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The body can be viewed from the next page.

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1 Introduction

Replacement of the Steelmaking Shops and the Hot Strip Mill of Chiba Works, Kawasaki Steel, was completed in May 1995. In the replacement, the steelmaking shops and the hot strip mills, which had been scattered around both the East Area and West Area of Chiba Works, were consolidated into two steelmaking shops and one hot strip mill in the West Area, as shown in **Fig. 1**. The hot strip mill is now connected directly to the steelmaking shops, reducing the time required to transport the slab from the steelmaking shops to the hot strip mill and the time required to reheat the slab to zero. The new plants are fully automated by process control computers, and as the result, the stabilization and improvement of product qualities and the development of new products can be achieved more easily than ever before with the older plants.

The new plants required a new production control system that was developed under a new concept, because the previous system of an old type was designed only to match the older plants, whose operation was conducted on a manual basis by the operators, and whose material transportation was too slow, in other words, the previous system was inadequate to support the operation of the new plants. The principal features are either to enhance or to develope the system including a overall-manufacturing-time-reduction-support function, an automatization-and-labor-saving-support function, and a new-product-development-support function.

This paper gives an outline of new Chiba Works steelmaking and hot rolling production control system, with the foregoing features being the major interests.

2 History of System Development and Approach to New System

Such large amounts of information processing are inevitable in the production control of a steelworks that Chiba Works has been aggressively computerized recently. Starting with batch processing, the steelworks had successively introduced on-line systems into the production control system of its major plants time and time again, and had completed in the mid-1970s.

However, as customer needs for better products performance and better products delivery grew even larger, factory automation and new product development, par-

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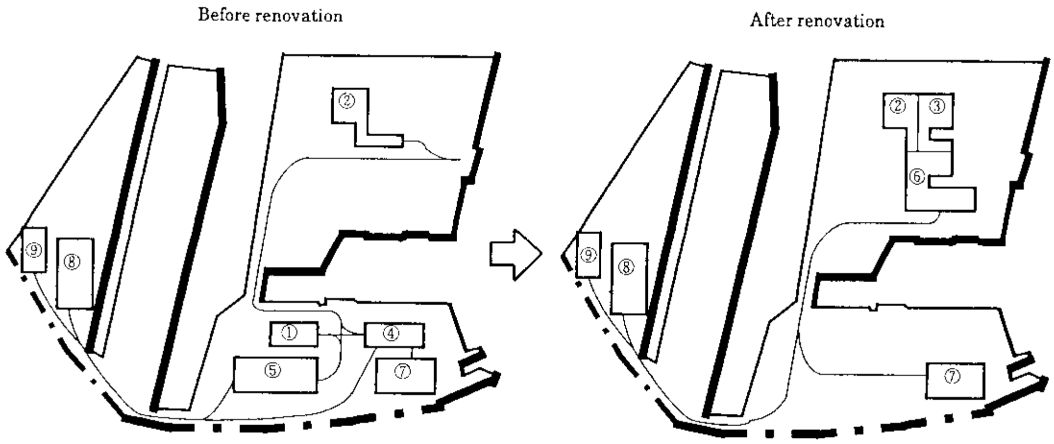

① No.1 Steelmaking Shop ② No.3 Steelmaking Shop ③ No.4 Steelmaking Shop ④ No.1 Hot Strip Mill ⑤ No.2 Hot Strip Mill ⑥ No.3 Hot Strip Mill ⑦ No.1 Cold Strip Mill ⑧ No.2 Cold Strip Mill ⑨ Stainless Steel Shop

Fig. 1 Plants layout at Chiba Works

ticularly to add higher value to products, have since been promoted. Under these circumstances, in the mid-1980s, Kawasaki Steel set about restructuring the production control systems on a whole-company basis, principally at Chiba Works and Mizushima Works, switching over in sequence to second-stage production control systems, where the objective was to consolidate and enrich the system functions.[1)]

This second-stage system, whose ultimate goal was full automation of the production control function by computer, was very large in size, with each sub-system having algorithms of very sophisticated logic. Unfortunately, for this reason, the system that once successfully met the purpose became incapable of keeping up with changes in the industrial environment around the steelworks, and the respective scheduling functions were not able to demonstrate their originally expected merits. In addition, the cost of both computer hardware and software maintenance was enormous in proportion to the size of system change.

