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An incorporate system with on-line measure-, control-, real time computing and off-line reconstructive design for compressors

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Abstract
This paper recommends a system incorporated as on-line automatic measure, control and real time computing and as off-line reconstructive design calculation for reciprocating compressors, that could be used to measuring and optimization control and safe calculation analysis for operating compressors, can obtain a mass of the real-time soft measurement data by means of the soft measurement technology of program, when the system is on-line; Moreover the program could also visually display diversified numeric and curvilinear data, give an alarm in good time for overrun data, automatically accommodate and control a lot of valves connected to pipelines. Also it could be used to thermodynamic, dynamical, technical and economic efficiency optimization calculations analysis, and could make technical reconstruction and innovatory design for industry, when the system is off-line. So it has practical significance for increasing economic efficiency.

1. Introduction

Up to now, the competitive system programmed together for on-line to do real time automatic measure, control and real computing analysis and off-line make reconstructive calculation have been seen less in home and abroad for multistage reciprocating compressors. Especially, for compressors inhaled high temperature, high-pressure, easily burnt and blast gases exist sometimes a danger, therefore the reliability and security for its operation, the accuracy for its calculation are also required to be very high. Proverbially, a designer designs a type of compressor that it could be usually only applied to a specifically technologic condition. But for a majority of factories and corporations, with their technologic systems are innovated now and again, so the technologic parameters are changed every now and then. Thereby must

require that the compressors concerned with this same technological process should be also correspondingly improved with technological reconstruction. Especially, for those good-sized reciprocating compressors are a complicated dynamic machine, if their mechanical efficiency of those machines is decreased, the wastage of power is increased, or an accident is begotten in case that will be huge expense. So design a multifunctional programs that it not only could be made measuring, control and safe analysis to be on-line for operating compressor, but also could be used to thermodynamic, dynamical, technical and economic efficiency optimization computing analysis to be off-line for industry technological reconstruction, so that it will be having practical applying significance for a lots of manufactories and corporations [1]. On the other hand, many petroleum, chemical and mechanical manufactories in some country, must be consumed generally a great lot of electric power ever year, and power consumed for compressors operation are usually occupied about 50-85% for some corporations. So the mechanical efficiencies are increased and ratio-power are decreased for compressors will be to have factual economy efficiencies to energy saving. This paper bases on the computer programs to measure, control, real time computing and analysis for its composing of reciprocating compressor, its principium and functions of programs introduce as follows.

2. Composings and its Principiums of the System

2.1. Composings of the System

Whole systems consist of the hardware decentralized-concentrated system (DCS) and the software constructing computing program of compressor. Depend on hardware the DCS, except for pressure control points of ten, temperatures of fifteen, flow rates of three, electric parameters of four, lube parameters of two can put up measure, monitor and alarm, and can also automatically turn on or turn off, and accommodate for thirteen valves connecting to pipelines。 Figure 1 is a distributing condition many of measure and control points cum various equipments such as measuring meters and valves to link pipelines for the M-H type compressor and its electromotor.

In software system has several big programming modules, which are the thermodynamic calculation, dynamic calculation and technical economy calculation, etc. And in each big programming module there are vast mathematical models made all computing programs, in which also contains some optimization models. Figure 2 is a main interface of programs that is the system incorporated as measure, control and computing analysis, it has been programmed to study references [4-6].

