medium petrochemical enterprises, the quality analysis of fractional column is taking samples manually. The disadvantage of this method is that the analysis duration is too long that directing production through the analyzed result is not timely, which will affect the products quality and further economic efficiency of devices.

The purpose of the thesis is to realize online forecasting of product quality in catalytic cracking fractional column which is developed for small and medium petrochemical enterprises. That is, under the present situation of small and medium petrochemical enterprises, transforming equipments with no change in the original DCS (Distributed Control System)hardware, and applying it widely on the base of the original DCS of oil refining plants. Therefore, this system has many advantages such as small investment, short transformation time and easy realization, etc. Meanwhile, it also has features of simple operation and easy installation and easy maintenance, etc.

1.1.2 . Meaning of the Thesis

According to this topic, the thesis, using neural network technology and establishing proper system model, realizes product quality forecasting. This topic is also the field supported in the process control in our country. According to the present situation of refining enterprises of our country, the attempt and discussion of applying this method to the production front line have great actual meaning.

The thesis takes catalytic cracking fractional column as research target, with the aim of forecasting quality level of products of fractional column, using technological parameters easy to measure to speculate the critical technological parameters hard or impossible to measure. This system is applied in fluidized catalytic cracking unit (FCCU) of refining plants to forecast and analyze product quality. Product quality forecasting is, using some relevant parameters that can be measured directly to forecast those parameters of product quality that cannot be measured directly. Product quality analysis is analyzing the main factors affecting product quality through this system. This system is to realize product quality online forecasting and analysis of fluidized catalytic cracking unit (FCCU).

The thesis, combining the method of neural network and other systems, develops product quality online forecasting and analysis systems of fluidized catalytic cracking unit (FCCU). This system has realized product quality online forecasting and analysis. On the one hand, this system can real-timely forecast dry point of cat gasoline and solidifying point of diesel fuel in fractional column; and on the other hand, this system can real-timely analyze the factors affecting dry point of cat gasoline and solidifying point of diesel fuel. This system can real-timely provide the information of product quality, which enables operation staff of production device to adjust timely technological parameters of fractional column. And also this system can real-timely provide factors affecting quality, which makes the adjustment of technological parameters more targeted and shorten adjustment time, increase work efficiency and further increase economic efficiency of enterprises.

1.1.3 Method of the Thesis Research

The method of neural network has ability of approaching nonlinear reflection at any precision. It provides a good modeling tool to solve the problem of nonlinear process. BP network in essence is a kind of reflection from input to output, which according to the provided data, through studying and training, means finding the inner relationship between input and output and further solving the problem. It also has ability of studying, fault-tolerance and robustness [22]. Manual intelligent technology developing in recent years has been widely applied in petrochemical enterprises. Especially applying this technology to monitor dynamically quality parameters of oil product has received good result and its confidence level of monitoring can be above 95% [22].

The thesis, taking catalytic cracking fractional column as research target with the aim of forecasting and analyzing product quality level of fractional column, establishes forecasting model of neural network. In the forecasting model of product quality, we use technological parameters easy to measure to estimate those critical technological parameters hard or impossible to measure. At present, the method of neural network which is widely studied has shown its advantages in establishing model of quality forecasting [27].

The thesis establishes reflection relationship of input and output between important parameters affecting product quality of fractional column and the products of fractional column, ie. dry point of cat gasoline and solidifying point of diesel fuel by the method of neural network. Acquiring data real-timely relevant to product quality can timely obtain parameter level of dry point of cat gasoline and solidifying point of diesel fuel.

Techniques used in the thesis:

1) Realizing quality forecasting of fractional column product through the method of combing utility function based on average level and neural network.

2) Realizing product quality analysis, ie. analyzing factors affecting product quality, through the method of combing fuzzy technology and neural network.

Meanwhile, this system combines neural network technology and configuration software and makes use of functions of dynamic display and data acquisition in configuration software DCS (Distributed Control System); it forecasts product quality of fractional column and analyzes factors affecting product quality through neural network technology, combines data acquisition and neural network technology, which finishes surveillance of operation state of the whole fractionation system. And further it can realize real-time forecasting and analysis of product quality.

1.1.4 Contribution of the Thesis

Fluidized catalytic cracking unit (FCCU) is one of the most important devices in oil refining plants. Its efficiency plays great role in oil refining plants. How to increase operating level of this device is a problem concerned greatly in the field of refining industry. Meanwhile, with the development of applying widely DCS technology into chemical process, it has been a hot topic studied recently of how to better use DCS and fully play the great potentiality of DCS system in the aspect of handling information and vigorously develop advanced computer control technology and relevant software. The thesis mainly studies, designs and develops product quality intelligent forecasting and analysis systems. There are the following aspects of the contribution of the thesis:

(1) The thesis has studied the overall structure of catalytic cracking control system, finished configuration of catalytic cracking system through configuration software, and realized real-time surveillance and control of operating system.

(2) The thesis, through combining utility function based on average level and neural network, forecasts product quality of fractional column. The experiment proves that evaluation results are consistent with results measured in actual production. This method overcomes the problems existing in other methods, such as deciding weights by some person in the method of vague comprehensive evaluation which cannot get rid of personal influence. This method has been explored and applied positively in product quality evaluation.

(3) In the intelligent analysis of product quality, fuzzy system and neural network are connected with tandem mode. The experiment proves that evaluation results are consistent with results measured in actual production. This method has been explored and applied positively in combining fuzzy technology and neural network. It realizes DCS and data interface of developed software of upper layer and combines organically DCS and developed software of upper layer.

1.2 Organizational Structure of the Thesis

The rest of this thesis is organized into the following chapters:

The third section of the first chapter is the introduction of product quality testing system of fluidized catalytic cracking unit (FCCU), including introduction of catalytic cracking production process, device composition, product quality testing content of fluidized catalytic cracking unit (FCCU), and the method of product quality testing. And at last, it introduces the present situation of product quality testing in small and medium enterprises in our country.

The second chapter introduces the structure of product quality testing system, including hardware structure and software structure; elaborates on the method and process to achieve configuration system and remote communication; introduces forecasting model of product quality of utility function based on average level and neural network. Meanwhile, it also introduces analysis model of product quality based on fuzzy technology and neural network and development platform of system. At last it briefly introduces the Visual C++ language.

The third chapter elaborates on forecasting system of product quality based average level utility function and neutral network. It introduces the basic principle and advantage of Artificial Neuron. The thesis analyzes the main factors affecting product quality, and finally determines four parameters as input parameter of product quality, that is, input quantity parameter, temperature parameter of tower top of fractional column, pressure parameter of tower top of fractional column, the temperature parameter of the 17^{th} layer of fractional column, and two parameters as output parameter of product quality of forecasting system., that is, dry point of cat gasoline and solidifying point of diesel fuel. According to the parameters above, the thesis establishes training model of neural network; according to which applying model of neural network is established. Because the dimension of the four input parameters is different, the dimensions must be normalized. In this chapter, utility function is given for normalization. And then BP network model of product quality forecasting system is designed. The algorithm of three-layer BP (Back-Propagation) network and the improvement of BP algorithm in this system have been given in the thesis. At last, the ability of product quality forecasting system is analyzed and tested through the method of selecting sample base and then training sample data by neutral network; finally the weight and threshold of three-layer BP network are determined. The result training actual data system shows that the precision of forecasting system based on neural network is high. Its average relative error is as following: the average relative error of dry point of cat gasoline is 0.05% and the average relative error of solidifying point of diesel fuel is 0.89%

The fourth chapter introduces the basal knowledge of the fuzzy logic and elaborates on analysis system of product quality based on fuzzy technology and neutral network. In actual production, the temperature and pressure often change, with which the quality of product also fluctuates. The abnormality of product quality will affect economic efficiency. Therefore, mastering quality condition and adjusting production technology timely are very important. In this chapter, first analyze the four main factors affecting product quality, that is, input quantity of fractional column, the temperature of tower top of fractional column, the pressure of tower top of fractional column, and the temperature of the 17^{th} layer. From the known condition of product quality, the thesis analyzes backward which factor of the four cause abnormality of product quality. According to the design concept above, the system analyzes factors affecting product quality through the method of combing fuzzy technology and neural network.

The thesis establishes training model of neural network according to parameters above, and according to training model applying model of neutral network is established. Fuzzy language will appear when product quality is abnormal, such as that dry point of cat gasoline is "above normal". The thesis takes subsets of fuzzification: above normal, normal, below normal. On the base of actual condition and experience of experts, the system deals with product quality with fuzzification, that is, using membership function deals with quality parameter of product and the dealt data become input parameter of neural network. The output after calculation of neural network is also fuzzy result and it needs to be dealt with defuzzification. So the thesis designs defuzzification. After that, BP network model of product quality analysis system is designed and the algorithm of three-layer BP network. At last, the ability of product quality analysis system is tested through the method of selecting sample database and then training sample data by neural network; finally the weight and threshold of three-layer BP network are determined.

The fifth chapter introduces the operation interface of the system and the result in actual application. The first Tianjin petrochemical plant has tried fluidized catalytic cracking unit(FCCU) for several weeks and the local operation result shows that data value of solidifying point of diesel fuel and dry point of cat gasoline forecasted real-timely in this system and laboratory value have goodness of fit, satisfying precision requirement of technology. At the same time, it also shows that it is feasible using neural network technology to forecast product quality of fluidized catalytic cracking unit (FCCU). This chapter also introduces some creative work and finally envisions the researched topic of the thesis.

1.3 Introduction of Testing System of Catalytic Cracking Product Quality

1.3.1 Introduction of Catalytic Cracking Process

In the whole course of refining crude oil into petroleum products, there are usually two processes. The first one is distillation process which is a physical process dividing crude oil into several distillation cuts. In process of dividing, the lighter cut fractions can directly become products and the heavier ones needed having further chemical processing before becoming oils such as gasoline, kerosene and diesel fuel and so on, because these cut fractions contain more wax oil. This chemical process is called the secondary processing of oil. Catalytic cracking process is one of main methods of realizing this chemical change. Its main task is to process heavy oil such as wax oil onto light oil such as gasoline, kerosene and diesel fuel and so on.

Catalytic cracking craft is the process that under the effect of catalyst and certain temperature crude oil cracks into light oil products after a series of chemical reactions. Fluidized catalytic cracking unit (FCCU) is composed of three systems. One is reaction-reactivation system; one is fractionation system and the third is absorption and stability system. The figure of catalytic cracking process flow is shown as Fig. 1.

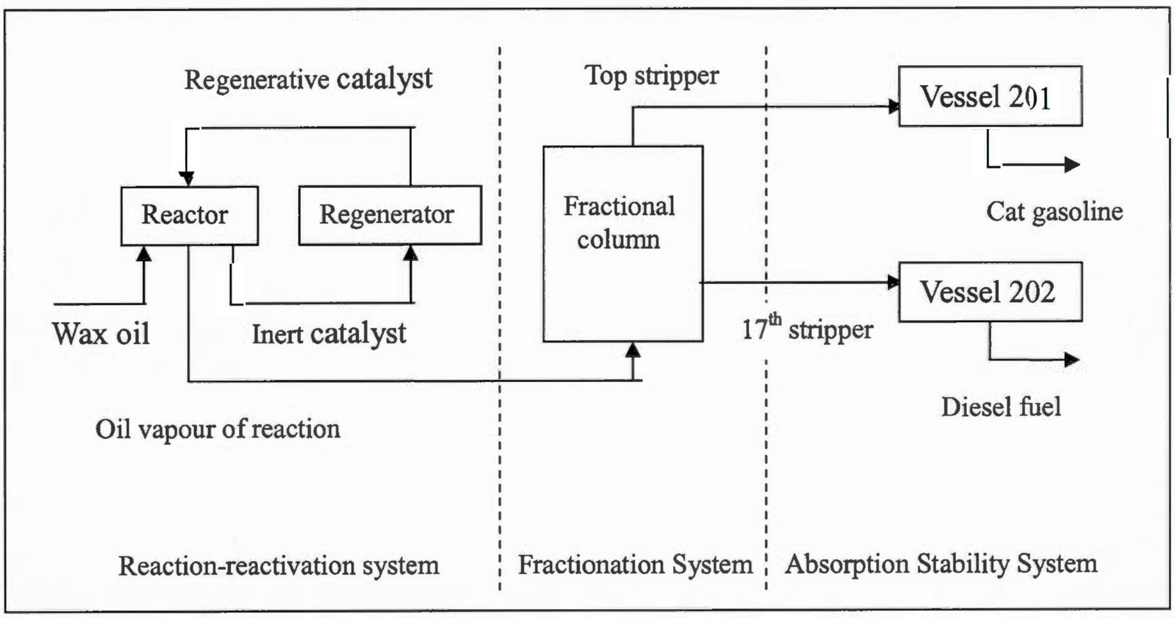


Figure 1: The catalytic cracking process flow

➢ Reaction-reactivation System

Reaction-reactivation system is the full name of reaction system and reactivation system. Cracking reaction takes place in reactor; catalyst regeneration takes place in regenerator. The raw material wax oil needs in the production of fluidized catalytic cracking unit (FCCU) is sent by pump to heating furnace where it is heated. The heated raw material contacts catalyst and chemical reaction happens in reactor. The reaction oil vapor generated after reaction is separated under the effect of separator and the separated oil vapor will be into fractional column in fractionation system.

The catalytic cracking catalyst is solid material. In the process of being used, there is a layer of oil vapor gluing on its solid surface which lowers the effectiveness of catalyst. Therefore, its reactivation must be continuously restituted. This process is called catalyst reactivation. Reactivation of catalyst is the process of running out the oil vapor on the surface of catalyst under the effect of high temperature. So the effectiveness of catalyst has been restituted and can continue to participate in chemical reaction in reactor. Cracking reaction and the effectiveness of catalyst go on recursively, which enables the production of fluidized catalytic cracking unit (FCCU) to continue working.

➢ Fractionation System and Absorption and Stability System

The oil products of reaction from reaction- reactivation system will be into fractionation system. The main reactor of fractionation system is fractional column. The raw material in fractional column enters from tower bottom and is distillated after being heated. The light oil is evaporated up from tower bottom and the oil vapor of high temperature flows down from tower top and exchange heat with the oil vapor from tower bottom. To increase the rate of heat exchange, establish many circles at different height of tower (ie. different tray decks). Because different kind of oil vapor has different distillation rang, oil vapor is refrigerated at different height. At last oil vapor flows out from side stripper of fractional column.

Fractional column has many side strippers. Oil vapor from different side strippers is different kind of oil. The oil vapor from tower top of fractional column is component product containing more cat gasoline; the oil vapor from the 17^{th} tray deck is component product containing more diesel fuel. These two parts of oil will respectively be into different towers. Cat gasoline product will be into vessel 201 of absorption and stability system and under the effect of absorbent, it will be separated in vessel 201. Diesel fuel product will be into vessel 202 of absorption and stability system. After sedimentation it will flow out from the bottom of vessel 202. So cat gasoline and diesel fuel from the oil vapor of fractionation system are absorbed. Cat gasoline and diesel fuel are the products finally needed. Fractionation system is the main research target and its process flow is shown as Fig. 2.

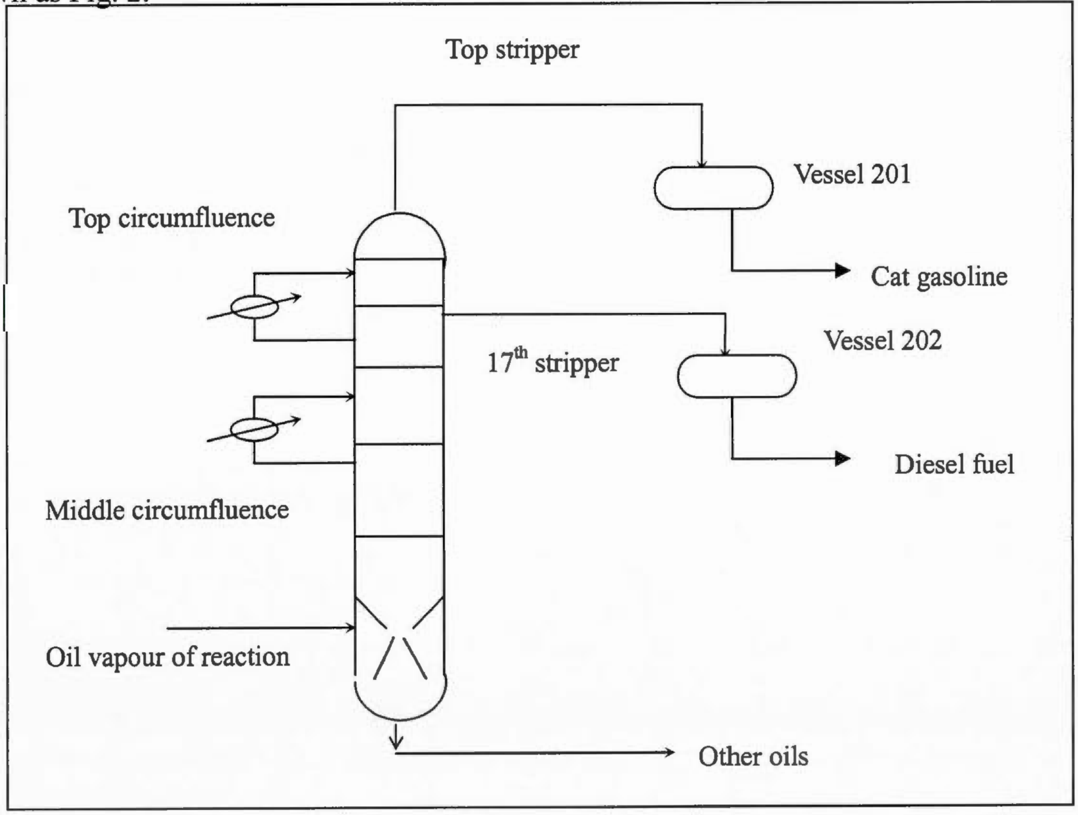


Figure 2: Fractionation system process flow

1.3.2 Testing Content of Catalytic Cracking Product Quality

In the fluidized catalytic cracking unit (FCCU), the main products are cat gasoline and diesel fuel, so the quality level of cat gasoline and diesel fuel is the main testing content of catalytic cracking product quality. At present, in the fluidized catalytic cracking unit (FCCU) in our country, the quality testing level of cat gasoline is its dry point while the quality testing level of diesel fuel is its solidifying point. Because cat gasoline and diesel fuel are mixture, their normal level should be the standard value adding or cutting three Degree Celsius (ie. normal value = standard value ±3 □[20])

1.3.3 Testing Method of Catalytic Cracking Product Quality

At present, there are two methods for fluidized catalytic cracking unit (FCCU) to test product quality [11].

One is using analyzer of online product quality to measure the quality. But the price of online analyzer is very expensive; preservation and maintenance is very complex; it has 5-20 minutes' measurement lag and the reliability of analyzed data also needs to be improved. Therefore, most of small and medium petrochemical enterprises do not adopt this method.

The second one is manual sampling chemical analysis. This method is taking samples of products every four hours, then sending the samples to laboratory to analyze product quality. But this method has disadvantage of fours' lag of quality result.

1.3.4 Present Situation of Small and Medium Enterprises

At present, in most of small and medium petrochemical enterprises, product quality analysis is taking samples manually every four hours and sending them to the laboratory to analyze and then according to the result of product quality of manual analysis, controlling the production operation of fractional column. The disadvantage of this method is that analysis duration is so long that it cannot quickly direct the production of fractional column, and the testing result will be out four hours later so that the control of the product quality is not real-time. If there is fluctuation in product quality, it can only be found four hours later. Adjusting production according the result of this testing method will cause great waste of products, which has bad effect on economic efficiency of enterprises [40].

CHAPTER 2

COMPOSITION OF QUALITY TESTING SYSTEM OF CATALYTIC CRACKING PRODUCT.