One reason for this problem was that an idea was too much accepted that developing a production control system was properly a matter of software development on the host computer.

In developing the new steelmaking and hot rolling production control system, based on the lessons from the second-stage system, we tried anew to understand the production control system to be a means of managing the production activities performed in a steelworks' production system that consists of people, materials, and machinery. The foremost design approach to the system development was to determine whether the human system part or the computer system part should perform each task as a part of the whole information processing system supporting production management. Also considered were what computer configuration the computer system should have and what functions each computer should be responsible for, including the process control computers on the production line, where the computers of the computer-system-part provide the human-system-part and/or the machinery-system-part (or the production facilities) with information or collect information from them.

3 Outline and Objectives of New System

3.1 Reduction of Manufacturing Lead Time

Reducing the time required for information processing results in reduction in lead-time and reduction in the inventories of slab and coil at a slight amount of investment (system development expense), producing both price and non-price competitiveness.

In the new plants, the machinery system, or the production equipment itself, is an efficient one with a markedly fast flow of materials, compared to the older plants. Such a poor information system as is incapable of developing manufacturing instructions with the succeeding process without the output data from the preceding process would run behind this efficient machinery system, and, as a result, the new plants would not demonstrate their true capabilities.

However, even in the case of steelmaking instruction, for example, it is a difficult job to balance the three key elements of customer delivery deadline, material requirement from the succeeding process, and steelmaking lot design so as to develop an appropriate set of execution instructions. Implementing an automatic instruction-set-making function on a computer system thus requires such process that a gigantic amount of algorithms should be computerized. In addition, keeping up with changes in the production environment on daily bases so that the computer programs are well-maintained and the system references are constantly updated forces both of the end-user departments and the maintenance department of the computer system to bear a heavier work load than the system development department.

3.1.1 Outline and objectives of the new system

It is hardly possible at this time to make an automatic instruction-set-making computer system capable of keeping abreast of daily changes in the production environment without system-maintenance work load increasing. We therefore allocated the system functions to people and computers in the following way:

(1) People perform the decision making fuction.

(2) The computers perform the functions of standard procedures, such as calculations and checks of data.

In making the steelmaking instruction, for example, it is people that balance the three elements of customer order delivery deadline, material requirement from the succeeding process, and steelmaking production capacity to determine the customer orders that should be processed in the steelmaking process for a period of one week, as well as the weekly steelmaking schedule. The role of the computers was limited to the function that they provide people with data so that people can finish their work in as short a time as possible and check what people generated as a plan against the steelmaking operational regulations to see if it is adequate as a steelmaking instruction.

As a result, the time required to develop a weekly steelmaking instruction satisfactory to both of the process control department and manufacturing line department has been shortened to three days (**Fig. 2**). A great amount of slash-down in the size of computer system has also been accomplished, compared to a completely-automatic-oriented system.

3.1.2 Computer system specifications

The requisites for computer system specifications for a system in which people and computers work together to develop manufacturing instruction are as follows:

(1) Excellent conversational ability with people

(2) Visualized data display to people

(3) Reliable high response

Because a computer system centered on host-system processing is inadequate for these requisites, we applied a computer system configuration in which the engineering work station (EWS) performs the instruction-making function and the host computer the data-preparation and data-updating function. **Figure 3** shows an example of visualized data display.

