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Introduction of "IT" to Production Processing Using a Machining Elements Method

by

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Abstract

Large steam turbines consist of tens of thousands of parts. Viewing from "machining elements", these parts are classified into less than one hundred "machining elements". Regarding machining time, it will take tens of thousands of hours in total to manufacture one complex product. On the other hand, the simple sum of the machining time of one hundred "machining elements" is only one hundred times.

So focusing the KAIZEN analysis on the "machining elements", it is possible to improve overall productivity effectively. Furthermore, by forming a database of the one hundred machining elements at the production engineering section, and connecting to local work stations through the internet, each local work station gains access to the latest techniques.

Therefore "anyone" can "easily" refer to the latest techniques "anywhere", "anytime", and all workers can implement the most efficient and effective manufacturing techniques.

Keywords: Machining elements method, Manufacture improvement system, Estimated values

1. Introduction

A practical method for improving the productivity at a manufacturing site is to decrease the number of man-hours which accounts for about 90% of the total cost. In a conventional method for decreasing man-hours, the machining process of each part is analyzed, the work analysis is performed by a time study and a work sampling of the process under investigation. The waste and irregularities are eliminated, a new tool is implemented, and a more efficient machining method is found. The man-hours are decreased by applying these methods to all works.

In this paper, an efficient manufacturing improvement system using information technology (IT) was developed. Conceptually the object for improvement was devised from the

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"parts" to the "machining elements" constituting the parts. It was found that thousands of parts constituting a product could be classified into at most hundreds of kinds of machining elements.

The man-hours of the total parts takes tens of thousands of hours, and it is also noted that the simple sum of the machining time of the machining elements is in the order of several hundred times. Thus, if improvement is performed focusing on the work of the machining elements, the effect of the improvement should be reflected to decrease for each part. However, how the new or improved skill is conveyed to the worker and applied by the worker is very important. To solve this problem, an information network for the entire process is established so that information can be "quickly" reviewed "anytime", "by anybody", "as required".

Thus, information on current improved technology and skills can be given to each worker using the "machining elements" information technology (IT) process proposed. In addition, the man-hour control and control of tool stock and budgets can be realized by inputting the machining time and the situation of the tool used at the work station. This should result in considerably improved productivity.

2. Conventional Work Improvement Method[1]

The conventional improvement method will be described here more specifically for the case of a large steam turbine.

Figure 1 shows an outline of parts configuration for a steam turbine. The manufacture of the steam turbine includes all parts which are subjected to machining, heat treatment and grinding of the various materials.

All parts including the completed high pressure outer casing, high pressure rotor and blade are put together in the assembly shop, and shipped to the customer after clearance adjustment, hydrostatic tests and operating tests.