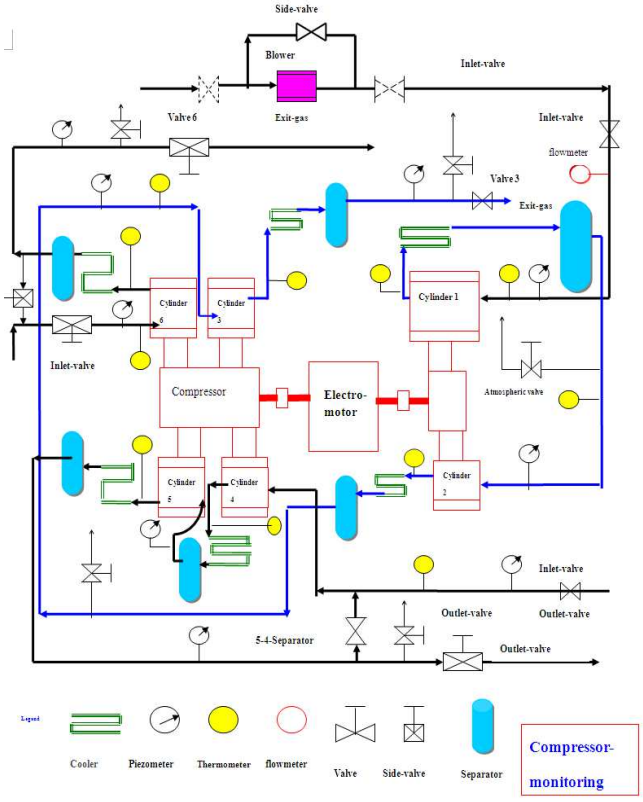

Figure 1. *distributing of each measure and control points of compressor.*

Figure 2. *main interface of measure, control, computing, and analysis of compressor.*

Depend on the different programs, can put up on-line computing and analysis collected from real time measured data mentioned above [2, 3], and also to do off-line reconstruction design and computing by technological innovation requirement.

2.2. Principiums of the System

Principium of the system controls are that some non-electric quantity signals transform into electric signals from transducers, with single-chip microcomputers (SCM) puts up collections, transforms and transactions for the data (Fig.3). A good many signals transmit to the PC from serial ports of communications, with the PC puts up surveillances for many technical and electric parameters (for instance, pressures, temperatures, currents and power factor, etc.), and gives an alarm for an overrunning index. Moreover, the PC compute and analyze on-line the technical and economic data in process of running compressor, display and print diversified data, plot various diagrams.

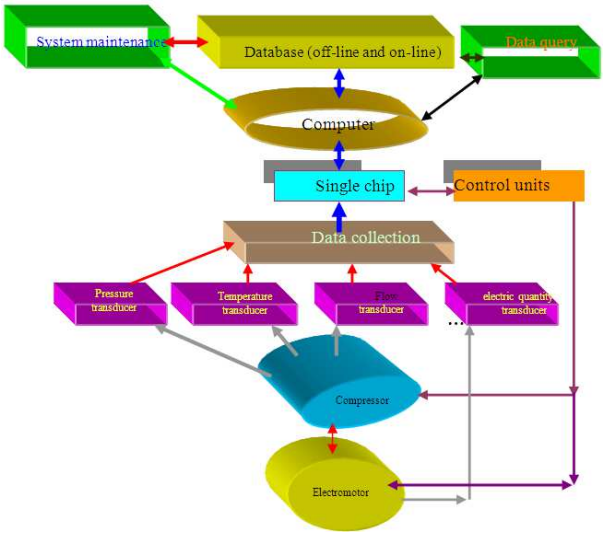

Figure 3. *electromechanical integration system of calculation and analysis of off-line and on-line for M-H-compressor.*

3. Main Functions of System

The programs use the object oriented programming, visual and emulating techniques, design several big modules which have the system setting, the measure and calculation, the real time measure, monitor and computing, the query and print of data, the system maintenance and the help etc.

3.1. Functions of the System Setting

In the system setting module, are designed with many of the secondary module having functions to connect or switch off with a server OPC., to start or switch off display data and backup or comeback database etc, achieve to connect or switch off with the server, accomplish the purpose of switch for operation as gotten off to on-line or for design as gotten off to off-line, and actualize the functions of real time visually display measured digital or curvilinear data. Besides the software is also designed with such programs as setting of holistic parameter and collecting data, which includes: the equipment position, communication port, baud rate, collection time, etc.