On the display, the instruction-making person determines and modifies the casting order and slab-width reversion, as though he is playing with blocks. The

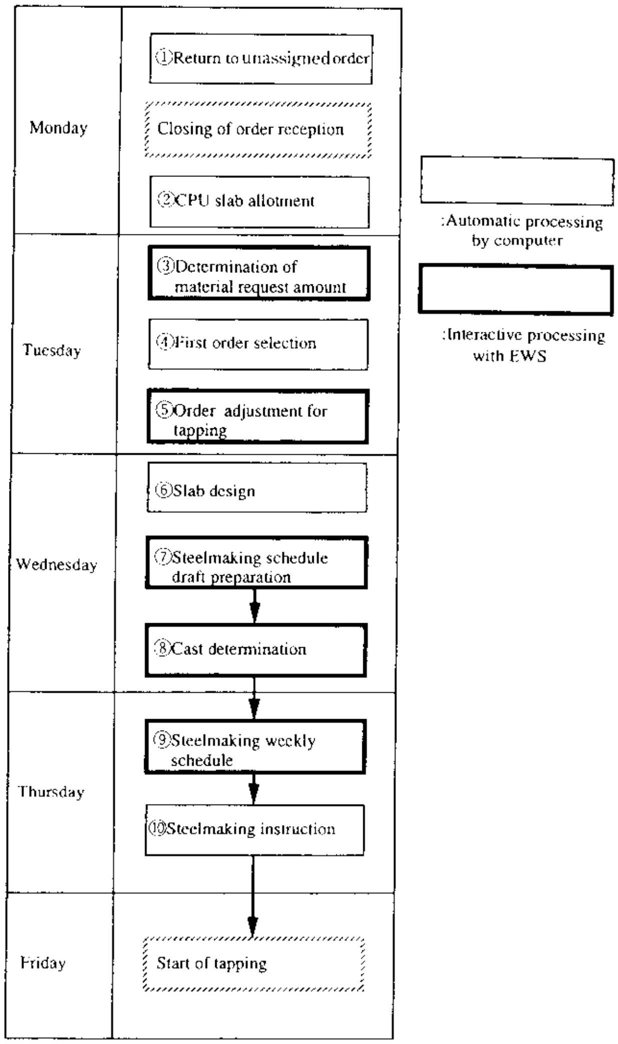

Fig. 2 Schedule of steelmaking weekly planning

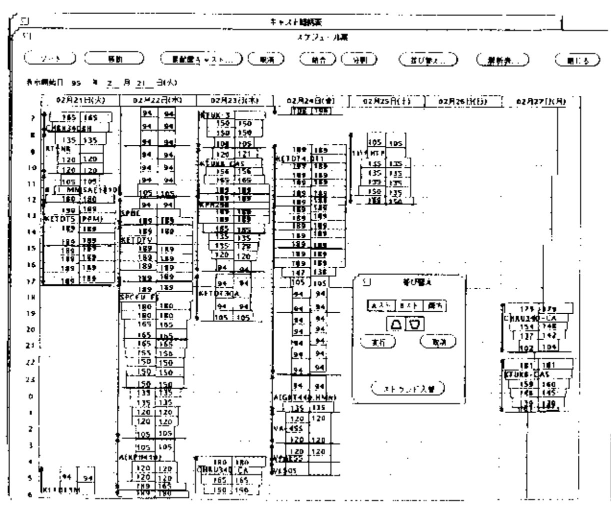

Fig. 3 EWS display image of cast scheduling

computer promptly checks what the instruction-making person has done against the steelmaking operational regulations, so he can immediately correct his mistakes, if there are any, and make an instruction of high quality in a short time.

3.2 Support of Operation of Automated and Labor-Saving Plant

The new Steelmaking Shops and Hot Strip Mill of Chiba Works are ones that thoroughly pursue automation and labor-saving, manned by the operators whose positions are designed on the assumption of the automatic operation of the plants: Accordingly, manual operation is basically impossible. Various special types of work which had been conducted through operators' decisions at the older plants were computerized so that operational guides are passed to the manufacturing lines through process control computers.[2,3]

The basic computer formation of control is the same as before. For example, in order to obtain the final manufacturing specifications for each production line, the operational control specifications, such as the strip width, thickness, rolling temperature for the object material quality, are determined individually from the customer order spcifications and the property of the very piece of material ready to be processed. This determination of the operational control specifications is conducted on the host computer by which the customer orders are managed. The process control computer then determines all other operational control specifications, using the manufacturing and control spcifications received from the host computer and the feed-forward and feed-back information derived from the manufacturing situation of the current and previous materials.