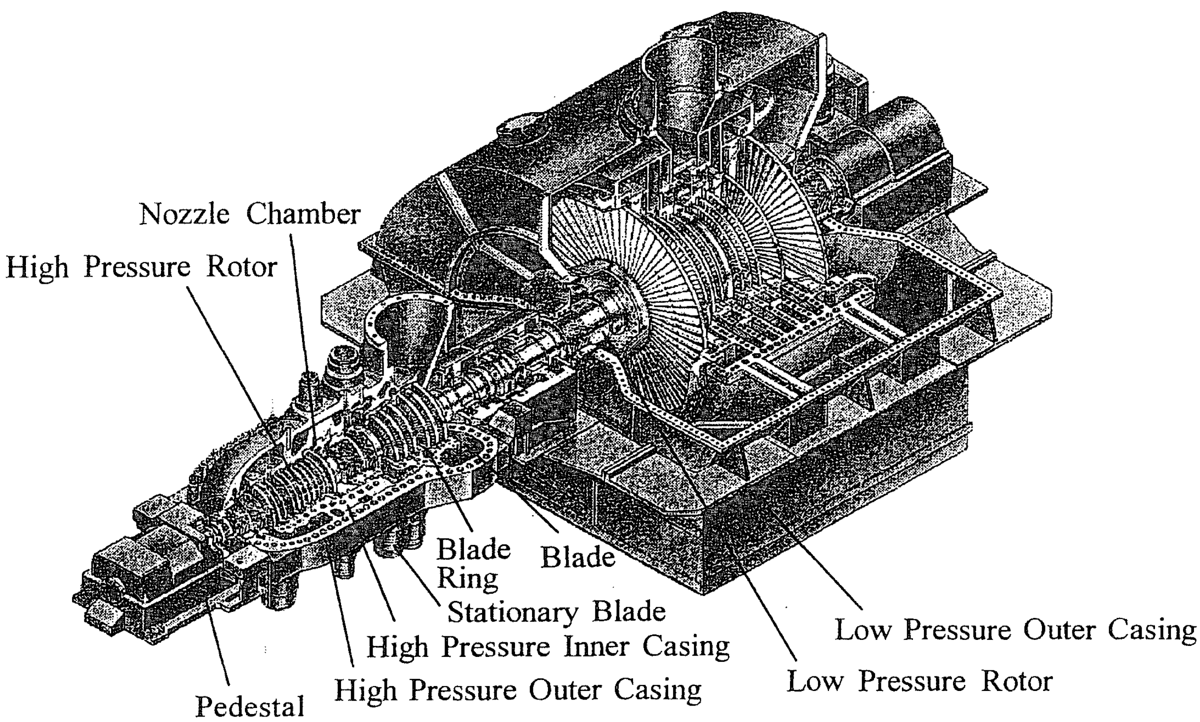

Fig. 1 Outline of Steam Turbine

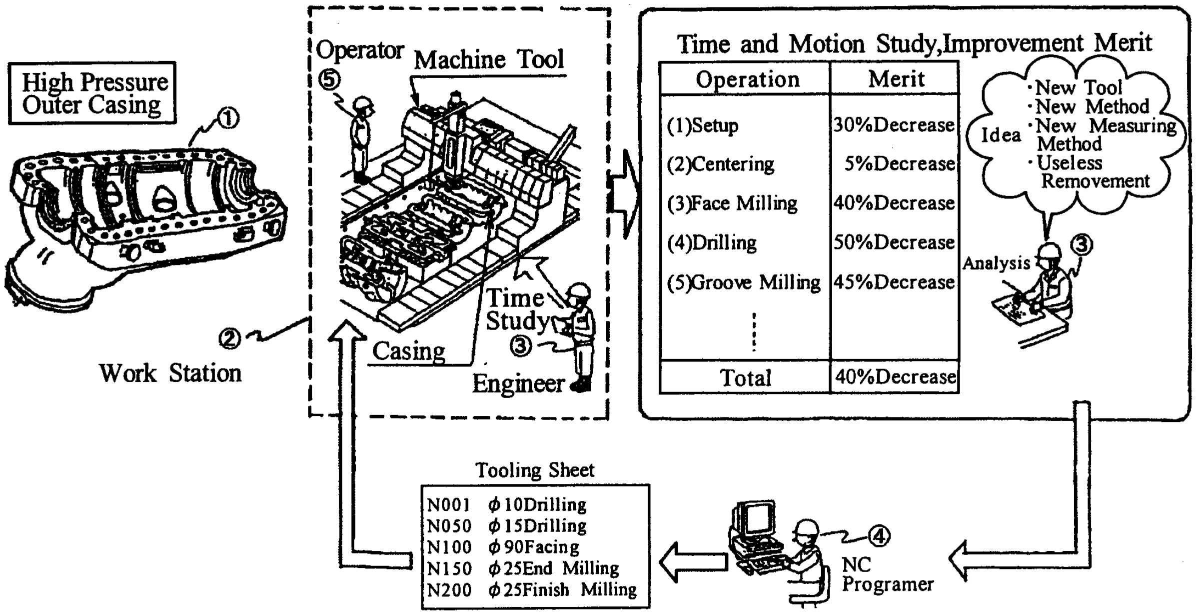

Fig. 2 Improvement Method of High Pressure Outer Casing Machining

Improvement of the manufacture of each part has been performed by process analysis and work analysis.

The specific improvement method is shown for the case of the high pressure outer casing in **Fig. 2**. Firstly, observation is made regarding production factors such as jigs and tools, the measuring method and the machining time for each stage. A stop watch and a video are used to monitor the machining conditions by a production engineer ③. Then work analysis is performed by summarizing the observation data. By analyzing the results attempts are made to reduce the number of man-hours. This is achieved by applying the improvement method to see whether or not a new tool could be used, or whether the machining paths can be reduced, whether any wasteful work can be reduced, or whether an easier way could be found to machine the part. For example, if an improved manufacturing process for the high pressure outer casing ① is available, the production engineer ③ has a meeting with the numerical control (NC) programmers ④ on an improved method, and the NC program and the tooling list are altered, and issued. The NC programmer ④ instructs the machining procedure to workers ⑤, and the improvement is tentatively complete. However, opinions regarding the alteration are discussed among the production engineers, workers, foremen, and branch managers. It often takes time to implement any alterations because of the differences in their levels of understanding or perspectives.