3.2. Functions of the Real Time Measure and Surveillance

After the system enters into a state of measure, it can put up pickings and transacting which are the flow rate of gas, inward and outward pressure, inward and outward temperature of each gas-cylinder; the pressure and temperature of lubricating oil in compressor; the voltage, current and power factor of electromotor; the upper limit and lower limit of all data, that are all put up per stated time interval (Fig. 4), real time display corresponding curves (Fig. 5). And the system can also all duly store, record and manage for multifarious data and curves in the compressor-black-box, or it could give an alarm, insure safe running when a signal of overrun is received from it.

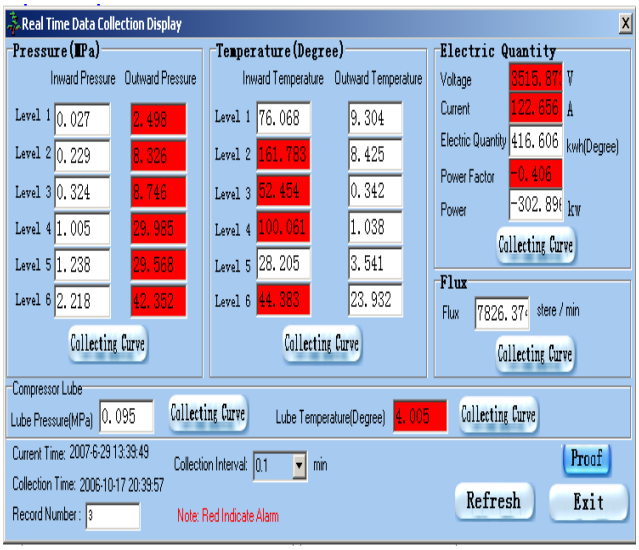

Figure 4. *digital data measured by real time pressure, temperature and electric quantity gettn off to on-line.*

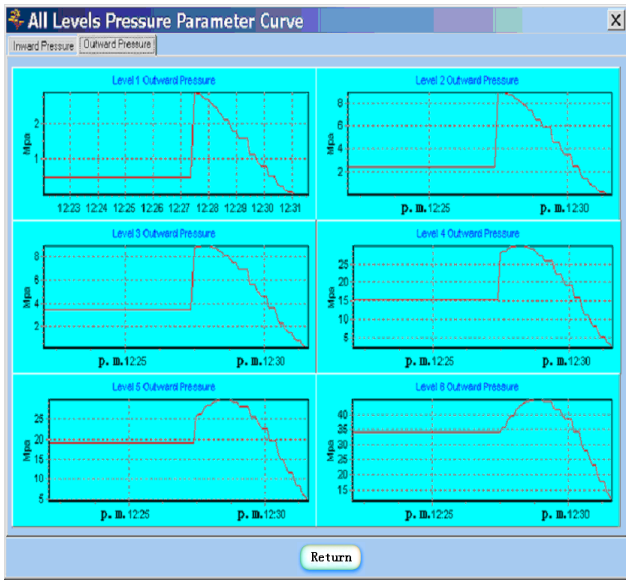

Figure 5. *pressure curvilinear data measured by real time in each gas-cylinder.*

3.3. Functions of the Real Time Measuring and Computing

The program modules have a number of the second class of the program modules and the soft measurement technologies, their functions are as follows:

1) The computing programs could be used to thermodynamic, dynamical calculations [7-9] for compressors; it could calculate multifarious forces and moment of resistance M_i for any an angle degree between both longitudinal section of crankshafts of left and right hand placed at electromotor.
2) A mass of data in database programs could be used visually to plot the ergograms of gas-force in each gas-cylinder (Fig. 6).