2.1 Hardware Structure of System

The figure of hardware structure of catalytic cracking control system is shown as Fig. 3.

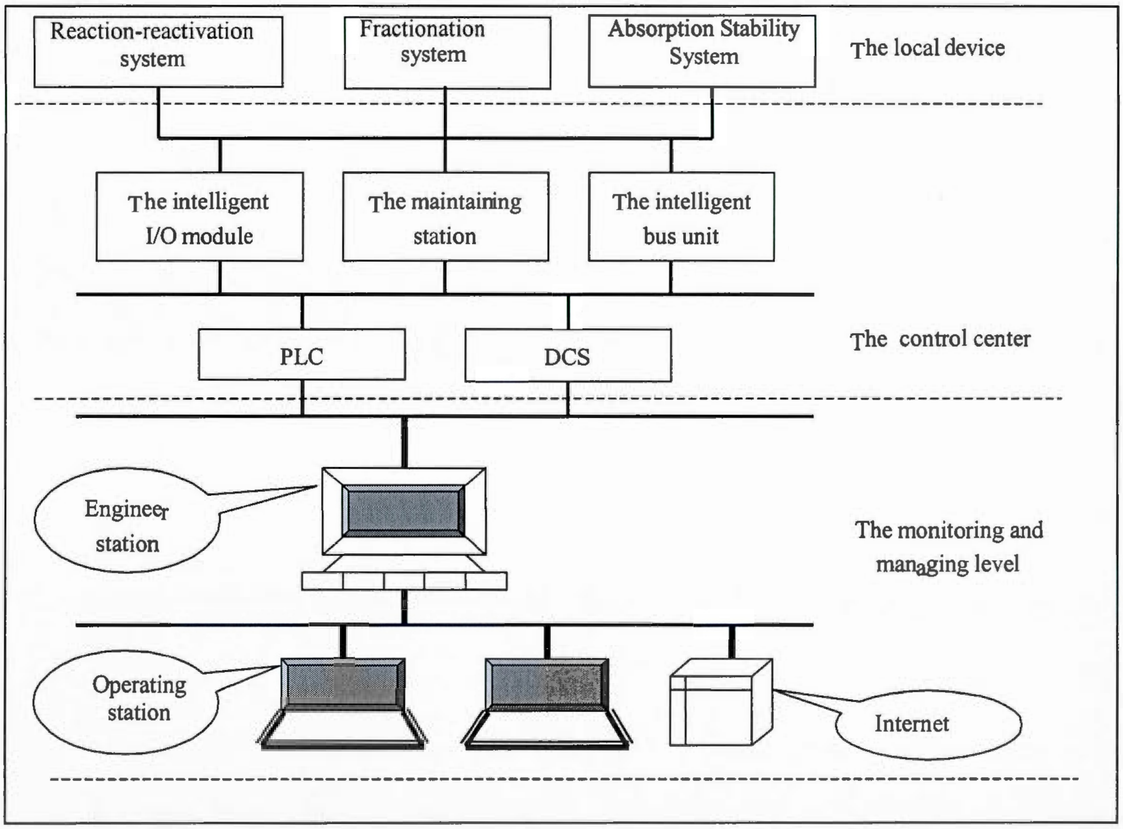


Figure 3: The hardware structure of catalytic cracking control system

The system structure is composed of three layers:The first layer is local layer. The data acquired by sensor and measurement instrument real-timely are sent to central-control room. These data and information include reflection temperature of system, flux, level and on-steam pressure, and so on. This information is the basic information to realize system control.

The second layer is direct control layer, which is composed of equipments of PLC (Programmable Logic Controller) and DCS (Distributed Control System). It can test and control all local equipments.

The third layer is monitoring and managing layer, including monitoring computer, operating station and engineer station. It supervises and controls comprehensively controlling points of the first and second layers, Sets and revises parameters, and realizes the processes of remote control and advanced control.

2.2 software structure of system

The systems of forecasting and analysis of product quality are composed of configuration system, Product quality forecasting system and Product quality analysis system. The figure of software structure of the system is shown as Fig. 4.

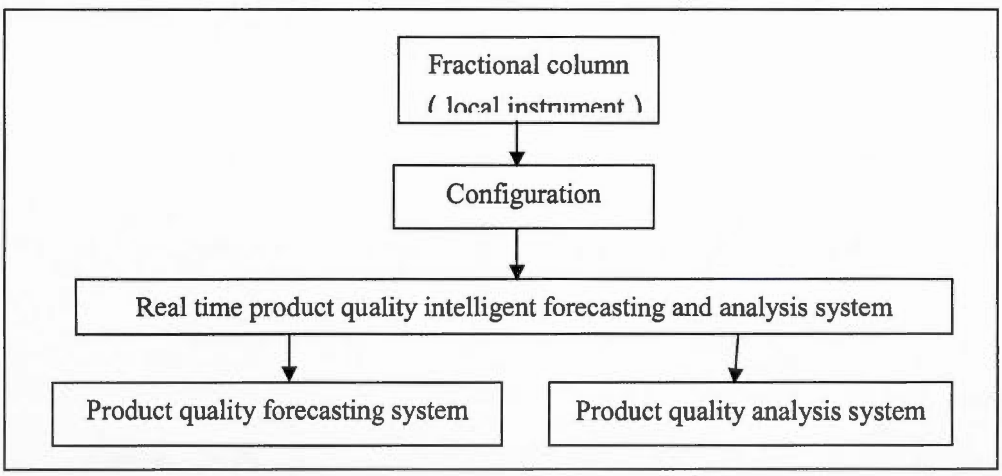


Figure 4: The software structure of the system

2.2.1 the Configuration of Process Flow of Fluidized Catalytic Cracking Unit (FCCU)

The concept of configuration is familiar to the vast technicians in the production process of automation with the appearance of Distributed Control System called DCS for short. It is the process of using tools and methods provided by application software to finish some specific task.

In the thesis, in order to obtain real-time production data of fractional column, working state of fractional column must be automatically controlled. In the system of automatic control, configuration software is centre of data collection and handling, centre of distant control, centre of data relaying. The centre of quick and responding control are made up of configuration software in operating state and all kinds of equipments of controlling and testing together

In the thesis, the technological flow of fluidized catalytic cracking unit (FCCU) is configured by DaQing Sunway® ForceControl software. Through configuration, interface between control system and operating staff has been finished. And surveillance, control and activation and management of the whole system are realized. Interactive interface between person and computer has two parts: one interface is used for everyday surveillance and setting system parameter; the other one is used for information of various statements, trending figure and helping information.

The process of system configuration in essence is to establish counterpart link between button, alarming and production trend figure, etc. on display interface of configuration and local executive equipments and instruments, which allows operating staff to control targets correspondingly to operate and supervise local executive equipments and instruments through pictures in system configuration [6].

This configuration system can conveniently and quickly construct data acquisition and control system that satisfies different requirements. Real-time data can be gained from local DCS (Distributed Control System)through I/O driving procedure provided by Sunway® Force Control software. After necessary processing data are visually displayed on computer screen in the form of figure or graphics on the one hand; and on the other hand, according to the requirements of configuration and orders of operator, control data are sent to I/O equipments to control executive agency or adjust parameter control.

According to the features of catalytic cracking production process and the requirements of product quality forecasting and analysis, fluidized catalytic cracking unit (FCCU) is divided into three systems to configure, ie. reaction-reactivation system, fractionation system, absorption and stability system. Configuration result of each system is shown in Fig. 5, 6, 7.

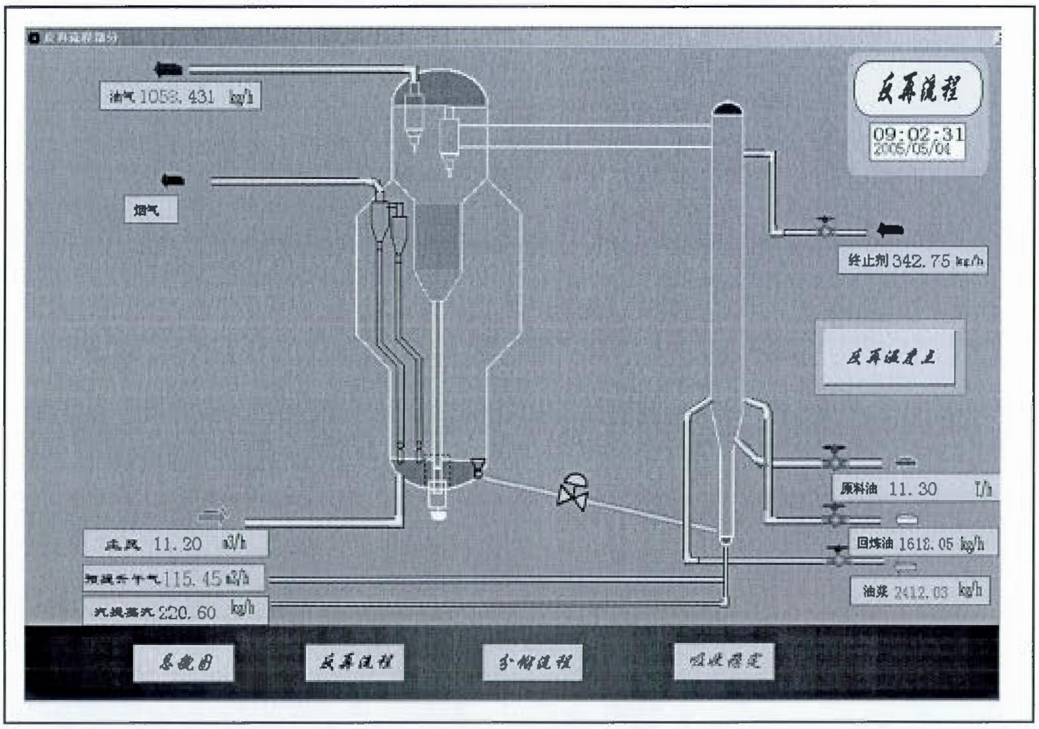


Figure 5: The Configuration of reaction-reactivation system

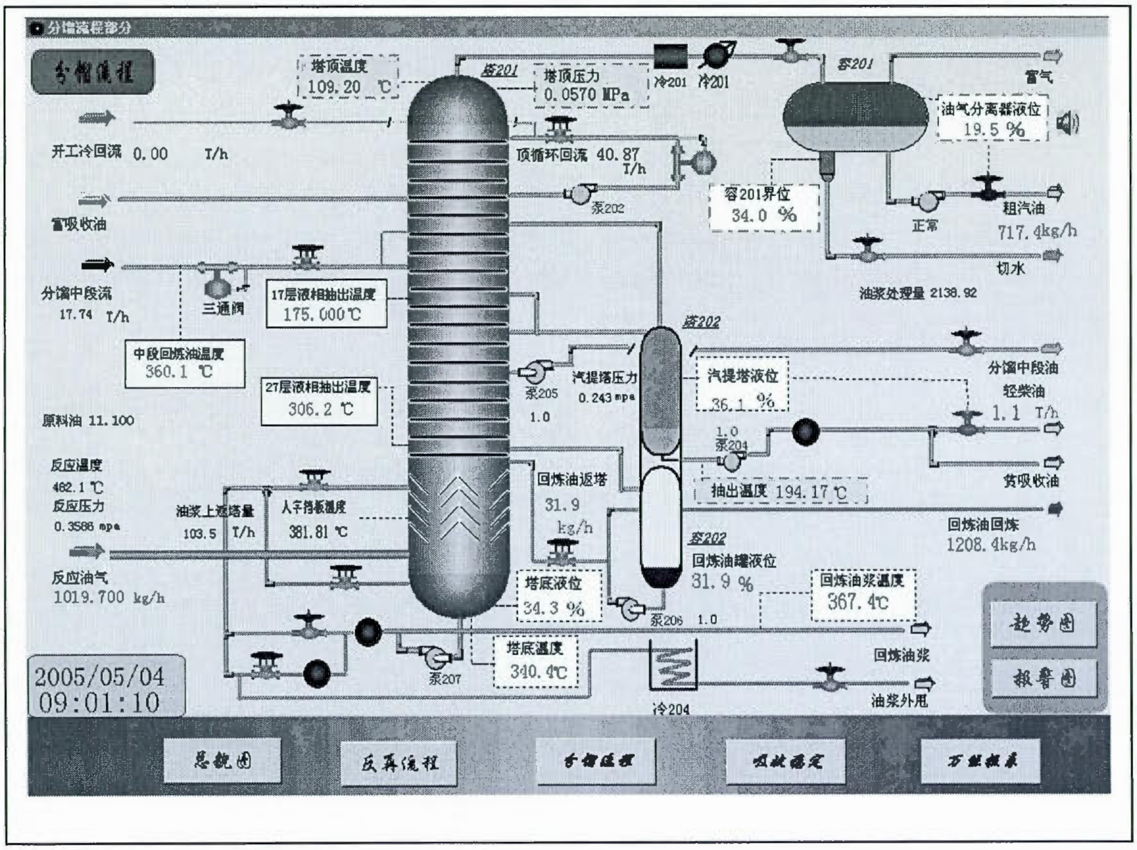


Figure 6: The Configuration of fractionation system

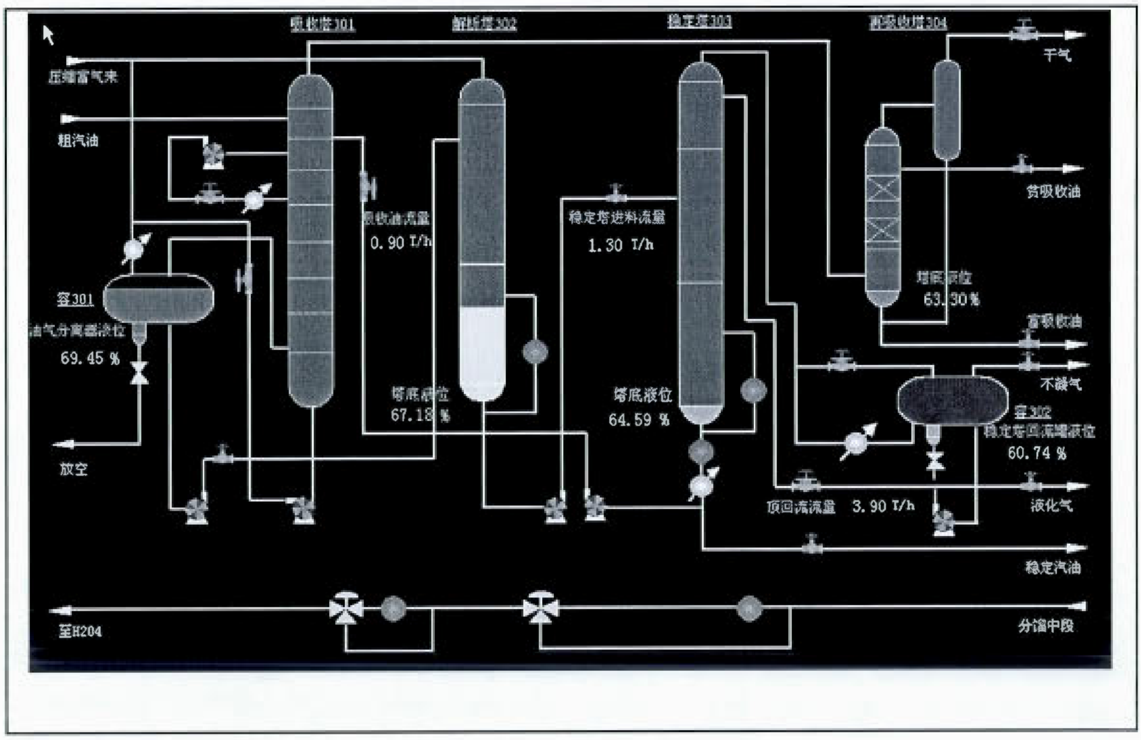


Figure 7: The Configuration of absorption and stability system

2.2.2 Design of Remote Control of System

In order to control distantly local immediate production situation, the system must have ability of long-distance communication. The Sunway® Force Control software provides function of DBCOM ActiveX. Therefore, we can realize data transmission from server to clients using Visual C++ language to transfer DBCOM ActiveX of Sunway® Force Control software.

Network remote control computers and control computers of the fluidized catalytic cracking unit(FCCU) (or DCS end), and designate server IP address of control computers on DBCOM ActiveX of remote control computers, then complete working numbers(ID) of each control point that need to be transmitted. After these procedures, remote control is realized. The figure inserting DBCOM ActiveX in Visual C++ language is shown as Fig. 8.

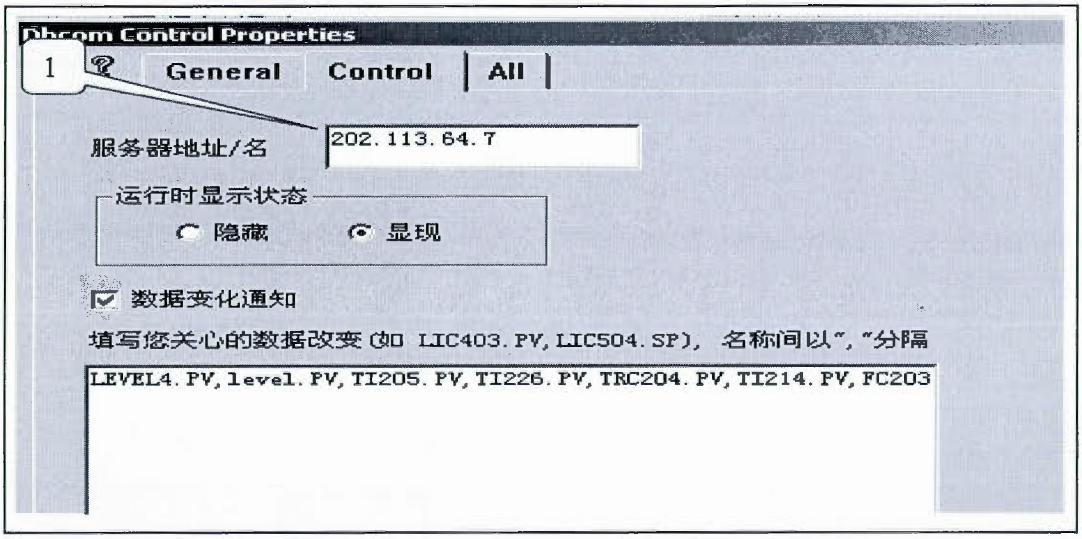


Figure 8: The inserting DBCOM ActiveX in Visual C++ language

Note :

1) The IP address of the remote server.

2.2.3 Structure of Product Quality Forecasting System

Product quality forecasting system is, according to input quantity of fractional column, the temperature of tower top of fractional column, the pressure of tower top of fractional column, the temperature of the 17^{th} layer which are collected real-timely, to forecast quality parameters of fractional column product, ie. dry point of cat gasoline and solidifying point of diesel fuel. The four input parameters of system are obtained from fluidized catalytic cracking unit (FCCU) through configuration software immediately; the two output parameters of system are the results of product quality forecasting through neural network calculating and then being put out. The structure model of product quality forecasting system is shown in Fig. 9.