In addition to the foregoing basic formation, the new system has the following two functions as basic specifications for the full automation of the manufacturing lines.

3.2.1 Centralized management function for process control variables

The new plants are highly advanced in automation, having an even larger number of automatically controlled items than the older plants. These items include many control variables which are modified on the side of end-user departments, including the operating, technical control, and process control departments. All of these control variables are provided on reference tables external to the computer programs for easy modification without program modification.

When the managing function of these references was separated into the host computer and the process control computer, disagreement of the references between the computers would cause the manufacture of defective products. Therefore, all of the references, including the host-computer-related, process-control-computer-related, and both-host-computer-and-process-control-computer-related references, are managed on the host computer in a centralized way: When modifying a process-control-computer-related reference, the modification mechanism is that the reference table on the process control computer is modified via the host computer.

As a result, troubles caused by disagreement of the references have disappeared. In addition, a slash-down in system size has been achieved by cutting down the functions duplicated in the host computer and the process control computer.

3.2.2 At-any-time modification function for control variable

Whenever necessary, experimental operations can be conducted with some of the control variables changed to see their effect in an attempt to improve the operation or to develop new products.

Whereas the experimental operations were possible with the older plants by issuing experimental specifications to notify the operators, they are impossible with the new plants, which are far advanced in automation, as long as the relevant control variables on the process control computers are not modified. It is the same as the case of a reference table that the experimental specifications are all managed together on the host computer in order to alter the control variables on the process control computers automatically via the host computer.

This has enabled operational experiments on the new automated manufacturing lines to be carried out effectively without increasing the operators' work load. There is an additional function that it automatically selects the exact quantity of objective materials for each experiment. This function greatly contributes to improvement of working efficiency of the white-collar workers involved in the experiments.

3.3 Support of Operation Improvement and New Product Development

The analysis of the actual data of product quality or operational records often gives clues to operation improvement or new product development.

Chiba Works has had a general-purpose data analysis system named TOMAS that was developed on a host computer for the purpose of analysis of operational records and product quality data, which system has provided the end-user department analyzing operational records or product quality data with a data filing function and data analysis tools. However, the TOMAS system as a host computer system had the following weak points:

(1) Regular analyses were so frequent at the beginning of every month that they deteriorated the response of the TOMAS system, becoming an obstacle to irregular analyses. (See **Fig. 4.**)

(2) When making a report on an analysis result, one was obliged to input the analysis result into the word processor.

The TOMAS system thus was not necessarily of

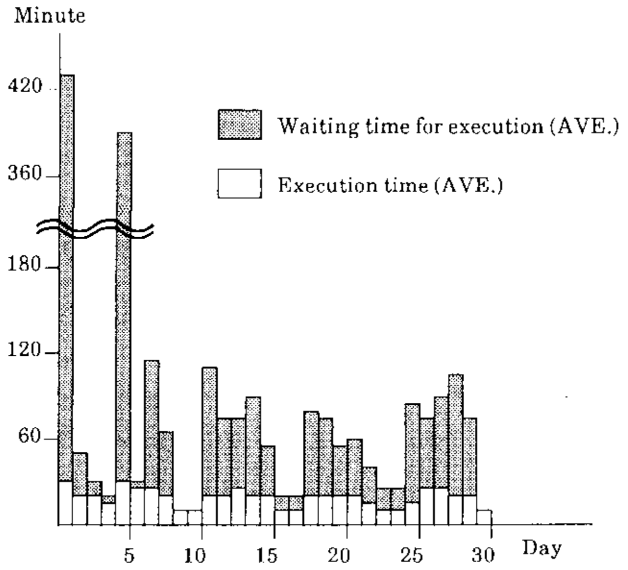

Fig. 4 Daily operation analysis of TOMAS

adequate use from the viewpoint of irregular analysis for operation improvement or new product improvement, and did not contribute very much to improvement of the working efficiency of the white-collar workers.