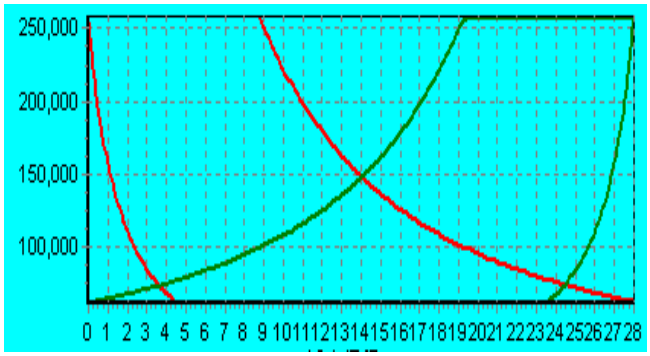

Figure 6. *the ergograms of gas-force in a gas-cylinder.*

3) A lot of diagrams are plotted by the programmed as the tangential force, the vector-area-value, the total tangential force and their extreme value, average value and optimization value, etc (Fig. 7) [10].
4) The computing programs also can be used to do technical economic computing and analysis for compressors on line (Fig. 10).
5) To design the program has also a significant purpose is that it not only must be obtained for the pressures, temperatures and the flow rates etc data which can easily be got by on-line measured from running compressors, but also can obtain more than thirty data of parameters by measuring instruments which can't obtain on the data-measures-values in thermodynamic-, dynamical-, economic efficiency-measures, where are computed and got by computational program. So it must be depending on the soft measurement technology [11,12, 13].

Its method is that at first, select easily by measured to take some parameters as variable (e.g. the pressure P, the temperature T, the flow Q); the second, for difficult to measured parameters (e. g. the synthetical piston-force ΣP_i, the mechanical efficiency η etc.) establish their optimized mathematical models by their function relationships between the relevant parameters and the variables, then design computing programs; the third, by means of the on-line measured parameters can just obtain a lot of the real-time soft measurement parameters from program computing. For example, it can rapidly calculate the momentary value of synthetical piston-force per degree from 1^o to 360^o with a running crankshaft for each cylinder (Table 1), the total tangential force and moment of resistance per degree from 1^o to 360^o for a running crankshaft, their average and optimized (extremum) values, and can also rapidly plot diversiform curves (Fig.7~8). Thereby realize real-time estimation their economic and technical indicators in operation process. Besides the system can yet measure the voltage, current and power factor, then rapidly calculate and analyze the indicated power, electromotor power, ratio-power, mechanical efficiency and dissipative electric quantity per unit produce on-line. Especially should be point that a great lot of valued parameters mentioned above are unable to detect and take when the compressors are under way by means of measuring instruments, only can depend on to build the mathematical model and the scientific method of computer simulation, achieve to get above much of data.

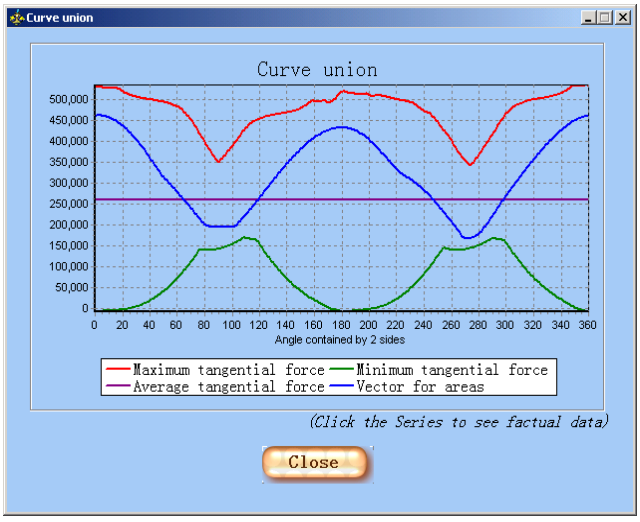

Figure 7. *An interface used to optimization computing, on-line or off-line, It can displaysome data of the crankshaft rotation every angle, e. g. total tangential force, their extremum, average value and optimization value .*