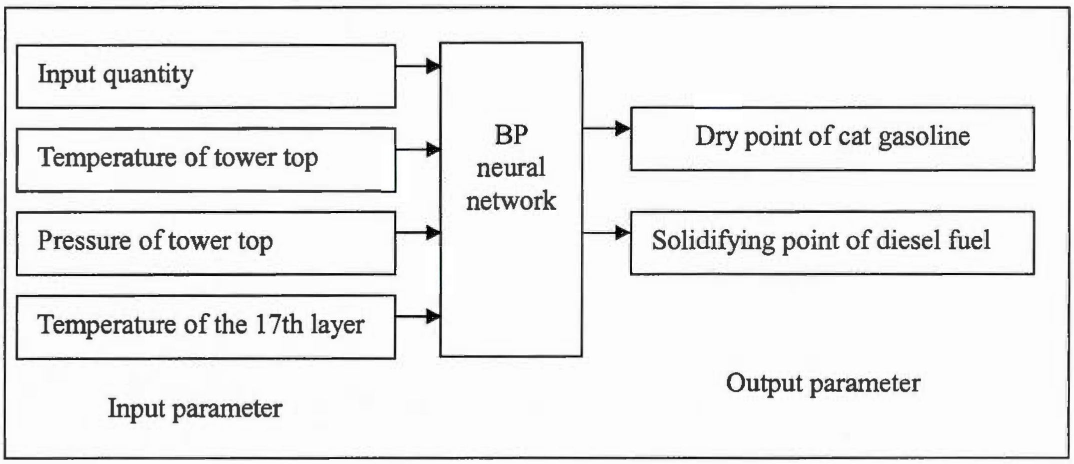


Figure 9: The structure model of product quality forecasting system

2.2.4 Structure of product quality analysis system

Product quality analysis system is analyzing the forecasting result. If the forecasting dry point of cat gasoline and solidifying point of diesel fuel are precise, still the input quantity of fractional column, the temperature of tower top of fractional column, pressure of tower top of fractional column, the temperature of the 17^{th} layer can be put out back. Then compare the difference between the output results and the original input to validate the precision of forecasting results; if forecasting results are not precise, it can be judged through analysis which one of the four affects product quality. According to these factors, adjust corresponding technological parameters to satisfy the requirements of quality level. The structure of product quality analysis system is shown as Fig. 10.

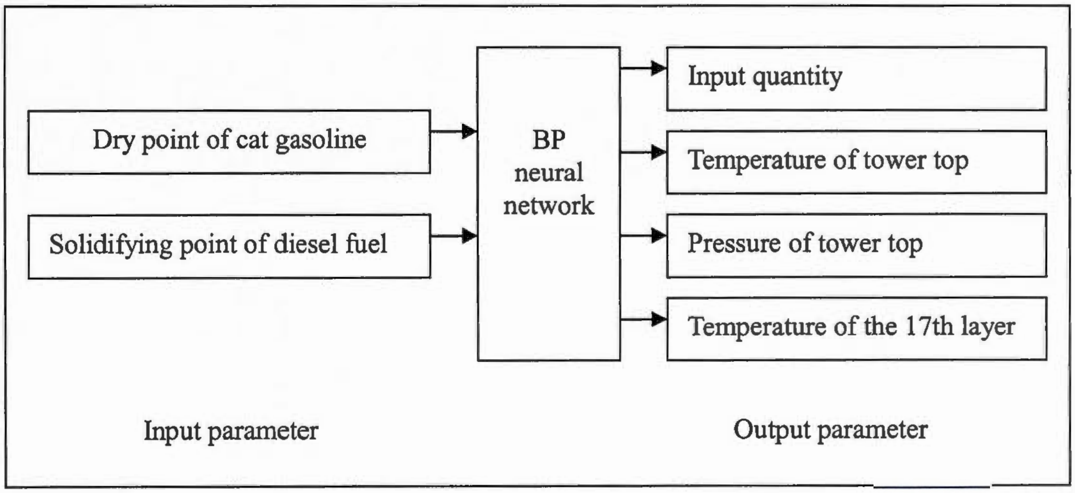


Figure 10: The structure model of product quality analysis system

2.2.5 Development platform of system

1) Realizing system configuration through Daqing Sunway® Force Control software developed in Daqing Sunway® Company. It is a kind of software operating on operation system of Windows98/NT/2000/XP.

2) Developing main procedure through VC^{++} Programming and immediate forecasting

system and analysis system of product quality in catalytic cracking fractional column. VC^{++} Language is a kind of software operating on operation system of Windows98/NT/2000/XP.

2.2.6 Introduction of Visual C++

Visual C++ is one of important products of Microsoft Company. It is the visualized develop tool with powerful functions, not only supporting the traditional software developing method, more importantly, also supporting the Object-Oriented and visualization develop style. Therefore, Visual C++ is also called integrated development environment (IDE), which provides the source editing functions of software automatic generation and visualization.

The Object-Oriented Programming of Visual C++ takes object as the module of the procedure and the object is the integration of data and behavior. Programming is the operation on a series of relevant objects, sending message to the object, and the object will execute the corresponding operation and feedback the result. What is emphasized is object. The programming has the following features [25]:

- Encapsulation: Combining data and code together, and hiding the realized details to the outside. The advantage of encapsulation is that it is good for the modularization of the programming.
- Inheritance: A new sub-object can inherit the attribute and method of a father-object. Its advantage is that it can provide the shared code.
- Polymorphism: One object type can produce multi object cases, and each case can have some difference.

Visual C++ also provides the Object-Oriented application procedure frame MFC (Microsoft Foundation Class) , which simplifies the programming work of programmers, and increases the reusability of the module; it also provides the tools of automatic generation and maintenance of visualized software based on CASE (Computer Aided Software Engineering) technology, such as AppWizard、ClassWizard、Visual Studio、WizardBar, and so on, which realizes the direct and visualized procedure design style, and conveniently compiles and manages various classes, and maintains the source code of the procedure; it encapsulates the API (Application Programming Interface) function of Windows, USER、KERNEL、GDI (Graphic Device Interface) function, which simplifies much complex work of establishing and maintaining windows in programming.

The features of VC++ language, that is high speed and high effectiveness, simple language, close to the hardware, feasible, variable, convenient to transplant makes it become the develop tool most widely applied. What is more, the DaQing Sunway® ForceControl software in the thesis provides good interface for Visual C++ language, and can realize the telecommunication through the interface procedure of Visual C++ language[21]. Therefore, the main programme in the thesis is developed by Visual C++.

2.3 Conclusion

This chapter introduces the structure of product quality testing system, including hardware structure and software structure. It also introduces the method to achieve system configuration and remote communication. Through configuration, interactive interface of control system and operating staff has been finished. And surveillance, control and activation and management of the whole system are realized; through DBCOM ActiveX of Sunway® Force Control software, the distant transmission of data has been realized and local production data of production device can be transmitted into the system. This chapter also elaborates on product quality forecasting model and product quality analysis model. At last, the development platform is introduced.

CHAPTER 3

PRODUCT QUALITY FORECASTING SYSTEM OF FRACTIONAL COLUMN

In fluidized catalytic cracking unit (FCCU), two kinds of main products are cat gasoline and diesel fuel. The quality level of cat gasoline is its dry point, the quality level of diesel fuel is its solidifying point. Therefore, product quality forecasting system is to forecast quality level of these two.

3.1 Main parameters affecting product quality

The basic components of fluidized catalytic cracking unit (FCCU) include reaction-reactivation system, fractionation system, absorption and stability system. The relationship of these three systems is complex with multivariate, nonlinearity and strong coupling and multi-disturbed distributed parameters

Product quality of fractional column is not only affected by its own production state, but also has something with reaction-reactivation system. Therefore, after studying technological principles of fractional column of fluidized catalytic cracking unit (FCCU), we find that the following four factors have great effect on level of dry point of cat gasoline and solidifying point of diesel fuel:

(1) Input quantity (charging rate) of fractional column

(2) The temperature of tower top of fractional column ;

(3) Pressure of tower top of fractional column ;

(4) The temperature of the 17^{th} layer ;

The conclusion above can also be confirmed in the 6^{th} periodical of 16^{th} column of Computer and Applied Chemistry of the thesis *Fuzzy Expert System of Quality Real-time Control of Stripper of Atmosphere Tower in Oil Refining Plants* by Tianpeng, etc. in Department of Chemical Engineering in Tinghua University[22]. Therefore, select these four parameters as input of neural network, ie. input quantity (charging rate) of fractional column, the temperature of tower top of fractional column, the pressure of tower top of fractional column, the temperature of the 17^{th} layer; and select two parameters of product quality as output, ie. dry point of cat gasoline and solidifying point of diesel fuel. Construct neural network with these four inputs and two outputs to realize product quality forecasting of fractional column.

3.2 The introduction of Artificial Neural Networks (ANN)

Artificial Neural Networks (ANN) is a kind of system using physics method to imitate the structure and function of neural cells in human brain. The international famous expert of neural networks Hecht Nielson defines the Neural Networks as " Neural Networks is a dynamic system taking the directional graph as topology structure. It handles the information through making state response to the continuous or discontinuous input."

The topology structure of the two-dimensional simple Artificial Neural Networks can be divided into two kinds: the feed forward neural networks and feed back neural networks. The thesis uses the feed forward neural networks to forecast the product quality. The model of the feed forward neural networks means that the links between each handling unit in neural networks is one-sided, and always pointing to the output direction of the networks.

3.2.1 The basic principle of Artificial Neuron

The basic unit of the Artificial Neural Networks is Artificial Neuron. The model of Artificial Neuron is the simulation and abstractness of biology neuron. The abstractness here is the description to biology neuron from the mathematic angle. The so-called simulation refers to the structure and function of neuron, equal to a non-linear threshold part of an apparatus of multi-input but single-output. It can abstract all kinds models of artificial neuron based on the biology archetype and from different angles.

In the following, A kind of classic model-- McCulloch-Pitts (M-P) model [37] will be introduced. Its structure is shown as the Fig. 11.

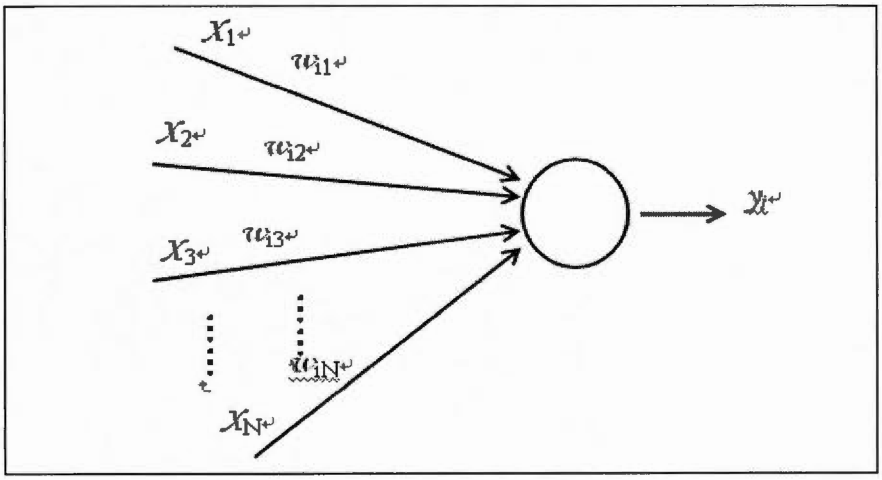


Figure 11: Mcluuoch-Pitts model

The i^{th} neuron accepts several signal x_j of other neurons. The link intensity is expressed by real factor w_{ij}, and it is the weight to the j^{th} input. All inputs are combined together through some kind of operation, called net-input, expressed by Net_i. There are many types of net-input expressions. The simple one is like using linear weight to calculate the adding : $Net=\Sigma w_{ij}x_j$. This kind of effect will cause the state change of neurons. The output y_i of neuron I is the function of its present state.

The mathematic expression of M-P model is as following:

$$y_i = \mathrm{sgn}(\sum_j w_{ij} - \theta_i)$$

Thereinto, θ_i is threshold, and $Sgn(\cdot)$ is sign function.

If considering the time lag between output and input, there is :

$$y_i\ (\ t+1\ )\ = \mathrm{sgn}(\sum_j w_{ij}(\ t\ ) - \theta_i)$$

The model of artificial neural networks is to organize the neurons introduced previously through certain structure, then it can construct artificial neuron networks. According to the difference of the topology structure of neuron links, it can be divided into the layered neural networks and the inter-link neural networks. The layered neural networks is to divide all the neurons in one neural networks model into several layers according to function, generally such as input layer, middle layer and output layer. The thesis uses the neural networks model of the layered neural networks.

3.2.2 The feature and advantage of artificial neural networks

The features and advantages of artificial neural networks are mainly shown in the following three aspects：

Firstly，it has the function of self-study. Study is a relatively long-lasting reasoning process. The study rules of neuron networks is mainly that the value of link power of networks has changed, and the studied content memory is in the link power.

Secondly, it has the function of association storing. It can realize this kind of association through the feedback networks of artificial neural networks.

Thirdly, it has the ability of finding the optimizing solution with high speed. It needs a great deal of calculation to find the optimazing solution of a complex problem. But it will find the optimizing solution very quickly if making use of a artificial neural networks designed only for certain problem and exerting the computer's ability of high-speed calculation.

Neural network is mainly applied in the fields such as data modeling, forecasting and mode identification and function optimization, and so on. The prominent advantages of this method in the aspect of product quality forecasting are mainly shown as the following: it can establish a kind of joint networks model according to the input and output data of the process, no need to know much mechanism knowledge of the process; because the structure of neural networks decides that all rationed and nature-determined information can equably distribute in each neuron of networks, it has the advantage of natural handing MIMO (Multiple Input Multiple Output) system[22]. Thus, it is an important application of neural networks in forecasting field to do soft measurement. This thesis mainly uses the method of three-layer feed forward BP neuron of networks to forecast and analyze the product quality.

3.3 Design of Product Quality Forecasting Model

The design of product quality forecasting model includes designs of training model and application model of neural network.

3.3.1 Design of Training Model of Neural Network

Before using neural network to forecast product quality, first establish model of neural network. Then use original data to train, and finally establish product quality forecasting model.

The original data include:

- Parameter of input quantity(charging rate)of fractional column
- Parameter of the temperature of tower top of fractional column
- Parameter of pressure of tower top of fractional column
- Parameter of temperature of the 17^{th} layer

Because the dimensions of these four parameters are different, it needs to use utility function to normalize their value into the same data interval, ie, the interval (-1, 1). And then put these four normalized data into neural network to train them. The training model of neural network is shown as Fig. 12.

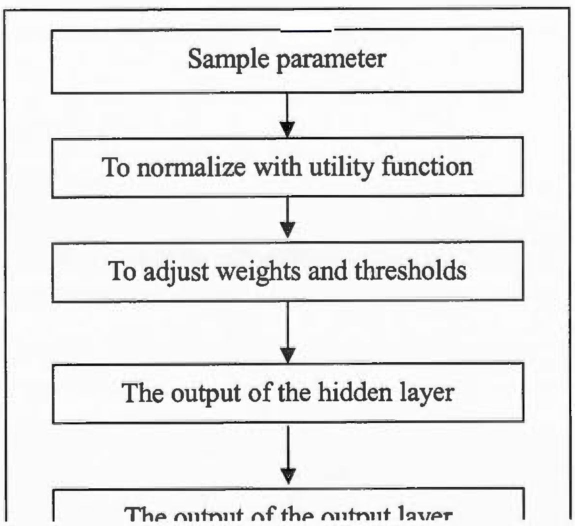


Figure 12: The training model of neural network

3.3.2 Design of Application Model of Neural Network

After establishing neutral network model of forecasting product quality, put data collected immediately in fractional column, ie. the input quantity (charging rate) of fractional column, the temperature of tower top of fractional column, the pressure of tower top of fractional column, the temperature of the 17^{th} layer, into system of neural network. After transferring neural network to calculate, put out the normalized value of product quality. Finally, convert the normalized value put out into quality parameters, ie. dry point of cat gasoline and solidifying point of diesel fuel, which are the results of system forecasting. The application model of product quality forecasting system is shown as Fig. 13.

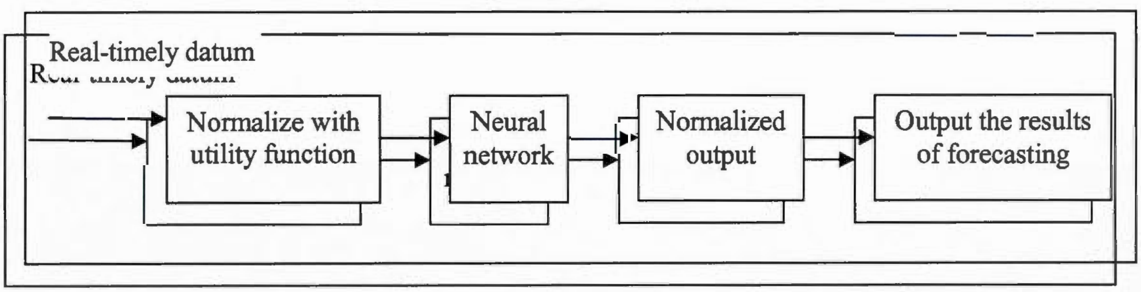


Figure 13: The application model of product quality forecasting system

3.4 Components of Utility Function

In the process of product quality forecasting, because the ranges of each parameter are different, it is hard to compare these levels. As a result, it needs to normalize these levels into an interval with the same rang according to some utility function, transmitting them into no-range value within interval of (-1 1). Therefore, it is important to construct utility function. Utility function based on average level is used in the system [33].

The construction formula is as following：

The average of the j^{th} parameter Z_j is：

$$\overline{Z_j} = (\sum_{i=1}^{m} X_i)/m, \quad j = 1,2,\cdots,n$$

Intermediate variable is：

$$M_i = \frac{X_i - \overline{Z_j}}{\left|\overline{Z_j}\right|}$$

Utility function transmitted into the interval of [-1, 1]：

$$r_i = \frac{1-e^{-M_i}}{1+e^{-M_i}}$$

Obviously, $r_i=f(M_i)$ is S-curve. Notice that M_i reflects derivation degree of original data X_i from average $\overline{Z_j}$. When X_i= $\overline{Z_j}$,then M_{ij}=0 ; when X_i >$\overline{Z_j}$,then M_i>0, and r_i increases nonlinearly with increase of M_i .

From the conversion above, we can see that, when the original value X_i is more than average, the value of utility function after conversion is above zero. The bigger the original value, the bigger the value of utility function will be; when the original value is four times of average, the value of utility function is approaching "saturation". Advantage of handling in this way is to prevent function value of some parameter level too big that it will affect the whole comprehensive level. Similarly, when original value is less than average, the value of utility function of this sublevel will not add value but conversely cut value. Therefore, its value of utility function will be below zero to show the principle of "award the good and punish the bad".

$$out = \begin{cases} below \quad normal & -1 < O_k < -0.537 \\ normal & -0.537 \le O_k \le 0.537 \\ above \quad normal & 0.537 < O_k < 1 \end{cases}$$

Here, *out* stands for evaluation result, and O_k stands for output value of the k^{th} output parameter in neutral network [33].

3.5 Design of BP Network Model

The studying process of BP (Back-Propagation) algorithm is composed of two parts:

forward propagation of signal and backward propagation of error. When signals are disseminated, model has effect on input layer, and after handling in hidden layer, signals are sent to output layer. But if output layer does not get expected output, then backward propagation of error will be coming. Return output error in some subform to input layer through hidden layer, and distribute to all units of each layer to get referent error or error signal of each unit as basis of correcting weight of each unit. The correcting process of weight matrix in each layer of dissemination of signal and reverse dissemination of error takes place in circle. The process of correcting weight continuously is the process of network studying (or training). This process will not stop until the error of network output gradually reduces to the degree that can be accepted or the set studying times

It has been proved that, three-layer BP network can realize the map from multiple unit cube R^m to R^n (multiple-level evaluation in essence is a map from R^m input to R^n output). Therefore, only suitable samples are needed, and the result making use of neural network to realize multiple-level comprehensive evaluation is convincing. This result overcomes difficulties, such as people setting weight. This is the method of intelligent comprehensive evaluation [29] [33].

3.5.1 Realization of BP Network Model

Three-layer BP network model is shown in Fig. 14.