3.3.1 Features and purpose of the new system

Regular analysis and irregular analysis are different in purpose and character; packing both functions into one system would be unreasonable. In addition, because it is often necessary to make reports on analysis results even in the case of regular analysis, a linkage would be desirable between the host computer and the personal computer. The computer formation and the mechanism of the data analysis system thus has been designed as follows:

(1) The host computer only files the data to be served for analysis.
(2) The data for analysis are transmitted to the data base served to respective end-user departments for their data analysis; thereby the system operation load of the TOMAS system is distributed to each data server for each end-user department.
(3) The data on the data server for each department are transmitted to the personal computers.
(4) Each end-user department analyzes the data and makes reports using the personal computers.

The series of work from data analysis through documentation thus has become available on personal computers, with the computer response improved for both regular and irregular analyses, and the working efficiency of data analysis has been greatly improved.

In addition, other various analysis reports which had been available on the host computer were left with the end-user departments to be made on their personal computers, except for regular reports such as costs reports. This resulted in a decrease in computer system size, compared to the conventional type of system.

3.3.2 Computer system specifications

As long as the new mechanism of data analysis function is so designed that the host computer and the personal computer work together, the data filed in the host computer should be developed onto a table on the personal computer with a simple procedure of operation.

In addition, a backup system for the data and the functions themselves should be prepared in consideration of the hardware reliability of the personal computer.

Therefore, what were required as a computer system ensuring the above features were that the host computer backs up the personal computers' data, as shown **Fig. 5**, and that each function should be available on more than one personal computer so that each function can be executed on another personal computer even if one personal computer malfunctions.

Concerning the functional tool that transmits the host computer's data onto a table on the personal computer, what was required was that the conventional users of the TOMAS system can go to the new system with no difficulty.

We realized these requirements by installing engineering work stations (EWSs) in each department as "department host computers," which each acts as a

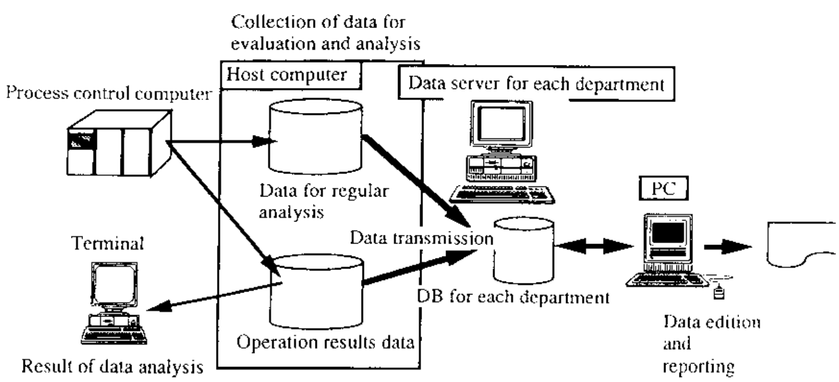

Fig. 5 New data analysis system

"department file sever" for the personal computers installed in each department, and by developing various analysis-supporting functional tools, including a functional tool that develops specific items of data existing on the host computer onto a spreadsheet on the personal computer via the department host computer.

Although the person in the end-user departments needs to be somewhat knowledgeable about comptuers, including personal computers, in manipulating this mechanism, the computer is common knowledge among today's young engineers, and the new system has been accepted and is used without difficulty.

4 Computer System Configuration and Its Features

On the occasion of restructuring the steelmaking and hot rolling production control system, in pursuit of a system that would provide the required functions, be easy to use, and be as economical as possible, we investigated what the most suitable computer configuration of the state-of-the-art technology would be.

The foremost issue of the investigation was downsizing to the UNIX system computer from the host computer of the key on-line system. Other issues included application of engineering work stations (EWSs) to the schedule-making work, use of personal computers in white-collar work, and dual-purpose use of the display terminals for both purposes of the production control system use and the process control system use.