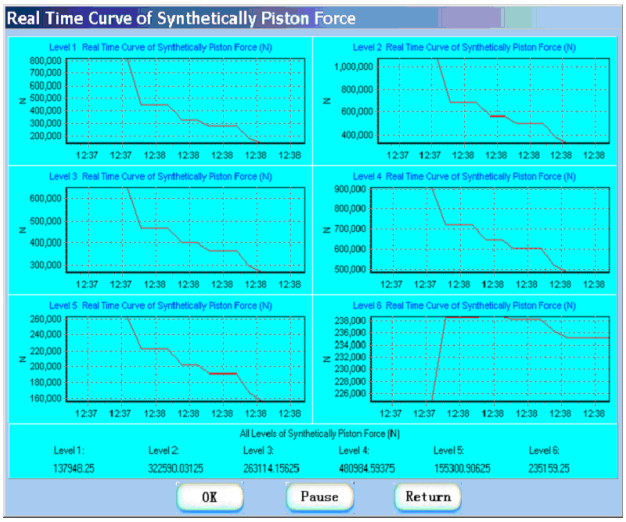

Figure 8. *Real time computing data of synthetical piston force on-line.*

3.4. Functions to do Reconstruction Design Technologically about Off-Line

On the other hand what about should increase the efficiency of the compressor, how arrive at the accuracy of calculation, this is only to use programs of functions with Object Oriented Programming, Visual Component Library, its emulating technique and good databases, thereby it can accomplish the optimization computing and operation for compressors. Therefore this system can also apply expediently this software to do design and computing for technical reconstruction as off-line compressor to user.

Table 1. *the real-time soft measurement data from program computing.* (*Units of force are all N*).

Crankshaft Angle, degree	Piston stroke, mm	Gas Force (N)	Inertia force (N)	Friction force (N)	Synthetical piston-force (N)
347	275.703	61473.44/-258127.94	142510.45	-5415.35	-59559.39
348	276.335	61473.44/-258127.94	143341.22	-5415.35	-58728.62
349	276.918	61473.44/-258127.94	144107.7	-5415.35	-57962.14
350	277.451	61473.44/-258127.94	144809.36	-5415.35	-57260.48
351	277.934	61473.44/-258127.94	145445.72	-5415.35	-56624.62
352	278.366	61473.44/-258127.94	146016.29	-5415.35	-56053.55
353	278.748	61473.44/-258127.94	146520.71	-5415.35	-55549.13
354	279.08	61473.44/-258127.94	146958.59	-5415.35	-55111.25
355	279.361	61473.44/-258127.94	147329.65	-5415.35	-54740.19
356	279.591	61473.44/-258127.94	147633.60	-5415.35	-54436.24
357	279.77	61473.44/-258127.94	147870.24	-5415.35	-54199.60
358	279.898	61473.44/-258127.94	148039.38	-5415.35	-54030.46
359	279.974	61473.44/-258127.94	148140.94	-5415.35	-53928.90

1) It can compute the adiabatic exponent K_i, pressure ratio ε_i and other various data in the computing program from the thermodynamic computing modules. Moreover it can also calculate the stroke volume v_i, the synthetical piston force, the indicated power, the ratio-power, shaft power, the mechanical efficiency of compressor, the electromotor power and so on. Thereupon confirm the diameter D_i of each cylinder, the areas F_i of piston and other main sizes; and obtains gas-acting-force p_i loaded at piston rod of a compressor, respectively.
2) It can compute the inertia force I_i, friction force f_i of reciprocating movement parts, the synthetically piston-force ΣP_i loaded at each piston-rod from the dynamic computing modules (Figure 9). Then calculate out the tangential force T_i, the vector-area value, the synthetically tangential force ΣT_i loaded at each journal of crankshaft, the moment of resistance and so on, respectively.
3) It can yet compute the outputs and cost etc of a compressor operation from the technical and economic analysis module (Figure 10). In economic query and calculations, it can do calculation and analysis for the isothermal efficiency and the mechanical efficiency which are computed by the inward pressure and the temperature etc. parameters, under condition are been process in off-line or on-line; And can put up output and the production value calculation and analysis, to obtain the output, production value for a single or multi machines. Thereby compare and analyze for the data between the practical operation and the theoretical calculation, the aims of achieving optimum the design and the operating data, to increase the output of a compressor, economize consume of power.