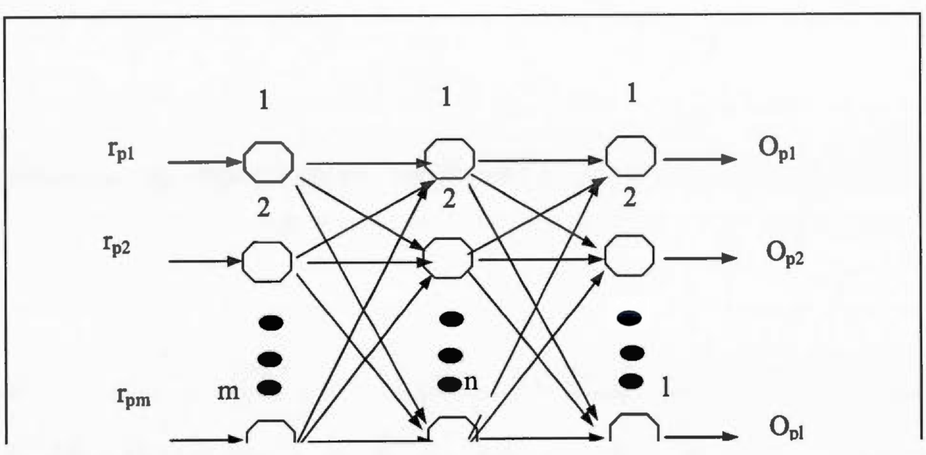


Figure 14: Three-layer BP network model

Initializing network, which means initializing weight, threshold of each node, error goal and the largest training times, is needed to establish three-layer BP network model. After being normalized by utility function, input and output of samples are taken as input and expected output of neutral network. Calculate respectively exciting output of nerve unit in hidden layer and exciting output of nerve unit in output layer and calculate error through exciting output and expected output in output layer of neutral network. Then propagate error backward and adjust weights of each layer and thresholds of each node until all samples are studied and satisfy error requirements or times below required training times.

During the process of training, selecting proper and precise parameters can speed training of neural network up and shorten training time of neutral network. As a result, satisfying training result will be obtained.

(1) Initializing value of weighting coefficients

In normal condition, weighting coefficients is usually initialized into random number within (0, 1), and should cover space domain of the whole weight matrix in order to prevent appearance of same initializing value of weighting coefficients.

(2) Learning rate

Generally speaking, the bigger the learning rate is, the quicker the convergence is, the easier it will be concussive; while if the smaller the learning rate is, the slower the convergence will be. In order to let BP network have certain kind of function and finish some task, the connected weights of each layer and thresholds of each node must be adjusted to keep the error between actual output and expected output of all samples within a smaller value.

The structure of three-layer BP network is shown in Fig. 15.

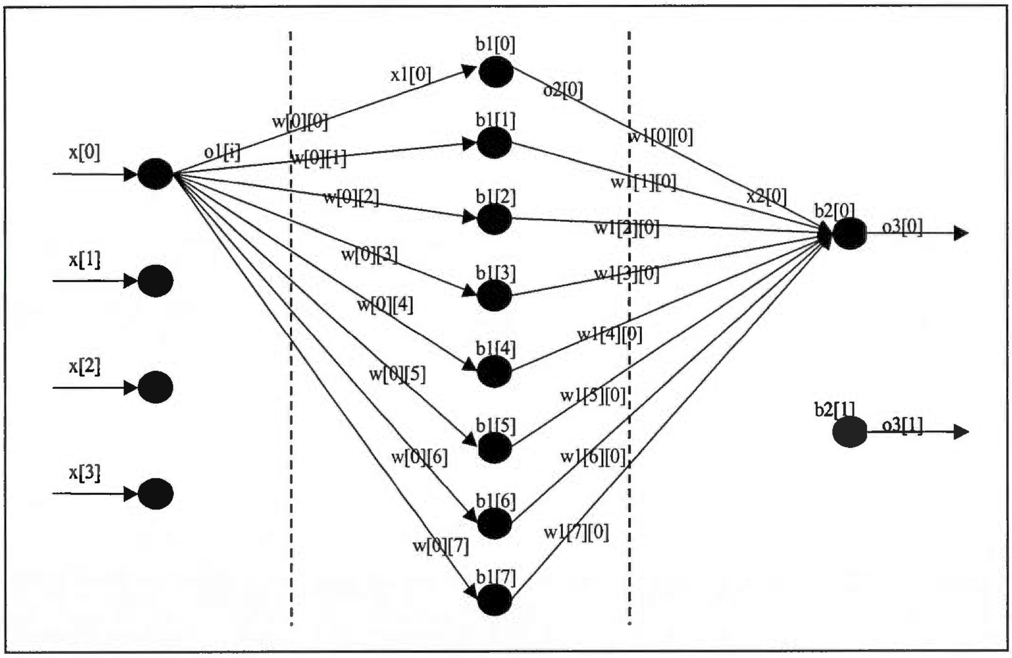


Figure 15: The structure of three-layer BP network

In the figure above, x[0] stands for input quantity of fractional column; x[1] stands for the temperature of tower top of fractional column; x[2] stands for the pressure of tower top of fractional column; x[3] stands for the temperature of the 17th layer; o3[0] stands for dry point of cat gasoline; o3[1] stands for solidifying point of diesel fuel.

Learning of three-layer BP network shown in the above figure is divided into two steps: forward propagation of output and backward propagation of improved weights.

3.5.2 Forward Propagation of Output

1) Input unit

$$O_{pi} = r_{pi}, \qquad i = 1,2,\cdots m$$

2) Unit of hidden layer

$$O_{pj} = f(net_{pj}), \quad j = 1,2,\cdots,n$$

$$net_{pj} = \sum_{i=1}^{m} \omega_{ij} O_{pi} + \theta_j, \quad j = 1,2,\cdots,n$$

3) Output unit

$$O_{pk} = f(net_{pk}), \quad k = 1,2,\cdots l$$

$$net_{pk} = \sum_{j=1}^{n} \omega_{jk} O_{pj} + \theta_k, \quad k = 1,2,\cdots l$$

3.5.3 Backward Propagation of Improved Weights

Improvement of weights from output layer to hidden layer and improvement of thresholds of neuron in output layer

$$\omega_{jk}(t+1)=\omega_{jk}(t)+\eta_t\sigma_{pk}O_{pj}$$

$$\theta_k(t+1)=\theta_k(t)+\eta_t\sigma_{pk}$$

Improvement of weights from input layer to hidden layer and improvement of thresholds of neuron in hidden layer.

$$\omega_{ij}(t+1)=\omega_{ij}(t)+\eta_t\sigma_{pj}r_i$$

$$\theta_j(t+1)=\theta_j(t)+\eta_t\sigma_{pj}$$

In the formula above, η_t stands for learning rate, and σ stands for node error. And also η_t and σ have the following relation:

$$\sigma_{pk}=(d_{pk}-O_{pk})O_{pk}(1-O_{pk})$$

$$\sigma_{pj}=O_{pj}(1-O_{pj})\sigma_{pk}\omega_{jk}$$

$$\eta_t=\eta_0\left(1-\frac{t}{T+M}\right)$$

η_0 stands for original step length and T stands for iterative frequency; M is any positive.

3.5.4 Improvement of BP Algorithm

Because BP algorithm has its own shortcomings, such as too small partial, slow convergence, and low learning rate, proper improving algorithm can greatly increase convergence feature of BP neural network. In this system, the method of impulse is used to improve BP algorithm [33].

According to the principle of impulse algorithm, we change formula of weight and threshold into the following:

$$\omega_{jk}(t+1) = \omega_{jk}(t) + \eta_t \sigma_{pk} O_{pj} + \alpha\left[\omega_{jk}(t) - \omega_{jk}(t-1)\right]$$

$$\theta_k(t+1) = \theta_k(t) + \eta_t \sigma_{pk} + \alpha\left[\theta_k(t) - \theta_k(t-1)\right]$$

$$\omega_{ij}(t+1) = \omega_{ij}(t) + \eta_t \sigma_{pj} O_{pi} + \alpha\left[\omega_{ij}(t) - \omega_{ij}(t-1)\right]$$

$$\theta_j(t+1) = \theta_j(t) + \eta_t \sigma_{pj} + \alpha\left[\theta_j(t) - \theta_j(t-1)\right]$$

$\alpha \in (0,1)$stands for momentum factor

During training process, it needs to train sample data through inputting group by group (inputting four input parameters and two corresponding outputs parameters in each group). The input sample data of each group (four input parameters) are transmitted from input layer to hidden layer and then to output layer. This process is one time of forward calculation. Immediately after, take output sample data in another group (two output parameters) as input data, and transmitted them from output layer to hidden layer then to input layer. This process is calculation of backward propagation. In the whole process (including forward and backward), input and output of each node in each layer, and relevant weights between layer and layer are continuously adjusted in order to make neutral network continuously be used to or approach data in each group and finally meet actual relevant principle. Through studying, training all samples, actual situation can be precisely reflected and stable structure of neutral network is established.

3.6 Ability analysis of product quality forecasting system

3.6.1 Establishing Sample Database

Before training neural network, it needs to select a certain number of sample parameters. Generally, small-size sample database includes less than forty sample parameters; sample database of more than forty but less than one hundred sample parameters is medium size; large sample database usually includes more than one hundred sample parameters. Usually, the more the sample are, the more widely the training data will cover, and the more precisely the actual situation of production device will be reflected, which will make the algorithm of neural network more precise and more reliable. But if there are too many data, the calculation of neural network will be large and it is more difficult for neural network to converge. After testing many times, we find that forty samples can guarantee data coverage and precision of BP algorithm. Therefore, we select forty samples to train neural network.

According to actual production data of some fluidized catalytic cracking unit (FCCU), we establish a sample database, as Tab. 1.

Table 1: Sample Database of Product Quality Forecasting System

Number	Temperature of tower top (□)	Temperature of 17th layer (□)	Input quantity (T/h)	Pressure of tower top (MPa)	Dry point of cat gasoline (□)	Solidifying point of diesel fuel (□)
1	112.8	176.0	12.7	0.068	180.9	-11.3
2	106.8	171.8	10.6	0.055	178.2	-13.2
3	108.9	176.5	11.1	0.053	179.3	-11.9
4	105.6	171.8	9.9	0.047	178.6	-13.0
5	110.2	173.5	11.9	0.061	179.7	-11.9
6	106.3	172.1	10.0	0.050	181.0	-12.9
7	111.5	176.0	12.2	0.063	178.6	-11.5
8	106.9	175.0	11.2	0.055	179.8	-12.4
9	112.1	176.1	9.9	0.061	181.2	-10.9
10	111.2	174.6	10.8	0.058	180.2	-11.6
11	105.8	172.3	11.1	0.050	179.1	-12.9
12	110.0	176.0	12.9	0.067	181.1	-10.9
13	111.4	173.8	10.9	0.059	181.2	-11.5
14	107.0	174.0	11.4	0.055	180.0	-12.2
15	110.9	176.0	11.1	0.067	182.0	-11.1
16	109.9	174.0	12.1	0.063	181.1	-12.0
17	114.0	179.0	12.6	0.069	181.9	-9.7
18	111.1	177.0	12.0	0.066	182.1	-10.9
19	104.0	174.5	10.2	0.049	179.1	-12.9

20	109.0	175.0	12	0.059	181.0	-11.2
21	112.2	177.6	11.9	0.067	182.1	-9.9
22	109.0	176.0	12.1	0.059	181.2	-11.6
23	108.0	175.0	12.0	0.060	180.2	-12.1
24	112.6	178.2	12.4	0.68	180.9	-10.6
25	108.0	172.3	11.0	0.050	178.9	-12.2
26	107.0	173.1	11.1	0.048	179.1	-12.9
27	110.2	176.5	11.9	0.064	181.4	-10.9
28	113.0	177.8	12.8	0.069	182.0	-10.1
29	109.0	175.0	11.0	0.059	179.7	-12.1
30	109.6	174.0	11.0	0.070	179.9	-12.4
31	112.5	176.3	12.3	0.068	179.3	-10.8
32	113.6	177.2	11.9	0.071	180.9	-11.9
33	110.0	175.0	12.1	0.058	179.7	-9.9
34	108.0	172.1	9.8	0.049	178.4	-13.1
35	108.0	173.5	11.8	0.057	178.9	-11.8
36	107.0	172.9	11.5	0.051	178.8	-12.9
37	108.2	171.5	12.0	0.054	179.0	-12.6
38	108.1	173.0	10.0	0.049	179.1	-12.5
39	111.2	174.0	11.0	0.063	180.1	-12.2
40	109.1	175.0	11.2	0.058	179.6	-11.9
41	111.0	175.4	11.2	0.060	179.4	-12.4
42	111.1	174.0	9.9	0.049	179.0	-13.2

3.6.2 Setting Weight and Threshold

Targeting this sample database and before training neural network, we set initialized value of weight and threshold as Tab. 2.

Table 2: Initialized Value of Weights and Thresholds

w1	1.0087 0.7202 1.0656 -0.8710 -0.8205 -0.1687 1.3893 -0.9764 0.5389 0.5822 -0.4942 -1.6356 -0.0496 1.0328 1.5207 0.3952 0.9122 0.9833 -1.1254 -0.5716 0.9529 0.8660 -0.5841 -1.1786 -0.1164 -0.8655 0.9143 -1.3949 -1.1596 -0.2271 -1.2891 0.6398
b1	-0.1293 1.0167 -0.0801 -0.1915 0.8152 0.0592 -0.7001 0.4053
w2	Columns 1 through 6 0.6762 0.3626 0.6636 0.4189 -0.3908 -0.6131 -0.9607 -0.2410 0.0056 -0.1422 -0.6207 0.3644 Columns 7 through 8 -0.3945 -0.6983 0.0833 0.3958
b2	-0.2433 0.7200

In tables above, *b1* stand for threshold of node in hidden layer, and *w1* stand for weight of node from input layer to hidden layer. *b2* stand for threshold of node in output layer, and *w2* stand for weight of node from hidden layer to output layer.

Converging after 10000 times training, improved weights and thresholds are as Tab. 3.

Table 3: Improved Weights and Thresholds

w1	0.0740 -0.5430 1.3358 -1.2258
	0.2290 0.0893 1.2254 -1.4048
	0.3046 0.9055 0.9783 1.0636
	1.1015 0.9857 0.4479 -0.8569
	-0.5184 -0.2301 -0.7441 -1.7253
	-1.2579 -0.4092 0.3967 -1.1322
	0.3284 1.2231 0.2687 0.8060
	-0.2311 0.2419 1.0579 -1.5456
b1	0.3346 1.0737 -0.0981 -0.6866
	-0.0164 1.0722 0.9160 0.3143
w2	Columns 1 through 5
	0.4754 -0.3605 0.5307 0.2438 0.5579
	-0.2426 -0.4420 0.3945 0.4380 0.4584
	Columns 6 through 8
	-0.1586 0.4053 -0.6940 0.0125 0.3455 -0.3868
b2	0.3779 0.5905

In tables above, *b1* stand for threshold of node in hidden layer, and *w1* stand for weight of node from input layer to hidden layer. *b2* stand for threshold of node in output layer, and *w2* stand for weight of node from hidden layer to output layer.

3.6.3 Operating Results and Evaluation

Through Comparing expected value and actual output value in above tables, it can be known that relative error of dry point of cat gasoline is 0.05%, and relative error of solidifying point of diesel fuel is 0.89%. The relative error is shown in Fig. 16. Evidently, this neutral network model has higher precision.

样本	粗汽油干点期望值	粗汽油干点输出值	粗汽油干点误差	轻柴油凝固点期望值	轻柴油凝固点输出值	轻柴油凝固点误差
[0.]	178.	177.9095	9.047991e-002	-13.5	-13.49012	-9.881978e-003
[1.]	178.2	177.9485	0.2514534	-13.3	-13.42285	0.1228473
[2.]	178.8	178.7752	2.476766e-002	-12.7	-12.72003	2.003327e-002
[3.]	178.8	178.8861	-8.606777e-002	-12.4	-12.5187	0.1186972
[4.]	180.	179.9576	4.235261e-002	-11.5	-11.55844	5.844053e-002
[5.]	181.	180.9975	2.548552e-003	-10.5	-10.58823	8.822896e-002
[6.]	178.4	178.3518	4.819141e-002	-13.1	-13.10569	5.69429e-003
[7.]	182.	181.8118	0.1882481	-9.5	-9.624517	0.1245172
[8.]	180.2	179.9196	0.2804342	-11.4	-11.46595	6.595397e-002
[9.]	179.2	179.1822	1.77908e-002	-12.3	-12.33341	3.341269e-002
[10.]	181.4	181.2642	0.1358328	-10.	-10.21399	0.213993
[11.]	180.4	180.332	6.804201e-002	-11.1	-11.17067	7.067337e-002
[12.]	178.5	178.412	8.799514e-002	-13.	-13.02962	2.962276e-002
[13.]	181.2	181.0691	0.130854	-10.3	-10.39604	9.604115e-002
[14.]	180.4	180.3656	3.44009e-002	-11.	-11.11958	0.1195822
[15.]	181.6	181.4382	0.1617512	-9.9	-10.00975	0.1097514
[16.]	179.2	179.2097	-9.718905e-003	-12.2	-12.28282	8.282002e-002
[17.]	180.8	180.7014	9.858352e-002	-10.7	-10.78311	8.311008e-002
[18.]	179.6	179.6146	-1.459353e-002	-11.8	-12.15691	0.3569105
[19.]	181.6	181.636	-3.600966e-002	-9.7	-9.848604	0.1486039

Figure 16: The relative error of product quality

Note:

1) The relative error of dry point of cat gasoline is 0.05%.

2) The relative error of solidifying point of diesel fuel is 0.89%.

Now, we use a group of actual data to test. The input is {107, 172, 10.5, 0.05 }; and after calculating in neutral network, the output is {178.77,-12.72}. From this, we can see dry point of cat gasoline is normal and solidifying point of diesel fuel is also normal. Testing of neutral network is shown in Fig. 17.

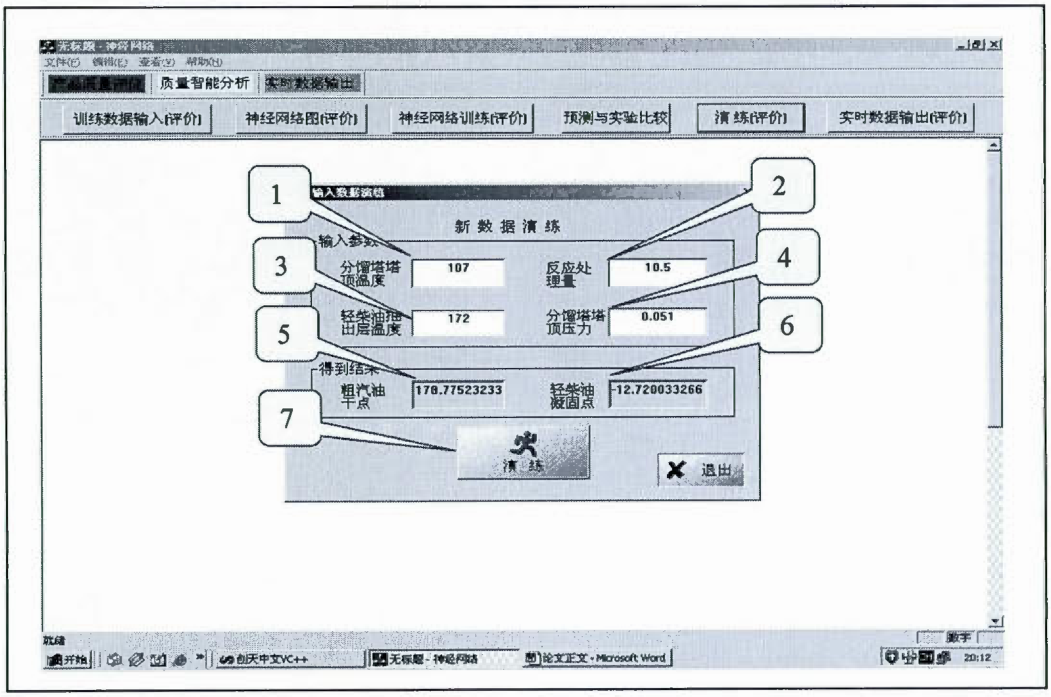


Figure 17: Testing of neutral network

Note:

1) The temperature of tower top of fractional column;
2) The input quantity;
3) The temperature of the 17^{th} layer;
4) The pressure of tower top of fractional column;
5) The dry point of cat gasoline;
6) The solidifying point of diesel fuel;
7) The [Training] button.