The computer configuration of the steelworks, which had been formed over a long history centering around the host computer, has been transformed, including the computer network, through the investigation.[4]

4.1 Downsizing to UNIX System Computer

As a result of the investigation, we decided to develop the new production control system on the UNIX system in prospect of reduction in computer costs, improvement of the flexibility of computer operation by means of a distributed system (e.g. stopping computers for system maintenance is easier in a distributed system, in which each computer carries only one sub-system, than in a traditional type of system, in which one host computer carries plural sub-systems), and benefit of choice from a wide variety of software packages available in the open-system market.

Application of the UNIX system computer has been conceived to be feasible through a series of studies since 1990. Nevertheless, the following additional investigations were carried out prior to actual application in regard to both hardware and software.

4.1.1 Software investigation

The software investigation was made prior to the hardware investigation. We investigated the data-base-management and data-communication-management functions requisite in both aspects of system operation and system development. A total of 203 functions were listed as desirable functions. Of these, 154 functions were selected as indispensable functions after repeated investigation. To ensure these functions, our approach was that we chose one software package having many of the functions we thought to be indispensable, and that we domestically developed the functions that were not included in the software package we chose.

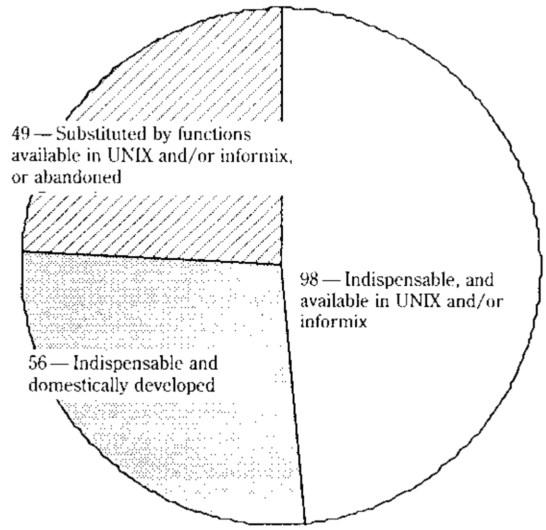

Fig. 6 Detail of preparing the 203 software functions required

We also investigated the use of an alternative language to COBOL, whose productivity we thought had reached the ceiling.

Among a group of software packages in the market, we chose informix by evaluating all these packages by degree of satisfaction of the functions we thought indispensable.

Figure 6 shows how we prepared those 203 functions.

4.1.2 Hardware investigation

Several hardware candidates for file server were evaluated in a benchmark test with a typical program and a data base that was modeled after an existing system prepared in an environment of the software package we chose. Although no decisive difference was seen in the test among the server machines of Fujitsu and other makers, the Fujitsu server was our choice in consideration of the line-up rich in high-capacity file servers and the availability of a hot-standby system.[5]

4.2 Application of EWS to Schedule-Making System

The engineering work station (EWS) contributed to the improvement of working efficiency in its application

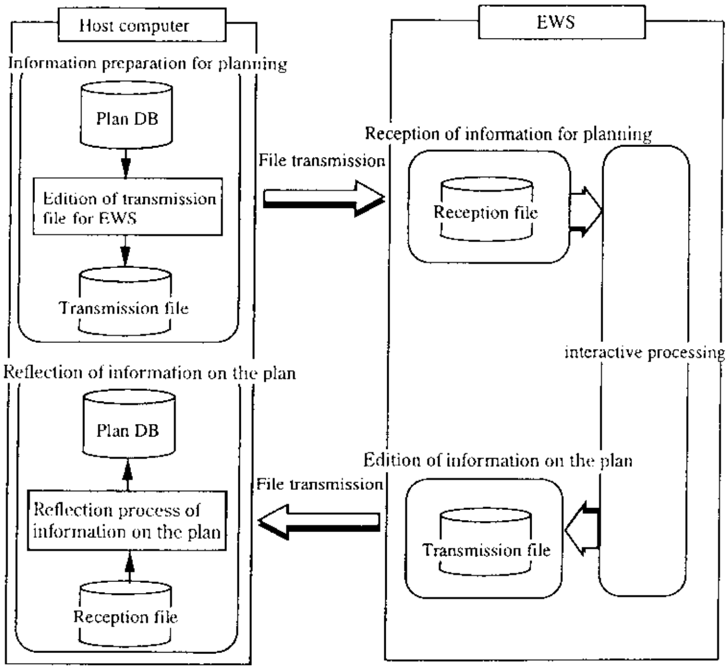

Fig. 7 Connection diagram of host computer with EWS

to schedule-making work, which is accompanied by repeated judgements of a high level.