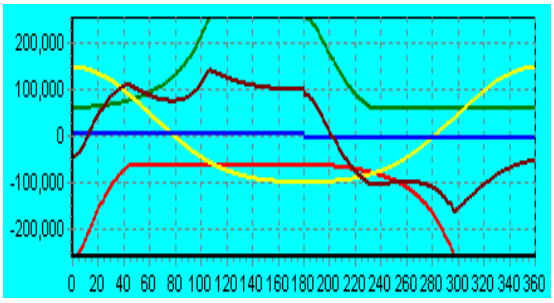

Figure 9. *compute curves of the gas-acting-force, the inertia force and friction force and synthetically piston-force of every degree angle, and so on.*

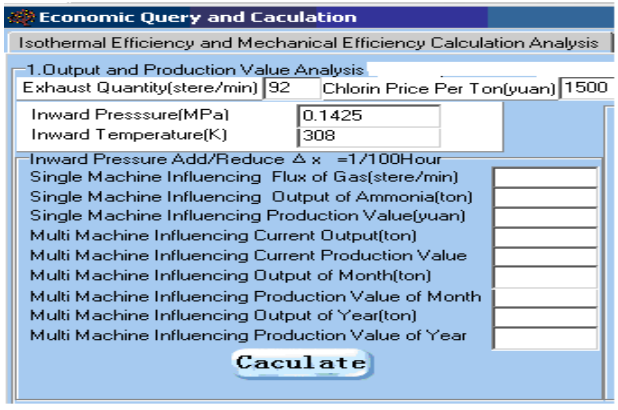

Figure 10. *An interface used to technical economic analysis to be off-line or on-line.*

3.5. Functions of Query and Print of Data

User can yet query various performance data of a compressor, and all it's checked-, measured-, and calculated

data of mentioned above (Figure 11). It not only could query the history data and the real time data, but also thermal and dynamic data; not only any digital data, but also curvilinear ones, under which are the data in any a class (level) gas-cylinder or whole a compressor. Besides could yet plot and print diverse types of curves, for example, the tangential force data and its diagram in any a class (level) gas-cylinder, or the synthetically piston force data and its diagram in whole a compressor, etc.

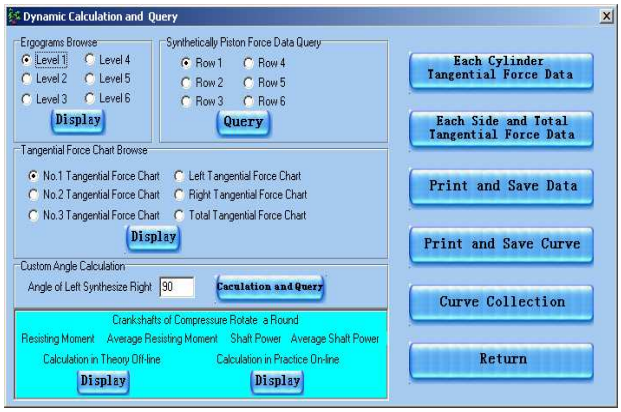

Figure 11. *Multifunctional computing and their data querying interface.*

3.6. Functions of System Maintenance

The system mounts the user's name and password, if to import continuously three times is wrong, the program can exit immediately the system. And it has also mounted user's different authority, which divides into two of type: ordinary user and administrators, and no other than administrator can achieve all operations. On the other hand the administrator of system has yet the authority to insert, delete, modify for data dictionary, for measuring object of data dictionary in database. Moreover the module has yet other multifold functions to create log files, to maintain system and to help etc.