3.7 Conclusions

This chapter mainly studies product quality forecasting system based on level utility function and neural network. The thesis analyzes main factors affecting product quality and finally sets four parameters as input parameter of product quality forecasting system, ie. parameter of input quantity of fractional column, parameter of temperature of tower top of fractional column, parameter of pressure of tower top of fractional column, parameter of temperature of the 17^{th} layer; and the thesis also sets two important levels of product quality, ie. dry point of cat gasoline and solidifying point of diesel fuel, and takes these two parameters as output parameter of product quality. According to the above six parameters, the thesis establishes training model of neutral network. And according training model, application model of neutral network is established. Because the ranges of four input parameters are different, they are normalized. In this chapter, utility function used for parameter normalization is given. And then, the thesis elaborates on the design of BP neutral network of product quality forecasting system. The algorithm of three-layer BP network and its improved algorithm are given. Finally, performance of product quality forecasting system is analyzed and tested. Select sample database and set weight and threshold of three-layer BP network by training sample database through neural network. Drill and test this system through actual production data. And the tested result shows that the precision of product quality forecasting system based on neutral network is high and its average relative error is in the scope of being qualified. The average relative error of dry point of cat gasoline is 0.05%, and the relative error of solidifying point of diesel fuel is 0.89%.

CHAPTER 4

PRODUCT QUALITY ANALYSIS SYSTEM OF FRACTIONAL COLUMN

In fluidized catalytic cracking unit (FCCU), the main products of fractional column are cat gasoline and diesel fuel. In actual production, if the quality of these two kinds of products is fluctuated, economic efficiency of enterprises will be affected. Therefore, it is important to analyze factors affecting product quality. But because the relationships between fractional column and other systems are complex, and fractional column is in the closed environment of tower, it is hard to analyze and judge directly factors affecting product quality. Therefore, developing an intelligent and real-time product quality analysis system is needed to analyze main factors affecting product quality.

From the previous exposition, we know that there are four main factors affecting product quality, ie. input quantity(charging rate)of fractional column, the temperature of tower top of fractional column, the pressure of tower top of fractional column, the temperature of the 17th layer. This conclusion can be confirmed in the 6th periodical of 16th column of Computer and Applied Chemistry of the thesis *Fuzzy Expert System of Real-time Ccontrol of Stripper Quality of Atmosphere Tower in Oil Refining Plant* by Tianpeng, etc. in Department of Chemical Engineering in Tinghua University [22]. Therefore, product quality analysis system based on fuzzy technology and neural network technology is developed. Through this system, we can real-timely know which factor of the four affects product quality. So, we can adjust technology parameter of fractional column purposely, which can reduce time of analyzing failure and increase efficiency and economic efficiency of enterprises.

4.1 The introduction of Fuzzy Logic

4.1.1 The appearance of Fuzzy Logic

Fuzzy Logic is put forward by the professor L.A.Zadeh in America California University. In 1965, professor Zadeh fist put forward "Fuzzy Sets". Fuzzy logic is to do the rude qualification handling according to the probable information to the concepts of human subjective behaviors. In the traditional control, it must establish precise mathematic model to realize control. However, we cannot list all the variables of the whole controlling system. We can only control those factors affecting greatly the system. In order to control these factors, it must confirm the fixed controlling quantity. But actually, there are some situations that cannot confirm the value so that it is hard to establish the mathematic model. Considering the problems mentioned above, Professor Zadeh put forward fuzzy logic to try to use human's thinking way to simplify the problem, and reach the aim that is the same as the traditional control method.

4.1.2 The expression of fuzzy logic

La Zadeh thought in his "fuzzy sets theory " of improving computer procedure: the traditional computer can only identify according to the dual logic such as "yes or no", "right or wrong", "0 or 1", but it has no ability to identify the fuzzy concepts such as cold, hot, big, and small. La Zadeh invented fuzzy logic through further research. With fuzzy logic, computer can span the boundary of two poles, and plays its role in "gray" intermediate zone. And also, it can provide precise answer under the condition of limited information.

Fuzzy logic is fuzzy sets in mathematic language. The basic idea of fuzzy sets is to make the absolute membership in the classic sets feasible. Spoken in feature function language, it is that the grade of membership of element to "set" is not limited 0 or 1, but can be any figure from 0 to 1.

The basic structure of fuzzy logic system is composed of four important parts: knowledge base, decision-making unit, fuzzification interface and defuzzification interface. Knowledge base includes fuzzy rule base and database. The definition of fuzzy rule in rule base shows the experts' experience and knowledge relevant to the problem of this field. While membership function is used in the definition of fuzzy rule in database. Decision-making unit will execute the reasoning process according to these rules and the given facts, and then find the reasonable output or conclusion. fuzzification interface transfers the fixed input to the fuzzy language value of the corresponding membership function, while the defuzzification interface transfers the fuzzy calculation result to the fixed output.

The thesis uses the membership function in fuzzy rule to handle the abnormal condition of product quality. When the product quality is abnormal, it will often appear as fuzzy language, such as the dry point of cat gasoline is "above normal", and so on. Here we select the fuzzy sub-sets "above normal, normal, and below normal". Handling in this way will enable the computer to handle the problem of fuzzy concepts such as cold, hot, big, and small, and so on, like human being. The thesis also uses the function of fuzzification interface and defuzzification interface to realize the joint with neural networks.

There are two main methods to determine the membership function: one is according to the subjective cognition or personal experience giving a concrete value to the grade of the membership; and the second one is according to the character of the problem, choosing some typical function as membership function. The thesis, on the basis of combining actual production condition and experts' experience, selects the following membership function to do fuzzy handling to the index of product quality [22].

$$f(\chi)=\frac{1}{1+e^{-2.4(\chi-a)/b}}$$

4.1.3 The advantages of combining fuzzy technology and neural networks technology

It is well known that neural networks has study ability, and meanwhile has the functions of association and memory. But its knowledge expression is not intuitionistic, but hidden in many neural joining intensity. However, fuzzy technology is just on the contrary. Its study ability is not so good and the acquisition of knowledge and experience is finished with the help of human being. But its knowledge expression is precise and very natural. In fact, really applicable system often combines these two, making use of each advantage and compensating each shortcoming. No matter ANN strengthened by fuzzy logic or fuzzy logic system strengthened by ANN, both can make the system have the ability of open self-study, and self-adaptation, and also have the satisfying rule reasoning process and conclusion [22].

4.2 Design of Product Quality Analysis Model

4.2.1 Design of Training Model of Neural Network

Before using neural network to analyze product quality, first model of neural network must be established, that is, train original data and after repeated training, finally constructing product quality forecasting model. Original data include two inputs, ie. dry point of cat gasoline and solidifying point of diesel fuel, and four outputs, ie. input quantity of fractional column, the temperature of tower top of fractional column, pressure of tower top of fractional column, and the temperature of the 17^{th} layer. Model of neural network including two inputs and four outputs is composed of these six original data. The training model of neural network is shown in Fig. 18.

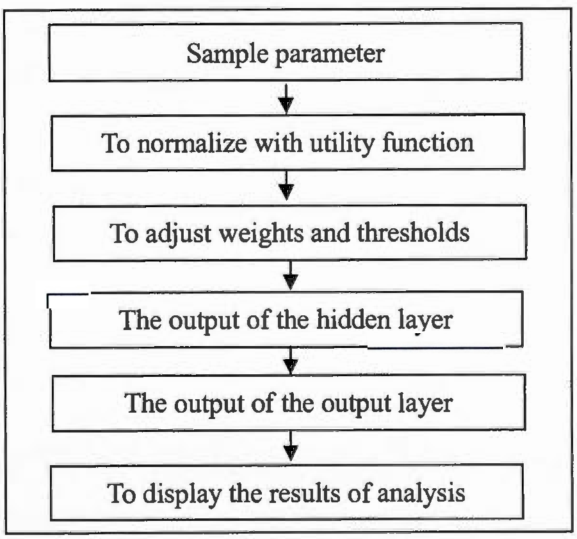


Figure 18: The training model of neural network

4.2.2 Design of Application Model of Neural Network

Application model of product quality analysis system based on fuzzy technology and neural network technology is shown in Fig. 19.

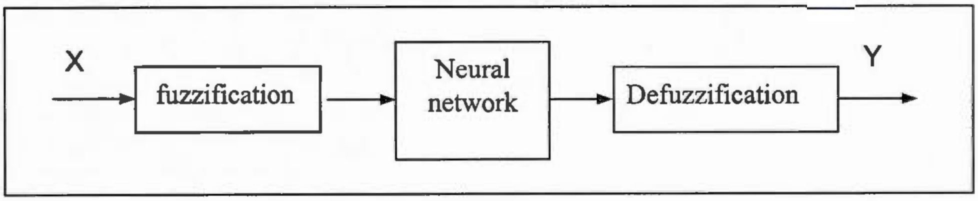


Figure 19: Application model of product quality analysis system

In the figure, X is input vector, Y is analyzed result. In intelligent analysis of product quality, the input is two nodes -- dry point of cat gasoline and solidifying point of diesel fuel; and the output is four nodes – the temperature of tower top, the temperature of diesel fuel in extractive layer, the pressure of tower top of fractional column and input quantity of reaction.

4.3 Fuzzification and Defuzzification

4.3.1 Fuzzification

When product quality is abnormal, fuzzy language will appear such as dry point of cat gasoline is "above normal", etc [27]. Here, we select subsets of fuzzification [above normal, normal, below normal]; on the basis of combining actual production situation and experience of experts, the system handles quality level of product with fuzzification, ie. handling quality parameter of product with membership function

Selecting membership function as the following :

$$f(\chi)=\frac{1}{1+e^{-2.4(\chi-a)/b}}$$

In the formula, a stands for average in normal operating interval; b stands for length of half interval in the normal operating scope; when $\chi \in [a-b,a+b]$, it is normal; when $\chi \in (a+b,\infty)$, it is above normal, or else it is below normal. In the system, two data after being handled with vagueness are taken as input data of neural network to participate in the operation of neural network.

4.3.2 Defuzzification

After the operation of neural network, the output data is result of fuzzification. Therefore, it must get four precise output value according to certain principle of anti-vagueness, ie. the value of the temperature of tower top, the temperature of diesel fuel in extractive layer, the pressure of tower top of fractional column and input quantity of reaction. We adopt the following principle of defuzzification:

$$out-1=\begin{cases} below\quad normal & 0 < out-d < 0.2315 \\ normal & 0.2315 \le out-d \le 0.7685 \\ above\quad normal & 0.7685 < out-d < 1 \end{cases}$$

Here, *out-1* stands for vague output; *out-d* stands for quantitative output.

4.4 Design of BP Neural Network Model

BP neural network model of the product quality analysis system based on fuzzy neural network is shown in Fig. 20.

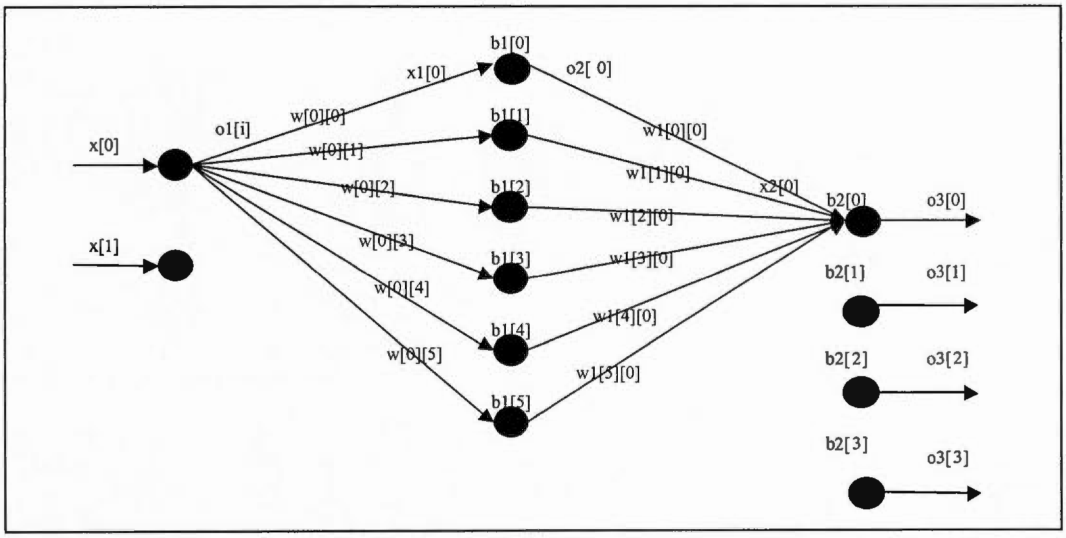


Figure 20: BP neural network model of the product quality analysis system

In the figure above, x[0] stands for dry point of cat gasoline; x[1] stands for solidifying point of diesel fuel; o3[0] stands for input quantity of fractional column; o3[1] stands for the temperature of tower top of fractional column; o3[2] stands for the pressure of tower top of fractional column; o3[3] stands for the temperature of the 17^{th} layer.

In order let BP network have certain function and finish certain task, it needs to adjust connected weights of the whole layer and thresholds of nodes in order to keep the error between actual output of all samples and expected output within the scope of a small value. First, initialize network, that is, initializing weights of neural network, thresholds of each node, error goal, the biggest training times. Take input and output of samples after being normalized by utility function as input of neutral network and expected output. Calculate respectively exciting output of nerve unit in hidden layer and exciting output of nerve unit in output layer. Calculate error through exciting output and expected output in output layer of neural network.

Then propagate error backward and adjust weights of each layer and thresholds of each node until all samples are studied and satisfy error requirements or times are below required training times.

During the process of training, input sample data group by group. Data of each group are composed of two inputs and four outputs. The input data are transmitted from input layer to hidden layer and then to output layer. This process is one time of forward calculation. Immediately after this, take output sample data in another group as input data, and transmit them from output layer to hidden layer then to input layer. This process is calculation of reverse propagation. In the whole process including forward and backward, input and output of each node in each layer, and relevant weights between layer and layer are continuously adjusted in order to make neutral network continuously be used to or approach data of group and finally meet actual relevant principle. Through studying, training all samples, actual situation can be precisely reflected and stable structure of neural network is established.

4.5 Ability of Analysis of Product Quality Analysis System

4.5.1 Establishing Sample Database

According to actual production data of some fluidized catalytic cracking unit (FCCU), we establish a sample database, as Tab. 4

Table 4: Sample Database of Product Quality Analysis System

No.	Dry point of cat gasoline (□)	Solidifying point of diesel fuel (□)	Temperature of tower top (□)	Temperature of 17^{th} layer (□)	Input quantity (T/h)	Pressure of tower top (MPa)
1	178.8	-12.6	107.6	172.0	10.7	0.053
2	178.2	-13.3	105.4	170.0	9.8	0.045
3	178.5	-13.0	106.4	171.0	10.1	0.049
4	181.0	-10.5	112.5	178.0	12.7	0.067
5	178.8	-12.7	107.0	172.0	10.5	0.051
6	180.0	-11.5	110.0	175.0	11.7	0.060
7	178.4	-13.1	106.0	171.0	10.1	0.048
8	180.2	-11.3	110.4	174.6	11.8	0.061
9	179.2	-12.3	108.0	173.0	10.9	0.054
10	182.0	-9.5	115.0	180.0	13.6	0.075
11	180.4	-11.1	111.0	176.0	12.1	0.063
12	178.0	-13.5	105.0	170.0	9.7	0.045
13	181.2	-10.3	113.0	178.0	12.9	0.069
14	179.6	-11.8	109.0	174.0	11.3	0.057
15	181.4	-10.1	113.6	178.5	13.1	0.070
16	180.4	-11.1	111.2	176.0	12.2	0.063
17	181.6	-10.0	114.0	179.0	13.3	0.072
18	179.2	-12.3	108.2	173.0	11.0	0.054
19	180.8	-10.7	112.0	177.0	12.5	0.066
20	181.6	-9.9	114.7	179.6	13.4	0.073
21	179.6	-11.9	109.3	174.5	10.9	0.054
22	181.3	-10.4	112.2	178.6	12.4	0.063
23	179.0	-12.8	107.5	171.4	10.2	0.049
24	179.0	-12.9	107.2	172.1	11.0	0.049
25	181.1	-11.6	112.1	175.1	12.1	0.060

26	181.0	-10.5	112.9	178.6	12.6	0.067
27	179.9	-10.5	112.8	178.4	13.0	0.068
28	181.8	-9.6	115.4	181.1	12.9	0.073
29	180.4	-11.0	111.3	176.4	12.4	0.062
30	181.8	-11.2	112.2	178.0	11.9	0.061
31	178.8	-13.2	107.3	172.1	11.3	0.050
32	178.3	-12.9	106.1	171.2	9.8	0.047
33	179.9	-12.0	109.9	175.2	11.6	0.055
34	181.5	-9.9	115.1	179.5	12.8	0.071
35	181.2	-11.3	110.9	177.0	12.8	0.061
36	180.9	-11.6	112.1	175.8	11.9	0.060
37	180.9	-11.6	111.1	175.4	12.1	0.059
38	179.1	-13.1	106.1	172.1	9.9	0.046
39	179.1	-11.9	107.1	172.2	10.9	0.053
40	179.0	-12.1	109.0	173.3	10.8	0.057
41	179.0	-12.1	107.3	172.6	11.0	0.052
42	179.6	-12.2	108.6	173.9	10.7	0.061

4.5.2 Setting Weights and Thresholds

Targeting this sample database and before training neural network, we set initialized value of weight and threshold shown in Tab. 5.

Table 5: Initialized Value of Weight and Threshold

w1	5.1403 -0.4971 -2.5178 -4.5090 1.6291 4.9006 -1.2690 -5.0060 4.9533 1.4612 3.4500 3.8428
b1	-0.8751 4.3302 -4.3750 2.8141 -1.7139 -2.2167
w2	Columns 1 through 5 -0.1795 0.6263 -0.6026 -0.9695 -0.0680 0.7873 -0.9803 0.2076 0.4936 -0.1627 -0.8842 -0.7222 -0.4556 -0.1098 0.6924 -0.2943 -0.5945 -0.6024 0.8636 0.0503 Column 6 -0.5947 0.3443 0.6762 -0.9607
b2	0.3626 -0.2410 0.6636 0.0056

Converging after 10000 times training, Improved weights and thresholds are as Tab. 6.

Table 6: Improved Weights and Thresholds

w1	5.0667 -0.5708 -2.1630 -4.1542 1.7312 5.0028 -0.9231 -4.6600 4.9253 1.4332 3.4189 3.8117
b1	-0.9927 4.1080 -4.3493 3.6305 -1.6491 -1.9603
w2	Columns 1 through 5 0.0821 0.5142 -0.0916 -0.8677 0.3109 0.7470 -0.7048 -0.1670 0.4007 -0.4324 -0.8025 -0.5382 -0.2765 0.0956 0.4534 0.0909 -0.7611 -0.3734 0.3097 0.4855 Column 6 -0.1964 0.0792 0.2213 -0.4040
b2	0.4712 0.2923 0.6773 0.4197

In tables above, *b1* is threshold of node in hidden layer, and *w1* is weight of node from input layer to hidden layer. *b2* is threshold of node in output layer, and *w2* is weight of node from hidden layer to output layer.