The man-hour decreasing activities have thus been performed while applying these methods to every part of the process. Issues of improvement include the following problems:

(1) Much time is necessary before obtaining any result because the work observation and the work analysis are performed over the total work process of every part constituting the product. It often takes several years to improve every part of the process.

(2) Only information through hearsay is available for achieving horizontal development of improvement results in similar works, and the communication takes time.

(3) Since the manufacturing process is diversified, the technical instructions are not conveyed to all workers, resulting in technology and skill variance with each work station.

(4) Contractors rarely employ production engineers, and the ordering side provides technical instruction to the contractors. However, the expected improvement is often not realized on account of people problems. For example misunderstandings occur due to instruction content

and the respective engineer's levels of technical understanding or ability.

In order to solve these problems, the machining elements analysis method was devised, and a new improvement method utilizing advances in IT with regard to speed and capacity has been developed. The content of the method which has resulted in considerable productivity improvement is introduced in the following section.

3. Machining Elements Analysis Method

The machining elements analysis method is a method devised using IT so as to easily understand the know-how and the technology in the manufacture of large and complex systems.

Regarding the definition of machining elements, if individual shapes of parts are examined, analyzed and classified, the parts are formed by combining various shapes of each part. The machining elements are defined by the shape and the dimensions are standardized for each classification. **Figure 3** shows the concept of the machining elements.

For example, these are various kinds of grooves having the inside diameter of parts A, B, C, …. The know-how of machining the grooves such as a rectangular groove, an L shape groove, and a double T groove is same even if their shapes vary. As the typical shape of these grooves, a shape having standard dimensions of a T groove is defined as a machining element. Thus, if the machining technology and the machining method of a T groove shape are established, they can be applied to any similar shapes.

For example, the process is explained regarding the machining elements analysis method in the case of a large-sized turbine. **Figure 4** shows the outline of the machining elements analysis method of the large turbine. Firstly, the total parts to be machined in the factory shop are listed up. The large-sized turbine has about 3,000 kinds of parts including a high pressure rotor, a low pressure rotor, a high pressure outer casing, a low pressure outer casing and a low pressure inner casing, etc.

If those parts are classified into common machining groups including outer diameter machining, grooving, planning and drilling, etc. They can be classified into 22 groups. Next, typical shapes and standard sizes are determined for each part. **Figure 5** shows part of the machining elements analysis. This table was coded for entry to an IT database using such as the outside diameter OS, the disk machining DK, the straight outside element is No.1. etc. Outer diameter machining and grooving machining are done on a lathe, machining locations of outer diameters are classified into 3 kinds including disk, shroud and bearing. In addition, the machining elements of the disk are further divided into 4 kinds such as straight outside