Taking advantage of the graphical-user-interface (GUI) tools of the EWS, we realized a high level of human-machine interface (HMI). To be more specific, the fetch of information and the direction of information processing after judgment are performed through mouse-operation, and the information displayed is of many graphic data or illustrations. Together with multiple windows, these features enable fast judgment. An additional merit of the EWS was that it realized a fast response because of its use as special purpose computer.

In developing the systems to run on the EWS, we made use of FROENS, one of the so-called fourth generation languages (4GL). **Figure 7** is a schematic diagram showing the cooperative relationships between the host computer and the EWS.[6]

5 Meaning of New System and View for Future

The meaning of the new steelmaking and hot rolling production control system of Chiba Works lies in that it restored the controlling substance of production management from the computer to people, distributing the information processing functions to the extent of the human system, which information processing functions had formerly been thought to properly be integrated in the host computer.

The data accumulated in the host computer are common property of the whole company, and it is necessary that a professional department, such as the systems department, assumes responsibility for managing them. On the other hand, making good use of those data is the role of each department on the production front.

In the past, because there were various kinds of regulations, including job control language (JCL), program language, and operational regulations, in using the host computer, a professional department specializing in information systems had developed all of the information systems. That organization tended to cause a situation in which the end-user departments made excessive functional requirements, including not only must-do, but also want-to-do items, and the sytems department lacked the ability to check the necessity of the requirements, leading to excessive growth in system size and increases in system costs.

This system development went back to the question of what the sytem structure was, and the relationship between people and computers went back to what it had been before, i.e. people, not computers, conduct production control, making use of the computer system as a data providing tool. As long as the computer system is one of the tools of production control, those in charge of production control should be knowledgeable about the tool's limitations and the condition of use of the tool, or the production control system cannot be operated on a satisfactory level.

In addition, because the computers only provide people with data, each person in charge of production control should make use of the personal computer and make information out of the data, or management and/or improvement of production cannot be made.

Personal computers came into wide use only recently, and those who are capable of manipulating personal computers are consequently limited to younger engineers, and people in the manager class are not necessarily computer-literate. Together with the fact that the distributed processing itself is still a growing technology, we would admit this new system is not sufficient in terms of end-user-development (EUD) and end-user-computing (EUC). However, the new steelmaking and hot rolling production control system of Chiba Works is at least surely the first large-scale and full-scale production control system following the latest trends in information processing technology.

Our view for the forthcoming restructuring of the second-stage production control system, including the cold strip mills, is that the system should be an even more compact and more flexible production-control system whose development process should be more advanced in terms of EUD and EUC and should be more end-user-department-controlled than it was in this work, according to the development of the distributed processing technology and changes in attitude in the future.

6 Conclusions

This is a report on the outline and features of a new production control system developed to filt the needs of the new Steelmaking and Hot Rolling Shops of Chiba Works, in which the steelmaking shops and the hot strip mill are directly connected to each other.

(1) The system functions were separated into the human system part and the computer system part in such a way that computers perform calculations and checks of data and people make decisions, thereby reducing the overall manufacturing time.

(2) Centralized management of the process control variables on the host computer has enabled the process control variables, which are to be passed to the automated manufacturing lines, to be modified on an at-any-time basis, with a minimal work load on the operation and technical control departments.

(3) A device which displays the data of operational records collected by the process control computers on personal computers via the host computer has improved the working efficiency of those in charge of operation improvement or new product development.

(4) Application of a distributed computer system configuration with UNIX system computers produced a production control system with operational flexibility at a low cost.

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