4.5.3 Operating results and Evaluation

After training, test the precision of neural network by ten groups of data in actual production. Input data are dry point of cat gasoline and solidifying point of diesel fuel and output data is reaction thruputs, the temperature of tower top, the pressure of tower top, and the temperature of the 17^{th} layer. The results after being handled in systems of product quality forecasting and analysis are shown in Tab. 7.

Table 7: Correlation of Testing Results of Product Quality Forecasting System and Analysis System.

No.	Temperature of tower top (□)	Temperature of the 17th layer (□)	Input quantity (t/h)	Pressure of tower top (MPa)	Dry point of cat gasoline (□)	Solidifying point of diesel fuel (□)
1	109.200	176.100	11.000	0.059	180.018	-11.857
2	109.076	174.316	11.244	0.057		
3	109.200	174.100	11.200	0.058	179.606	-11.916
4	108.907	173.957	11.204	0.056		
5	109.000	174.000	11.200	0.059	179.575	-11.897
6	108.954	173.979	11.227	0.056		
7	110.000	176.000	11.200	0.060	180.090	-11.683
8	109.503	174.709	11.425	0.058		
9	111.200	175.200	11.200	0.059	179.998	-11.655
10	109.568	174.713	11.461	0.058		
11	110.200	175.100	11.300	0.062	179.920	-11.588
12	109.728	174.801	11.536	0.059		
13	109.200	174.100	11.200	0.062	179.611	-11.751
14	109.311	174.295	11.381	0.058		
15	111.000	174.200	11.300	0.058	179.775	-11.723
16	109.389	174.447	11.401	0.058		
17	110.200	174.000	11.000	0.061	179.623	-11.777
18	109.249	174.250	11.353	0.057		
19	109.200	174.000	11.100	0.057	179.560	-11.996
20	108.714	173.769	11.122	0.056		

The first four value of odd row in the above table are four input of product quality forecasting system, ie. the temperature of tower top, the temperature of the 17^{th} layer, input quantity, and the pressure of tower top. The last two value are output results of product quality forecasting, ie. dry point of cat gasoline and solidifying point of diesel fuel. The even-numbered rows are four outputs of product quality analysis system, ie. the temperature of tower top, the temperature of the 17^{th} layer, input quantity, and the pressure of tower top and dry point of cat gasoline and solidifying point of diesel fuel. Its inputs are outputs of product quality forecasting system in even-numbered rows, ie. dry point of cat gasoline and solidifying point of diesel fuel. Through comparing data in odd and even rows, we can see that the system developed in this thesis has high credibility to the results of forward product quality forecasting and backward product quality analysis. The error is within the scope of provision.

The testing results show that the goodness of fit of data in the above row and the below row is good and the evaluated results are consistent with results measured in actual production. The method of combining fuzzy logical technology and neural network technology used in the thesis has got good effect on evaluation of product quality of fractionating production.

4.6 Conclusion

This chapter mainly studies product quality analysis system based on fuzzy technology and neural network. in actual production, because varieties and nature of raw materials often change, the product quality of fluidized catalytic cracking unit(FCCU) will often fluctuate, which will affect economic efficiency of enterprises. Therefore, it is important to master quality situation and adjust production processes timely. In this chapter, four factors affecting product quality are analyzed, ie. input quantity of fractional column, the temperature of tower top of fractional column, the pressure of tower top of fractional column, and the temperature of the 17^{th} layer. The main content of this chapter is to analyze factors causing quality to be abnormal. Therefore, its design concept is from product quality to analyze which factor of the four causes product quality to be unusual. Based on this concept, in the system, the method of combining fuzzy technology and neural network is used to design product quality analysis system. According to the parameters above, training model of neural network is established. And according to training model, application model is established. When product quality is abnormal, fuzzy language will appear, such as that dry point of cat gasoline is "above normal" etc. The thesis selects subset of fuzzification [above normal; normal; below normal]. On the base of actual condition and experience of experts, the system handles product quality with fuzzification, that is, using membership function to handle quality parameter of product and the handled data are taken as input parameter of neural network. The output result after calculation of neural network is also vague. The thesis handles output structure with defuzzification. This chapter elaborates on design of BP three-layer network of product quality analysis system. And then select sample database and train sample data with neural network; finally the weight and threshold of three-layer BP network are determined.

CHAPTER 5

CONCLUSION AND ENVISION

5.1 Operational Interface of System

➢ Operation of Configuration System

This system uses Sunwayland^{R} Force Control software to realize configuration of process flow. First of all, the system should activate Sunwayland^{R} Force Control software, then configuration system, and then main interface of procedures (as is shown in Fig. 21)

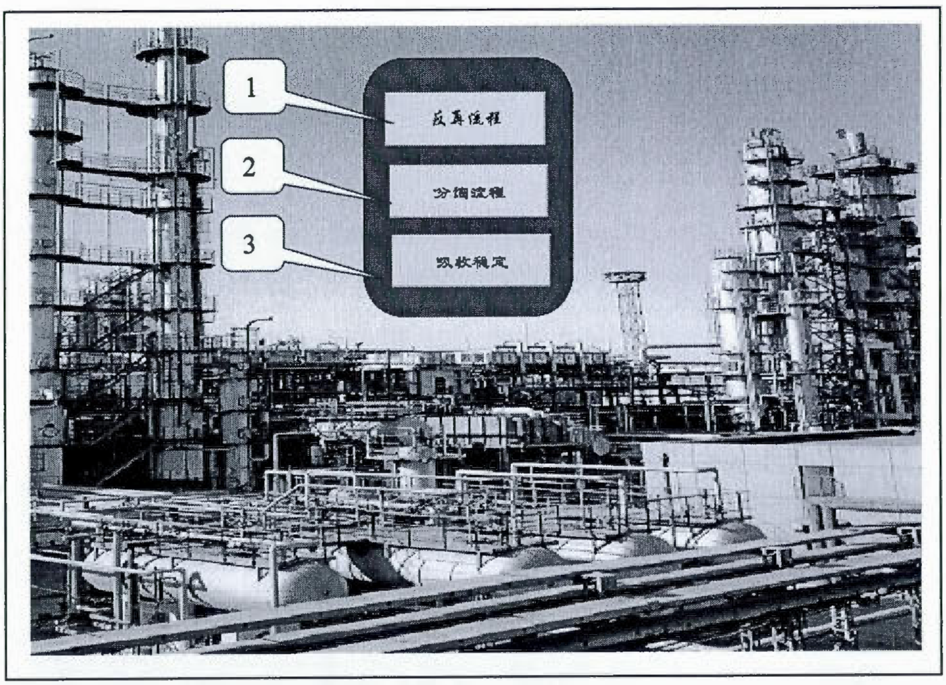


Figure 21: The main interface of the configuration system

Note: (for Figure 21)

1) The [reaction-reactivation system] button;
2) The [fractionation system] button;
3) The [absorption and stability system] button;

1. Click [reaction-reactivation flow], then the procedure will enter the figure of control flow of reaction-reactivation system (as is shown in Fig. 22). Here, the procedure can enter flow figures of other systems from the main interface

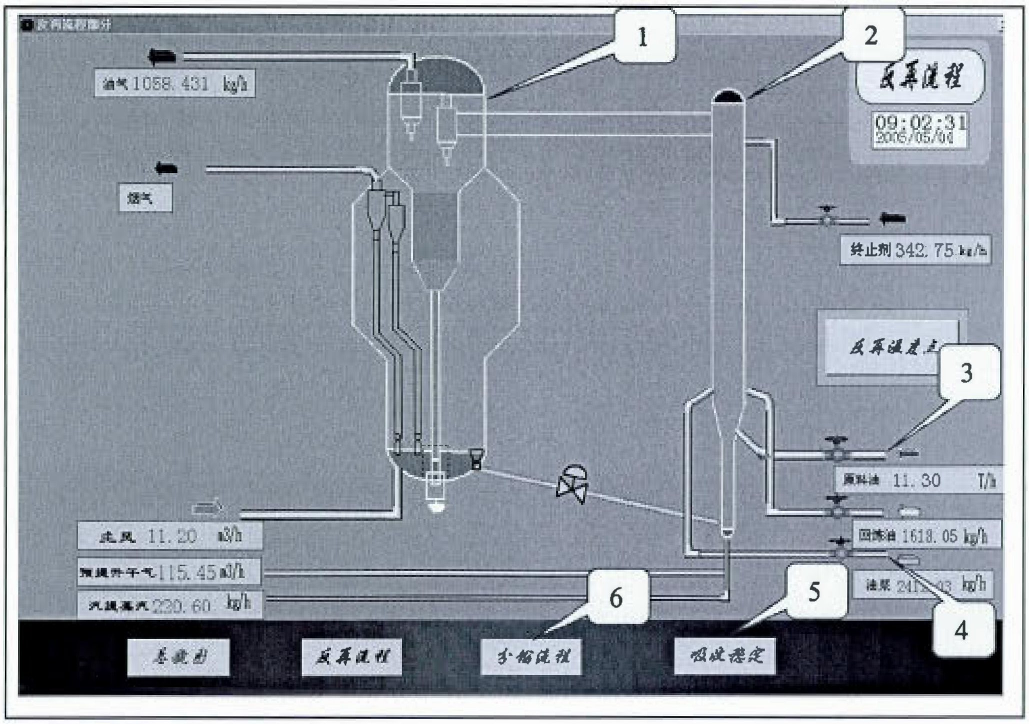


Figure 22: The configuration of the reaction-reactivation system

Note:

1) The regenerator;
2) The reactor;
3) The material wax oil (input) ;
4) The oil vapour of reaction (output) ;
5) To switch to [absorption and stability] interface;
6) To switch to [fractionation system] interface;

2. click [fractionation flow], then the procedure will enter the figure of control flow of fractionation system (as is shown in Fig. 23). Here, procedure can enter flow figures of other interfaces.

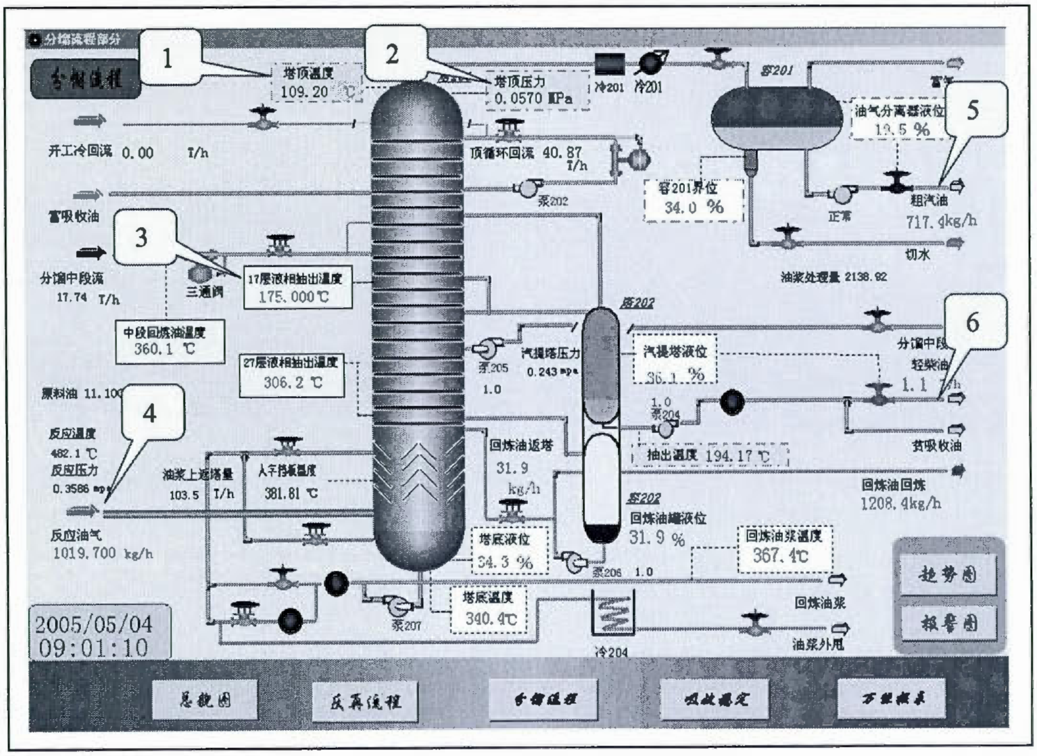


Figure 23: The configuration of the fractionation system

Note:

1) The temperature of tower top of fractional column;
2) The pressure of tower top of fractional column;
3) The temperature of the 17^{th} layer;
4) The input quantity;
5) The product of cat gasoline;
6) The product of diesel fuel;

3. Click [absorption and stability flow], then the procedure will enter the figure of control flow of absorption and stability system(as is shown in Fig. 24).

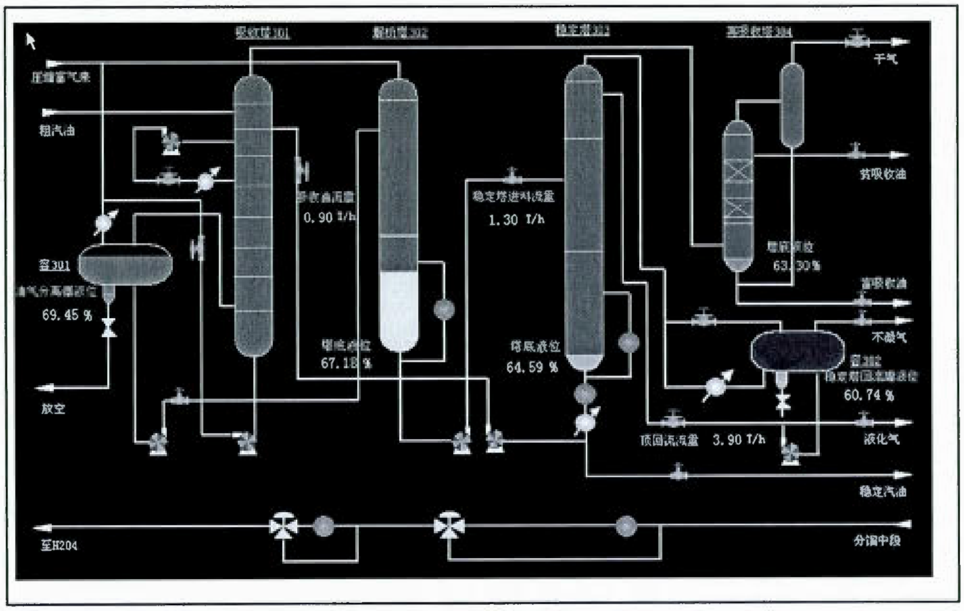


Figure 24: The configuration of the absorption and stability system

➢ Operation of Product Quality Forecasting System

1. In the main interface of procedure, enter the item of [training data input [evaluation]]. Then it is possible to input data of product quality forecasting system (as is shown in Fig. 25). Certainly, it can also use the item of "historical data", that is, both "new input data" and "historical data" can be used to train neural network. After clicking "confirming", the input data or historical data will be displayed. (as is shown in Fig. 26)

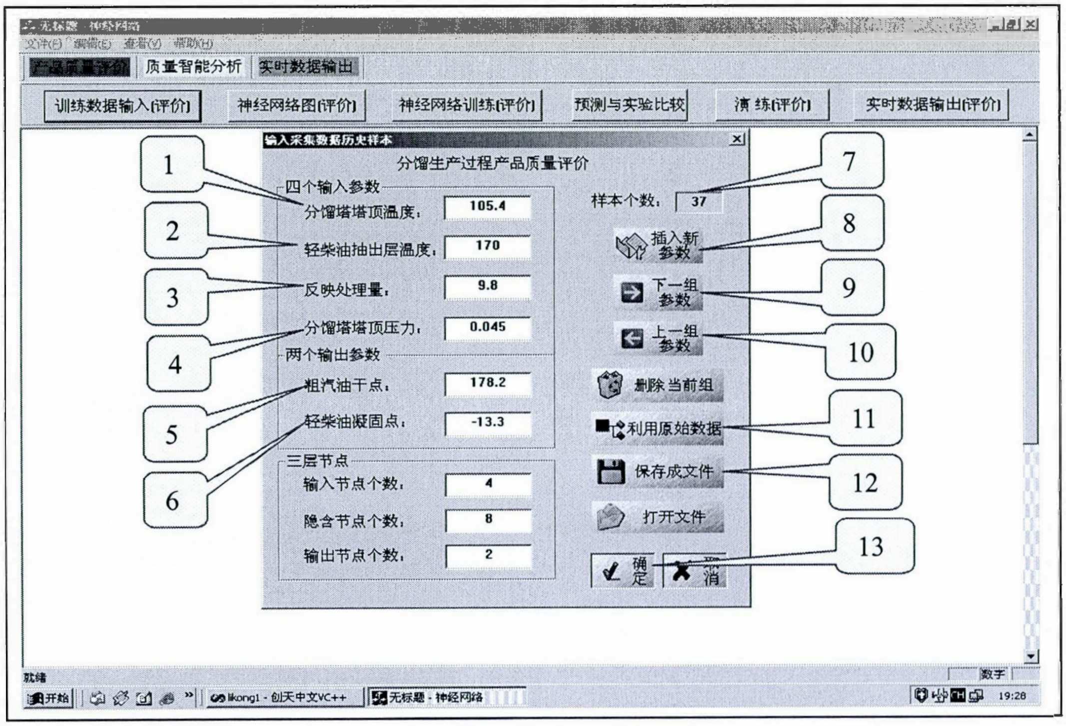
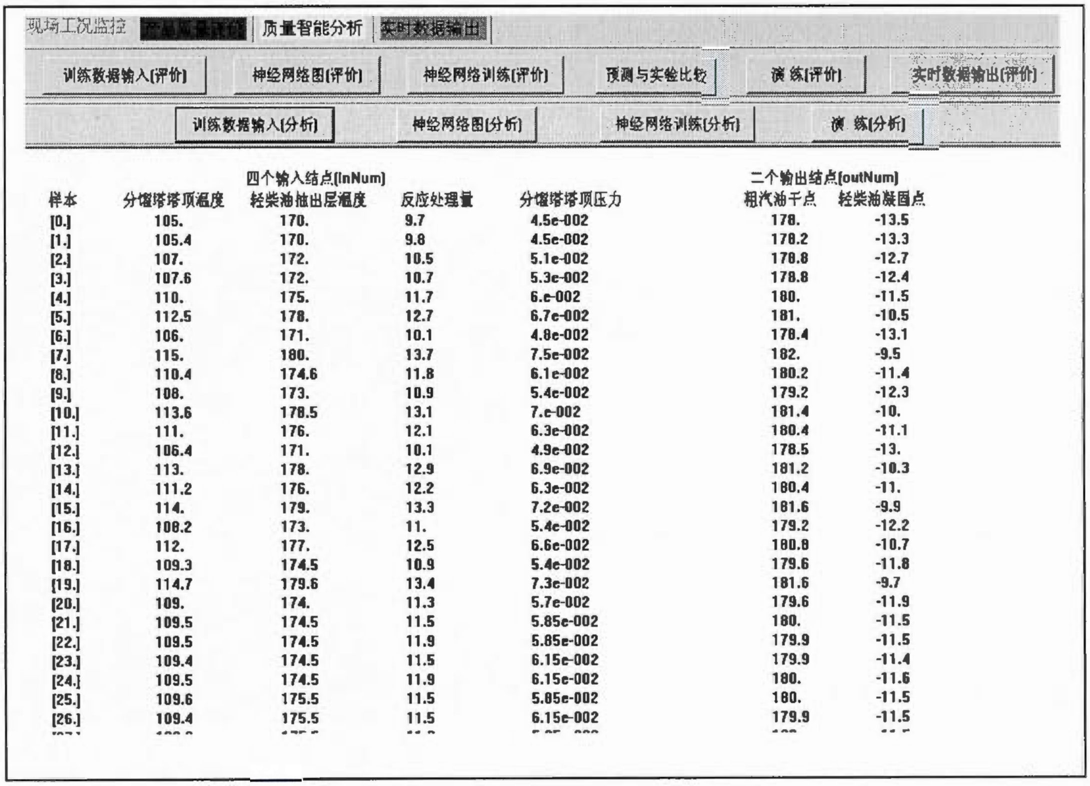