4. Summary

The system has following traits:

1) The system is placed all together for the on-line optimization operation, control and safe analysis and for the off-line optimization design and calculation to compressor technical reconstruction, this is the first trait of the system that will be offering a useful scientific computing and analysis tool, so that it can use new technology to reconstruct the traditional industry and the techniques.
2) The system can measure and rapidly to do computing in second time for above real time measure parameters, and real time display the data and curves in good time, for overrunning index can duly give an alarm, this is the second trait, which will be creating nicer conditions for safe running of compressors.
3) The system has a program of technical and economic analysis, this is the third trait that will be having practical significance for intensifying manages, inspiriting operational positivity.
4) The system can all put up in good time for real time digitized computing analysis, optimization control, display and alarm; for real time computing the synthetical piston force, resisting moment, shaft power, ratio-power etc data, this is the fourth trait which will be having practical significance to promoting safe productions, energy savings and increasing economic advantages.

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References

[1] Kumar Subramanian, L R Ganapathy Subramanian, Benny Joseph etc. Mathematical modeling and simulation of reciprocating compressor A review of literature. Mathematics modelling and applied computing. Research India Publications, ISSN 0973-6093 Volume 1 Number 1 2010, pp. 81-96

[2] Huaicheng Yan, Xinhan Huang, Min Wang, Delay-dependent Stability Criteria for a Class of Networked Control Systems with Multiple Time-delays, Advances in Systems Science and Applications, Vol.6, No.2, 2006, pp.184-192.

[3] Yu Yangui (Yangui Yu), Li Ying, Wan Changjiang, Xu Feng, Ma yanghui. "Integrate Method by Fatigue Fracture Calculation with Virtual Design and Monitor Analysis to Realize Safety and Energy-Saving Operation for Power Machinery". Engineering Structure Integrity: Research, Development and application.Vol. 1, pp.121-124. October 2007. China Machine Press, China[Proceedings of the UK Forum for Engineering Structure Integrity's ninth International Conference on Engineering Structural Integrity Assessment, China, 2007]

[4] Kang Bo Studio. Practical tutorial on Visual C++ New Start 6.0, Machinery industry press,pp. 297-312(in Chinese).

[5] HONG Guosheng, 2001, C++Builder Procedure design, QingHua University publishing house, pp.165-346 (in Chinese).

[6] CHEN Xiaobing and ZOU Fengyi, 2002, SQL Server 2000 textbook, QingHua University publishing house, pp.135-169. (in Chinese).

[7] Editor Group of piston-compressor design handbook, 1970, design handbook of piston-compressor, Mechanical industry publishing

[8] Yu Yangui (Yangui Yu), Ma Yanghui, Sun Yiming, CenGang, "Techniques by software accomplish the optimization design and calculation of reciprocating compressors", Integrated Design and Process Technology. Printed in the United States of America. June 2005, 13.4 PDF.

[9] Yangui Yu (Yangui Yu), "Calculating programs of reciprocating compressor, Proceedings of the 5th International Conference on Compressor and Refrigeration", pp. 111-118，July 2005 [XI'AN JIAOTONG UNIVERSITY PRESS, CHINA, 2005].

[10] Senlin Cheng, Liang Huang, Shiqiang Peng, Jing Kang，The Optimization of Manufacturing System Based on Material Flow and Capital Flow，Advances in Systems Science and Applications，Vol.5, No.2，2005, pp. 266-270.

[11] Ma Yanghui, Yiming Sum, Yangui Yu, "The programming and application of optimization procedure in design and calculation software for thereciprocating compressor", Proceedings of the 5th International Conference on Compressor and Refrigeration, pp. 190-197, July 2005 [XI'AN JIAOTONG UNIVERSITY PRESS, CHINA, 2005].

[12] Fortuna L, Graziani S, Xibilia M G, Sot sensors for product guality monitoring in debutanizer distillation columns. Control Engineering Practice. 2005, 13(4), pp. 499-508.

[13] LI Yong, SHOA Cheng, Soft-sensor technology and its application development, Industrial instrument and automated assembly. 5, 2005, pp.6-11, (in Chinese).