Figure 25: The interface of the training data input

Note:

1) The temperature of tower top of fractional column;
2) The pressure of tower top of fractional column;
3) The temperature of the 17^{th} layer;
4) The input quantity;
5) The dry point of cat gasoline;
6) The solidifying point of diesel fuel;
7) The number of the samples;
8) Insert a new sample;
9) Last group sample;
10) Next group sample;
11) Using historical data;
12) Save a file;
13) Enter;



	四个输入结点(InNum)				二个输出结点(outNum)	
样本	分馏塔塔顶温度	轻柴油抽出层温度	反应处理量	分馏塔塔顶压力	粗汽油干点	轻柴油凝固点
[0.]	105.	170.	9.7	4.5e-002	178.	-13.5
[1.]	105.4	170.	9.8	4.5e-002	178.2	-13.3
[2.]	107.	172.	10.5	5.1e-002	178.8	-12.7
[3.]	107.6	172.	10.7	5.3e-002	178.8	-12.4
[4.]	110.	175.	11.7	6.e-002	180.	-11.5
[5.]	112.5	178.	12.7	6.7e-002	181.	-10.5
[6.]	106.	171.	10.1	4.8e-002	178.4	-13.1
[7.]	115.	180.	13.7	7.5e-002	182.	-9.5
[8.]	110.4	174.6	11.8	6.1e-002	180.2	-11.4
[9.]	108.	173.	10.9	5.4e-002	179.2	-12.3
[10.]	113.6	178.5	13.1	7.e-002	181.4	-10.
[11.]	111.	176.	12.1	6.3e-002	180.4	-11.1
[12.]	106.4	171.	10.1	4.9e-002	178.5	-13.
[13.]	113.	178.	12.9	6.9e-002	181.2	-10.3
[14.]	111.2	176.	12.2	6.3e-002	180.4	-11.
[15.]	114.	179.	13.3	7.2e-002	181.6	-9.9
[16.]	108.2	173.	11.	5.4e-002	179.2	-12.2
[17.]	112.	177.	12.5	6.6e-002	180.8	-10.7
[18.]	109.3	174.5	10.9	5.4e-002	179.6	-11.8
[19.]	114.7	179.6	13.4	7.3e-002	181.6	-9.7
[20.]	109.	174.	11.3	5.7e-002	179.6	-11.9
[21.]	109.5	174.5	11.5	5.85e-002	180.	-11.5
[22.]	109.5	174.5	11.9	5.85e-002	179.9	-11.5
[23.]	109.4	174.5	11.5	6.15e-002	179.9	-11.4
[24.]	109.5	174.5	11.9	6.15e-002	180.	-11.6
[25.]	109.6	175.5	11.5	5.85e-002	180.	-11.5
[26.]	109.4	175.5	11.5	6.15e-002	179.9	-11.5

Figure 26: Displaying the new input data or historical data

2. Click [neural network training [evaluation]], then clicking "confirm", begin to train. And after training, display training result. (as is shown in Fig. 27). Display weights, thresholds, utility value of input sample parameter and output sample parameter.

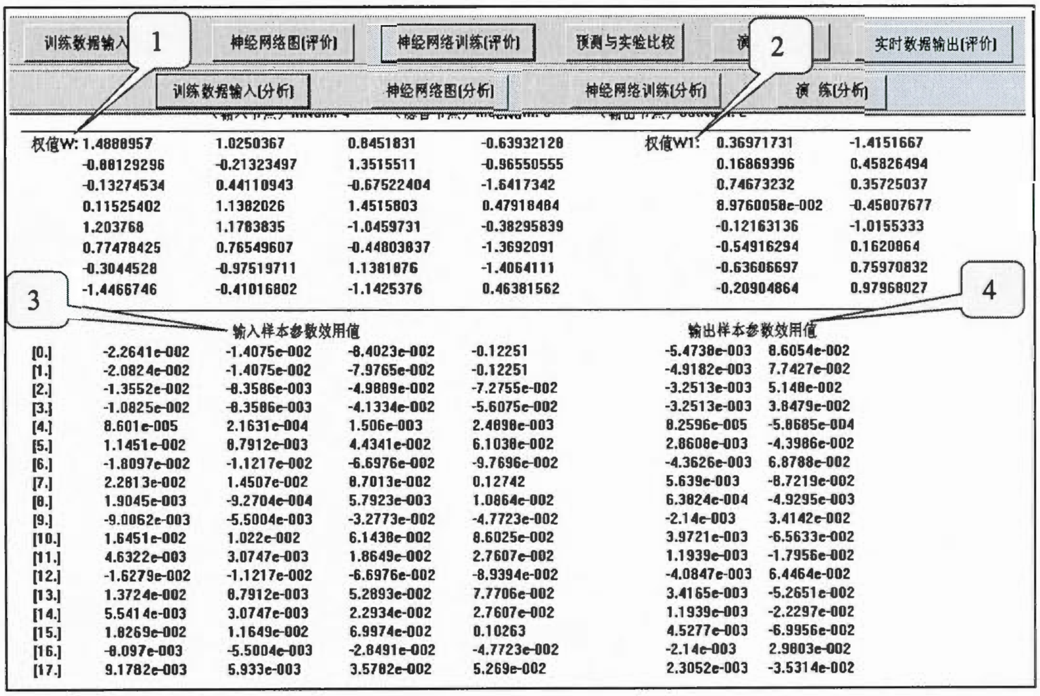


Figure 27: The training result of the neural network

Note : (for figure 27)

1) Initialized Value of Weights
2) Improved Value of Weights
3) The value of input utility function;
4) The value of output utility function;

3. Click [forecasting and experimental comparison], then display error of evaluation level after training, ie. Average relative error of dry point of cat gasoline and solidifying point of diesel fuel. (as is shown in Fig. 28)

样本	粗汽油干点期望值	粗汽油干点输出值	粗汽油干点误差	轻柴油凝固点期望值	轻柴油凝固点输出值	轻柴油凝固点误差
[0.]	178.	177.8364	0.1636338	-13.5	-13.50077	7.699567e-004
[1.]	178.2	177.8821	0.3178523	-13.3	-13.42536	0.1253551
[2.]	178.8	178.742	5.799524e-002	-12.7	-12.73393	3.39297e-002
[3.]	178.8	178.861	-6.099036e-002	-12.4	-12.54425	0.1442535
[4.]	180.	179.9471	5.285879e-002	-11.5	-11.57405	7.404753e-002
[5.]	181.	180.9736	2.63648e-002	-10.5	-10.58555	8.555478e-002
[6.]	178.4	178.3009	9.912006e-002	-13.1	-13.11812	1.812374e-002
[7.]	182.	181.727	0.2729553	-9.5	-9.629308	0.1293084
[8.]	180.2	179.9087	0.2913169	-11.4	-11.4911	9.109762e-002
[9.]	179.2	179.1618	3.818971e-002	-12.3	-12.34838	4.838222e-002
[10.]	181.4	181.2222	0.1777682	-10.	-10.21518	0.2151841
[11.]	180.4	180.3181	8.19141e-002	-11.1	-11.18569	8.568558e-002
[12.]	178.5	178.3793	0.1207264	-13.	-13.0337	3.369542e-002
[13.]	181.2	181.0313	0.1686733	-10.3	-10.40766	0.107655
[14.]	180.4	180.3473	5.271128e-002	-11.	-11.13505	0.1350519
[15.]	181.6	181.3798	0.2201824	-9.9	-10.01842	0.1184165
[16.]	179.2	179.1869	1.313643e-002	-12.2	-12.29847	9.846597e-002
[17.]	180.8	180.6785	0.1215433	-10.7	-10.79682	9.681589e-002
[18.]	179.6	179.6524	-5.243157e-002	-11.8	-12.08099	0.2809853
[19.]	181.6	181.5891	1.091273e-002	-9.7	-9.830373	0.1303727

1 粗汽油干点平均相对误差：6.668178e-002%　轻柴油凝固点平均相对误差：0.9309303% 2

Figure 28: Relative error between forecasting value and experimental value

Note : (for figure 28)

1) The average relative error of dry point of cat gasoline;

2) The average relative error of solidifying point of diesel fuel.

4. Clicking [training [evaluation]] can realize the function of manual training and evaluate product quality of input parameters in one group (as is shown in Fig. 29) after inputting four parameters and clicking [training], the evaluated result will be output immediately.

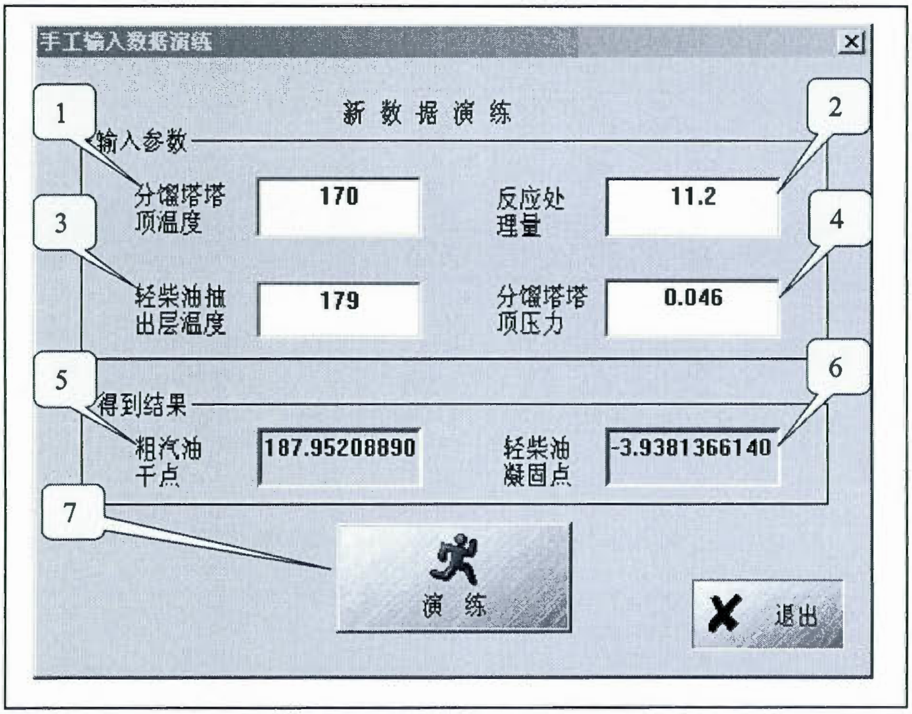


Figure 29: Manual forecasting product quality with one group sample

Note:

1) The temperature of tower top of fractional column;
2) The input quantity;
3) The temperature of the 17th layer;
4) The pressure of tower top of fractional column;
5) The dry point of cat gasoline;
6) The solidifying point of diesel fuel;
7) The [Training] button.

5. Clicking [immediate data output] can realize evaluate immediate product quality (as is shown in Fig. 30). In the figure, the above four figures are four subinput of real-time acquisition, and the following two are immediate output of product quality, ie. real-time output of dry point of cat gasoline and solidifying point of diesel fuel. The left below is the button of "historical curve". Click it and then the historical curve of four subinputs and two suboutputs will display. (as is shown in Fig. 31).

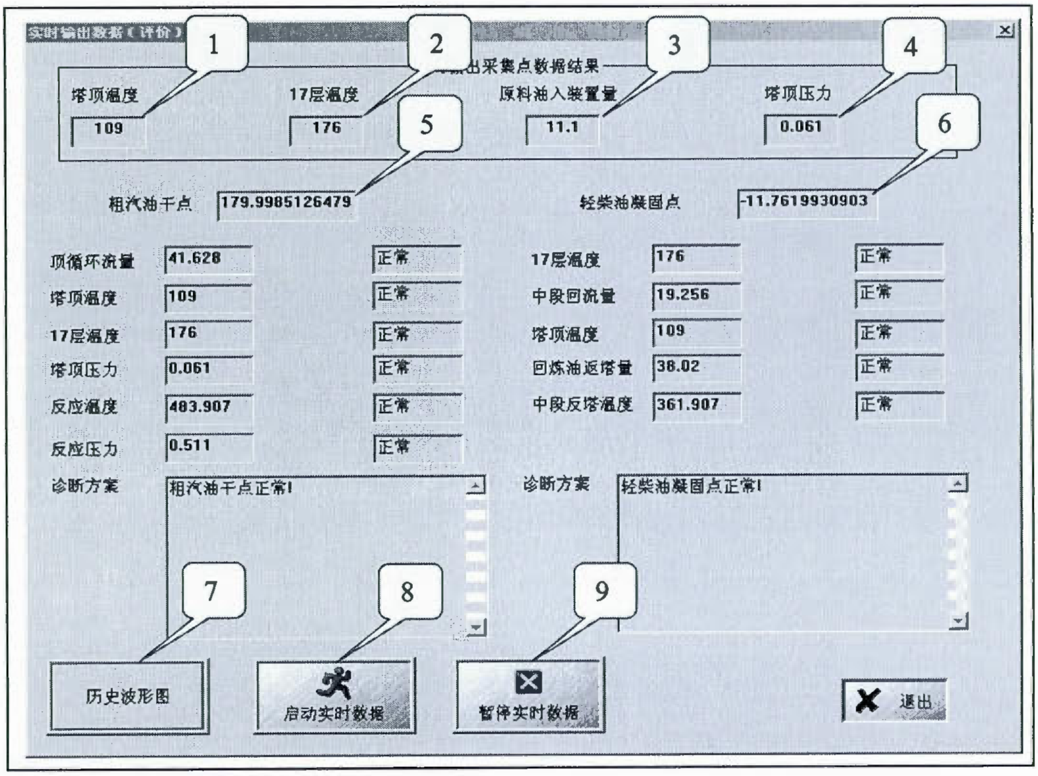


Figure 30: The real time forecasting product quality

Note:

1) The temperature of tower top of fractional column;
2) The temperature of the 17^{th} layer;
3) The input quantity;
4) The pressure of tower top of fractional column;
5) The dry point of cat gasoline;
6) The solidifying point of diesel fuel;
7) The [historical curve] button of the input and output parameter;
8) Start-up the real-time forecasting function;
9) Stop the real-time forecasting function.

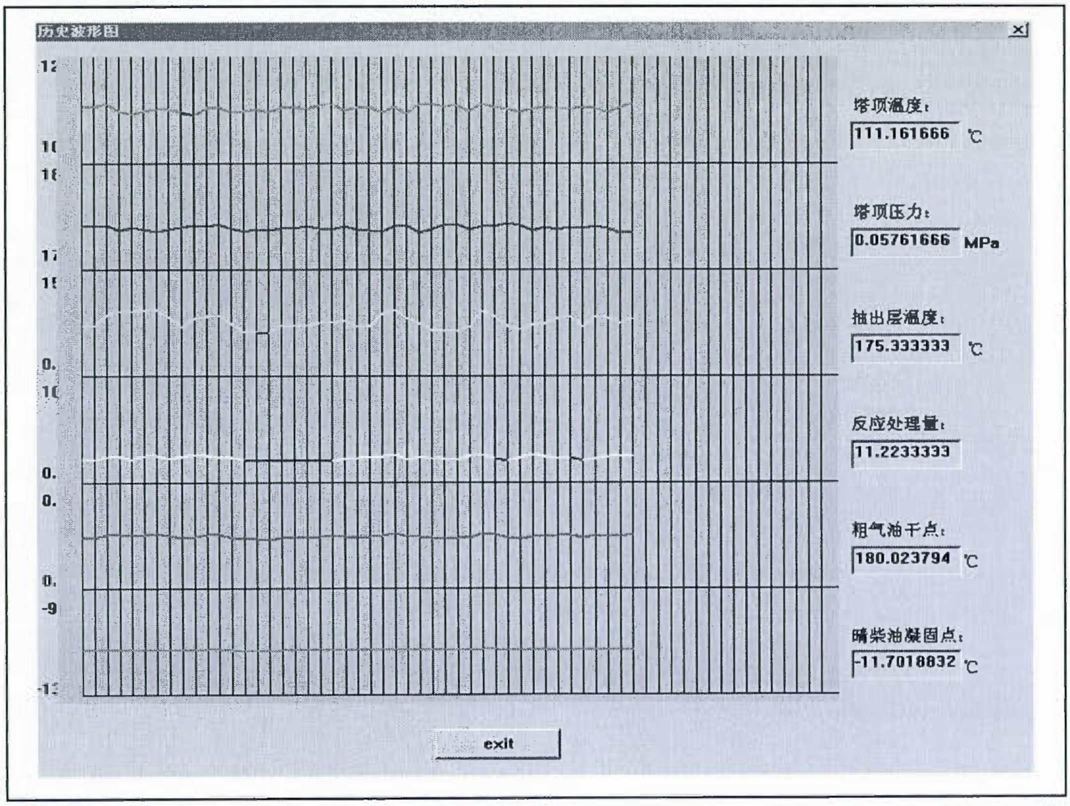


Figure 31: The historical curve of the input and output parameter

➢ Operation of Product Quality Analysis System

1. Click [training data input [evaluation]], then it is possible to input data of product quality analysis system (as is shown in Fig. 32). Certainly, it can also use the item of "historical data", that is, both "new input data" and "historical data" can be used to train neutral network. After clicking "confirming", the input data or historical data will be displayed (as is shown in Fig. 33). Click [neural network training [analysis]], which is to give neural network training to all the input data or historical data.

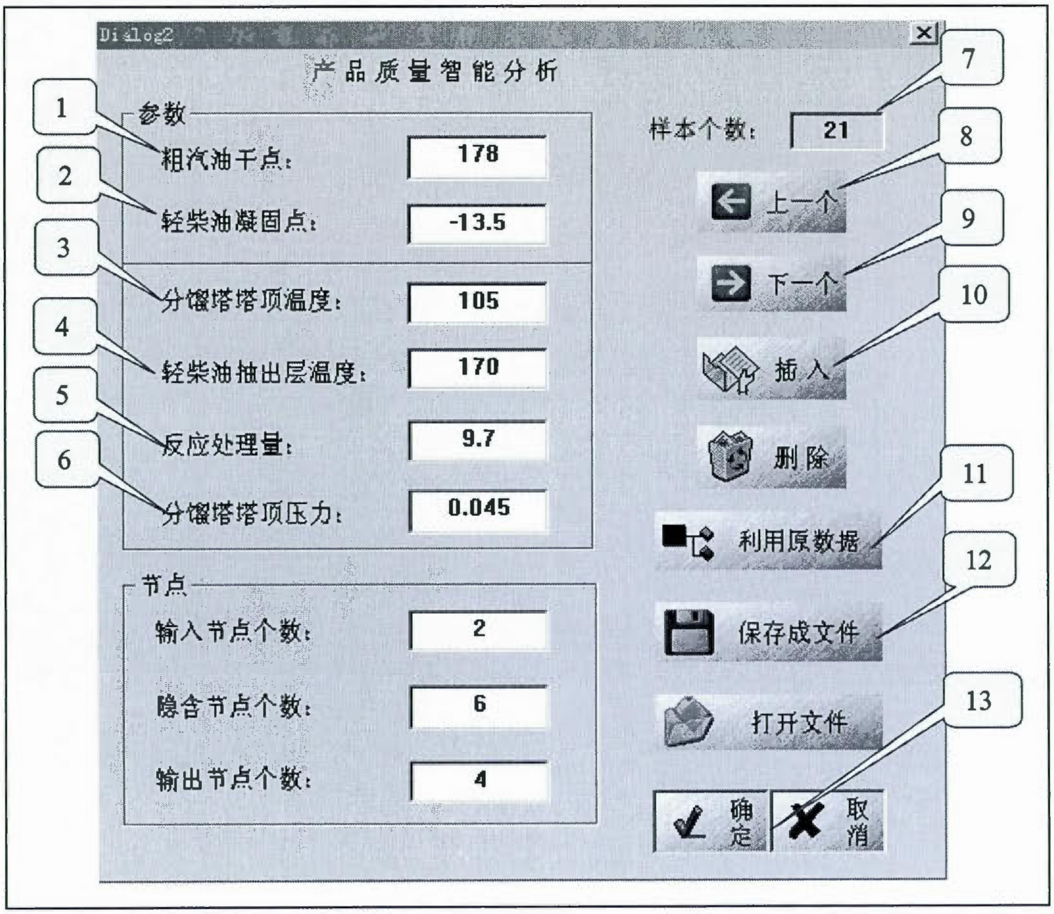
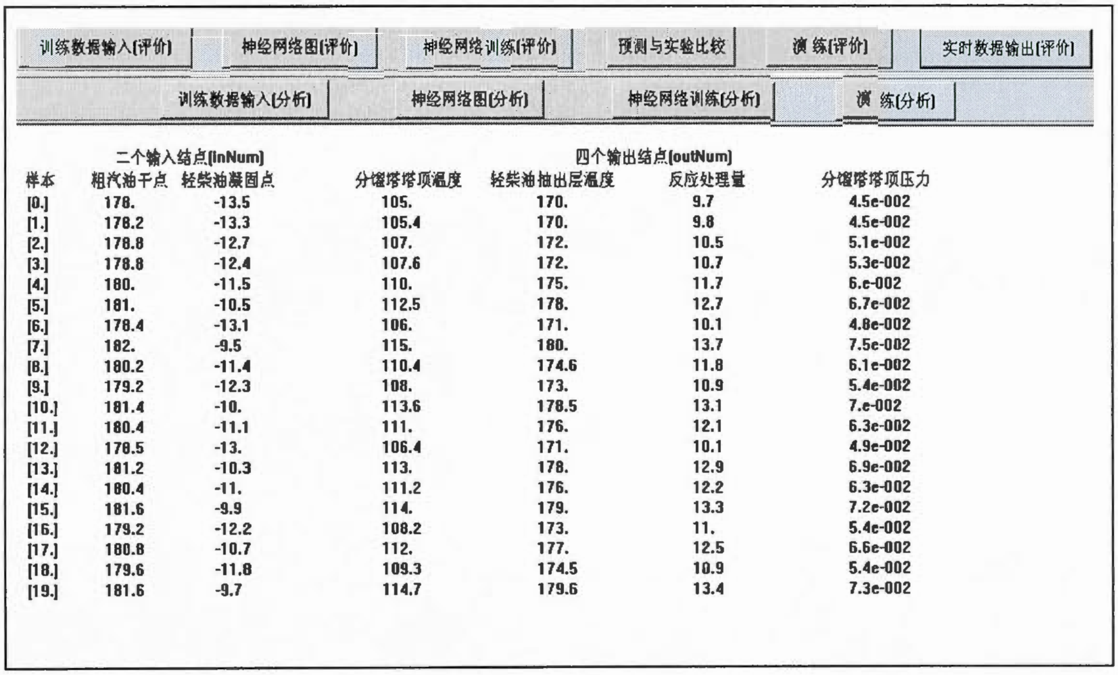


Figure 32: The interface of the training data input

Note:

1) The dry point of cat gasoline;
2) The solidifying point of diesel fuel;
3) The temperature of tower top of fractional column;
4) The temperature of the 17th layer;
5) The input quantity;
6) The pressure of tower top of fractional column;
7) The number of the samples;
8) Insert a new sample;
9) Last group sample;
10) Next group sample;
11) Using historical data;
12) Save a file;
13) Enter;



	二个输入结点(inNum)		四个输出结点(outNum)			
样本	粗汽油干点	轻柴油凝固点	分馏塔塔顶温度	轻柴油抽出层温度	反应处理量	分馏塔塔顶压力
[0.]	178.	-13.5	105.	170.	9.7	4.5e-002
[1.]	178.2	-13.3	105.4	170.	9.8	4.5e-002
[2.]	178.8	-12.7	107.	172.	10.5	5.1e-002
[3.]	178.8	-12.4	107.6	172.	10.7	5.3e-002
[4.]	180.	-11.5	110.	175.	11.7	6.e-002
[5.]	181.	-10.5	112.5	178.	12.7	6.7e-002
[6.]	178.4	-13.1	106.	171.	10.1	4.8e-002
[7.]	182.	-9.5	115.	180.	13.7	7.5e-002
[8.]	180.2	-11.4	110.4	174.6	11.8	6.1e-002
[9.]	179.2	-12.3	108.	173.	10.9	5.4e-002
[10.]	181.4	-10.	113.6	178.5	13.1	7.e-002
[11.]	180.4	-11.1	111.	176.	12.1	6.3e-002
[12.]	178.5	-13.	106.4	171.	10.1	4.9e-002
[13.]	181.2	-10.3	113.	178.	12.9	6.9e-002
[14.]	180.4	-11.	111.2	176.	12.2	6.3e-002
[15.]	181.6	-9.9	114.	179.	13.3	7.2e-002
[16.]	179.2	-12.2	108.2	173.	11.	5.4e-002
[17.]	180.8	-10.7	112.	177.	12.5	6.6e-002
[18.]	179.6	-11.8	109.3	174.5	10.9	5.4e-002
[19.]	181.6	-9.7	114.7	179.6	13.4	7.3e-002

Figure 33: Displaying the new input data or historical data

2. clicking [training [analysis]] can realize the function of manual training and analyze product quality of input parameters in one group. After inputting two parameters and clicking "training/drilling", a group of data will be output immediately (as is shown in Fig. 34), ie. The input quantity of fractional column, the temperature of tower top of fractional column , the pressure of tower top of fractional column , the temperature of the 17^{th} layer. These four parameters can be used to check whether the evaluated results of evaluation system are precise or not.

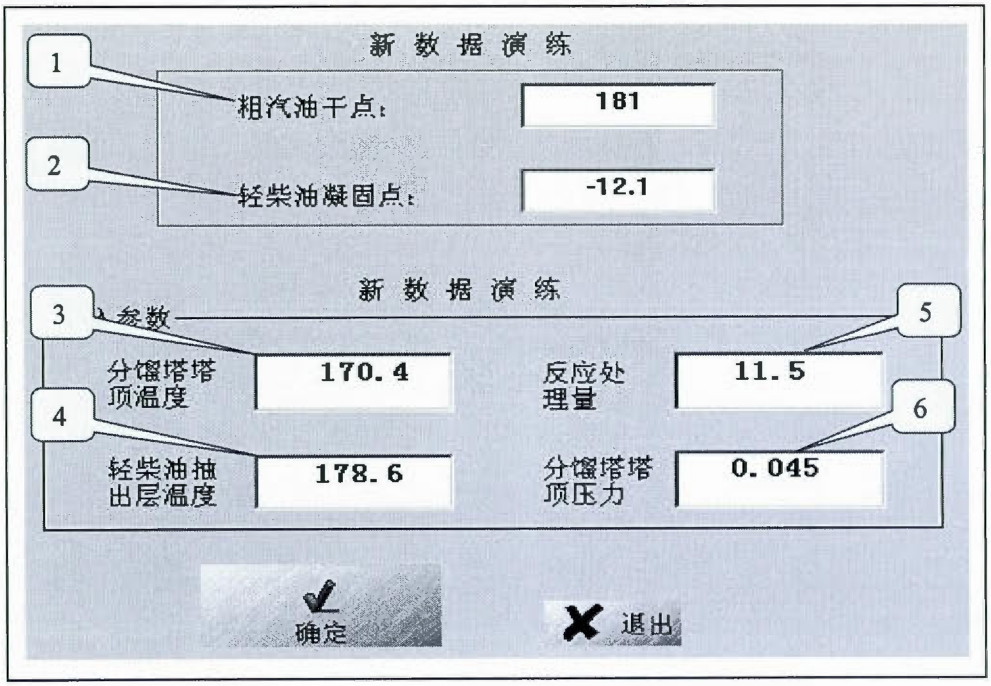


Figure 34: Manual analyzing product quality with one group sample

Note:

1) The dry point of cat gasoline;
2) The solidifying point of diesel fuel;
3) The temperature of tower top of fractional column;
4) The temperature of the 17th layer;
5) The input quantity;
6) The pressure of tower top of fractional column;

3. In the main interface of procedure, enter the item of [immediate data input], then enter the interface of product quality real-time forecasting and analysis system (as is shown in Fig. 35). in the item of [product quality forecasting system], there are

two items [manual input] and [automatic obtaining]. Clicking [manual input] can realize product quality forecasting manually; clicking [automatic obtaining] can automatically obtain data from configuration system and at the same time can forecast product quality . Clicking [product quality forecasting] can realize real-time forecasting of product quality. Clicking [product quality analysis] can realize real-time analysis of product quality, that is, real-time analyzing factors affecting product quality.

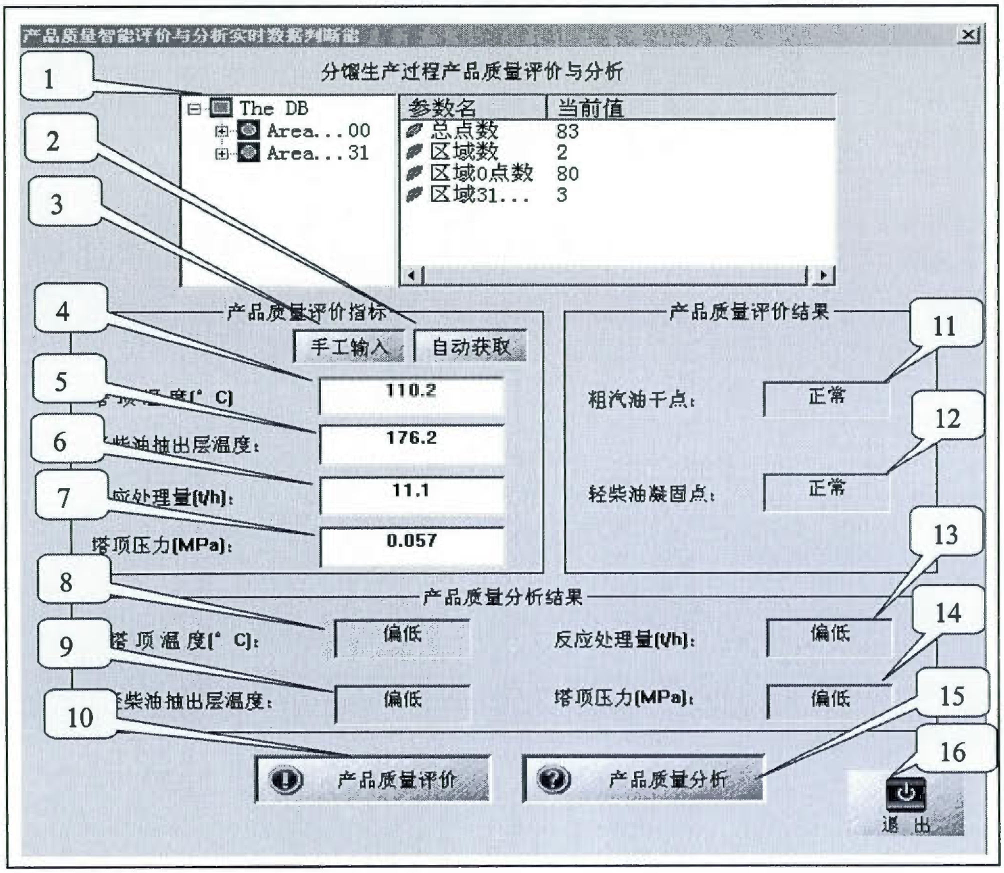


Figure 35: Real time product quality forecasting and analysis system

Note: (for figure 35)

1) DBCOM ActiveX inserted in VC^{++} language;
2) Start up [automatic obtaining] button;
3) Start up [manual input] button;
4), 5), 6), 7) The interface of manual input, it is the temperature of tower top of fractional column, the temperature of the 17^{th} layer, the input quantity, the pressure of tower top of fractional column in turn;
8), 9), 13), 14) The result of product quality analysis, it have three situation ie. Above normal, normal, below normal;
10) Start-up [product quality forecasting] button;
11) The result of product quality forecasting, the dry point of cat gasoline, it have three situation ie. Above normal, normal, below normal;
12) The result of product quality forecasting, the solidifying point of diesel fuel, it have three situation ie. Above normal, normal, below normal;
15) Start-up [product quality analysis] button;
16) Exit;

5.2 Experimental conclusion

We have tried the product quality forecasting and analysis system on the fluidized catalytic cracking unit (FCCU) in Tianjin First Petroleum Chemical Plant in China. And we compare actual laboratory data of product quality of the fluidized catalytic cracking unit (FCCU) of several weeks with the results of system forecasting, see Table 8:

Table 8: Comparison between Laboratory Data and Software Measuring Data.

No.	Dry point			Solidifying point		
	Laboratory value ℃	Forecasting value ℃	Error ℃	Laboratory value ℃	Forecasting value ℃	Error ℃
1	183	198.10	15.10	-11	-5.87	5.13
2	186	197.23	11.23	-11	-5.95	5.05
3	184	190.36	6.36	-10	-5.27	4.73
4	183	189.01	6.01	-11	-9.99	1.01
5	184	188.14	4.14	--11	-10.01	0.99
6	181	184.93	3.93	-12	-9.89	2.11
7	183	183.72	0.72	-11	-10.86	0.14
8	183	182.83	-0.17	-11	-10.78	-0.78
9	182	182.01	0.01	-11	-11.21	-0.21
10	181	181.20	0.20	-7	-7.44	-0.44
11	181	181.31	0.31	-8	-7.77	0.23
12	181	180.86	-0.14	-11	-10.98	0.02
13	182	181.99	-0.01	-11	-11.25	-0.25
14	182	182.42	0.42	-11	-11.24	-0.24
15	181	181.50	0.50	-3	-3.1	-0.10
16	184	183.50	-0.50	-2	-2.66	-0.66

17	183	183.20	0.20	-11	-11.76	0.24
18	182	181.50	-0.50	-11	-10.95	0.05
19	181	180.00	-1.00	-11	-11.15	-0.15
20	184	183.29	-0.71	-11	-11.02	-0.02
21	180	180.56	0.56	-11	-11.96	0.04
22	181	180.73	-0.27	-13	-11.56	1.44
23	181	181.20	0.20	-11	-11.26	-0.26
24	180	180.75	0.75	-10	-11.01	-1.01
25	180	180.54	0.54	-11	-10.88	0.12
26	178	179.50	1.50	-8	-9.05	-1.05
27	181	180.80	-0.20	-11	-10.96	0.04
28	180	180.21	0.21	-13	-12.25	0.75
29	184	183.67	-0.33	-11	-11.35	-0.35
30	183	183.89	0.89	-10	-11.01	-1.01
31	183	183.01	0.01	-10	-9.43	0.57
32	182	181.49	-0.51	-10	-9.75	0.25
33	181	181.22	0.22	-10	-10.36	-0.36
34	183	183.56	0.56	-11	-10.98	0.02
35	182	181.67	-0.33	-10	-10.66	-0.66
36	178	179.00	1.00	-6	-4.15	-0.11
37	180	179.56	-0.44	-5	-6.04	-1.04
38	181	180.69	-0.31	-8	-7.85	0.15
39	181	181.10	0.10	-8	-7.68	0.32
40	181	181.15	0.15	-11	-10.99	0.01
41	183	182.49	-0.51	-8	-8.16	-0.16
42	181	180.80	-0.20	-6	-6.04	-0.04

From the table we can see that: when it is put into use during the early period, data of system forecasting have larger difference from laboratory data, because the data of the first six groups are used to study modeling. But with inputting more and more calibrated data, the error begins to lower. Generally speaking, the difference between software measuring value and laboratory value will not be over 3□ which is within the permitted scope. After the calibration of software measuring system is over, from the 7^{th} group on, the forecasting value deviation of dry point of cat gasoline and solidifying point of diesel fuel lowers evidently, which shows that the dry point of cat gasoline and solidifying point of diesel fuel forecasted in the system are reliable. Therefore, the system can guide production operation. And with the increase of calibrated data, the precision of software measuring will go on increasing.

The system has been tried on the fluidized catalytic cracking unit (FCCU) in Tianjin First Petroleum Chemical Plant in China. The local operating results show that the data value of solidifying point of diesel fuel and dry point of cat gasoline forecasted immediately in the system have better goodness of fit with laboratory value.

The testing results also show that it is feasible to use neutral network technology to forecast product quality of fluidized catalytic cracking unit (FCCU). The thesis, using the method of neutral network, establishes reflection relationship of input and output between important parameters affecting product quality and products of fractional column, ie. dry point of cat gasoline and solidifying point of diesel fuel. Collecting data relevant to product quality can real-timely get parameter level of dry point of cat gasoline and solidifying point of diesel fuel and at the same time can calibrate product quality to analyze factors affecting product quality. Compared with the traditional method, it needs less prior experience and avoids model identification which is always a difficult problem. And further, the system has feature of real-timeness, so it will not affected by measurement lag and it is expected to have great improvement in quality control.

5.3 Envision

The system should be improved in the following aspects :

1) The product quality online forecasting and analysis system of catalytic cracking fractional column has important value in promotion and application. If it is possible to establish many samples in fluidized catalytic cracking unit FCCU) of refining and chemical enterprises in our country and apply this system in different kinds of fluidized catalytic cracking units (FCCU), it will bring great economic efficiency and value in project.

2) The system has good compatibility. If it can be combined with other systems, the function and actual applied value will greatly increase. For example, if combined with the product quality expert system, it can be used to product intelligent diagnosis and control. In the process of production, once product quality fluctuates and unqualified products are produced, product quality analysis system will give factors affecting product quality and transmit this information to product quality intelligent expert system. And expert system can, according to technological mechanisms and their experience, automatically drive DCS or I/O equipments of production device to adjust

relevant parameters in order to make product quality become normal and finally produce qualified products.

3) Website constructing and system remote control. Making use of professional website design and developing tools, construct an information website of enterprise combining this topic. Making use of Web function provide by Sunway® Force Control software, it is needed to install force control software on the Web server and meanwhile, the Web server preserves HTML documents issued by force control software, transmits data required by documents and provides sites of browsing service for users. Users can use IE browser to visit real-time operational picture at the clients' side.

If it is possible to access control information in the process of industry production into Internet, under some condition, Internet can be used to supervise production system and operating state and various parameters of local equipments. The supervisor needs not to be present, which can save a great deal of man power and materials. The managing staff can distantly supervise operating situation of production, and according to business requirements, send out orders of adjustment timely. The studying agency can make use of local abundant resources of software and hardware to have advanced process control (APC for short) over remote targets.

5.4 Concluding Remarks

Fluidized catalytic cracking unit (FCCU) is one of the most important devices in oil refining plants. Its interest plays an important role in oil refining plants. How to increase operating level of this device, eliminate failures, make production stable, and reduce system non-plan suspension, is a problem concerned greatly in the field of refining industry. Meanwhile, with the development of applying widely DCS technology into chemical process, it has been a hot topic studied recently of how to better use DCS and fully play the great potentiality of DCS system in the aspect of handling information, and vigorously develop advanced computer control technology and relevant software. The thesis mainly studies, designs and develops product quality real-time forecasting and analysis systems and has some discussion in the aspects of applying neutral network in product quality forecasting. I hope sincerely to continue to discuss this topic with experts in this field and comrades who are interested in this field.

ANNEXES

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