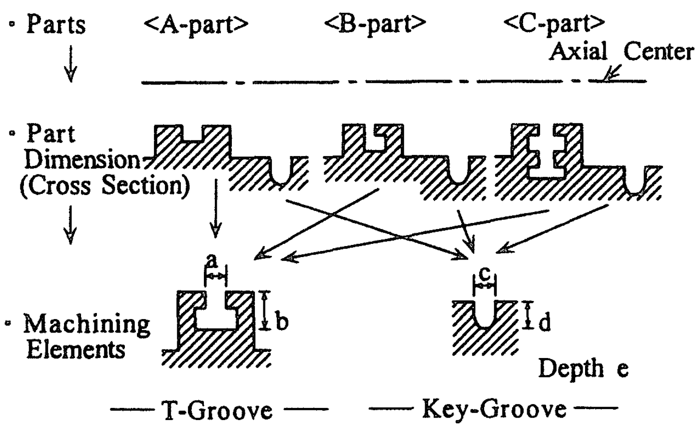

Fig. 3 Concept of Machining Elements

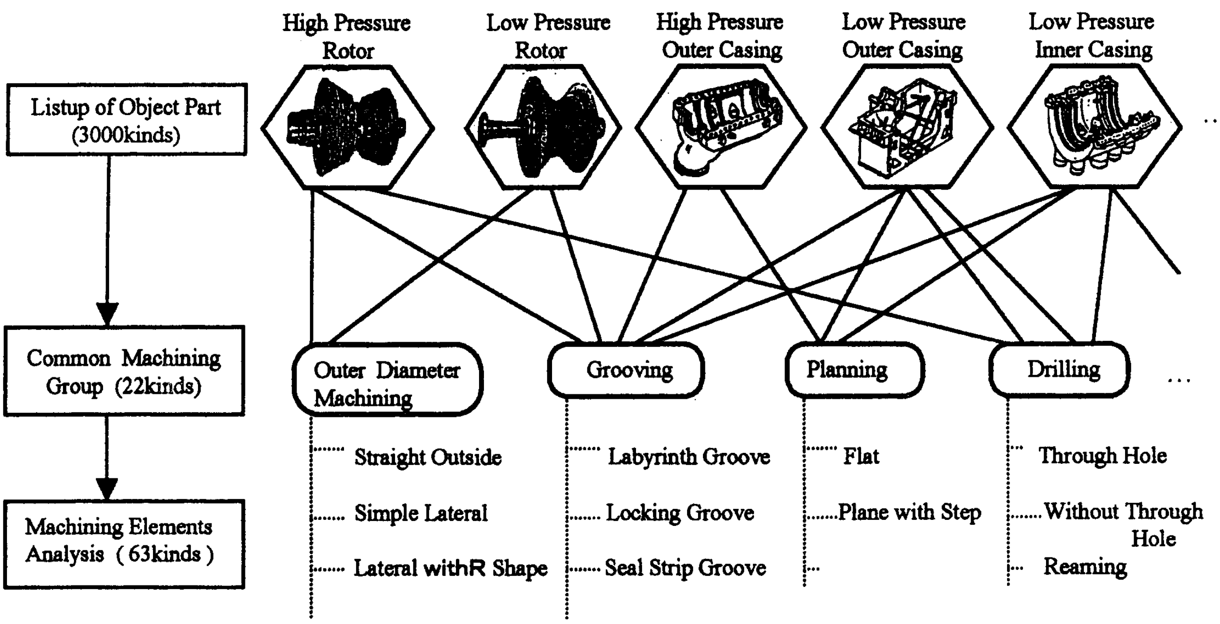

Fig. 4 Machining Elements Analysis Method of the Large Turbine

Machine	Common Group	Machining Location	Machining Elements			
Lathe LL	Outer Diameter OS	Disk DK	1 Straight Outside	2 Simple Lateral	3 Lateral with R	4 Concave Disk
		Shroud SR	1 Flat Line	2 Shroud with Groove	3 Side	
		Bearing JK	1 Straight Line	2 Side with Groove	3 Side	4 Journal
	Grooving GR	Simple SG	1 Labyrinth Groove	2 Locking Groove	3 Seal Strip Groove	
		Concave CG	1 Side Locking	2 T Root	3 Special T Root	
Horizontal Boring Machine BH	Planning FC	Plane FC	1 Flat	2 Plane with Step		
	Drilling HL	Hole TH	1 Through Hole	Without Through Hole		
		Reamer RM	1 <Φ30	2		

Fig. 5 Code Table of Machining Elements

diameter, simple lateral, lateral with R shape and concave disk. The machining locations of the shroud are classified into 3 kinds of machining elements including flat line, shroud with groove and side.

As a result of the analysis, the large turbine could be analyzed into 63 machining elements. Thus, if these machining elements are improved by focusing on the production technology, the result of improvement can be reflected in every part. The accumulated time for machining these machining elements is less than 1% of the time for machining every part. Thus, if works on the machining elements occupying less than 1% are thoroughly observed, analyzed and improved, the machining time of every part can be decreased by the ratio of the improvement effect.

In addition, only 63 database items including production factors, the machining content, the machining method, the machining time and the tooling are sufficient in utilizing the information technology, and thus, the database information can be input systematically, and easily retrieved. Workers having a certain skill level can access the information and apply it to the production factor of the machining elements, and contribute to increased production efficiency.

Therefore, regarding the technical know-how of the manufacturing industry which is the initial target, the "latest technology" can be "easily" and "instantly" reviewed by "anybody", "anywhere", through a work station terminal unit. A remarkable productivity improvement can be obtained.

4. IT of Manufacture Improvement System[2),3)]

The preparation process of the standard process sheet of the machining elements forming the IT database is explained later in this paper.

The following describes the improvement system utilizing the information communication network.

Figure 6 shows the outline of the parts machining improvement system.

In **Fig. 6**, the management station⑦ comprises a personal computer and a server (for the

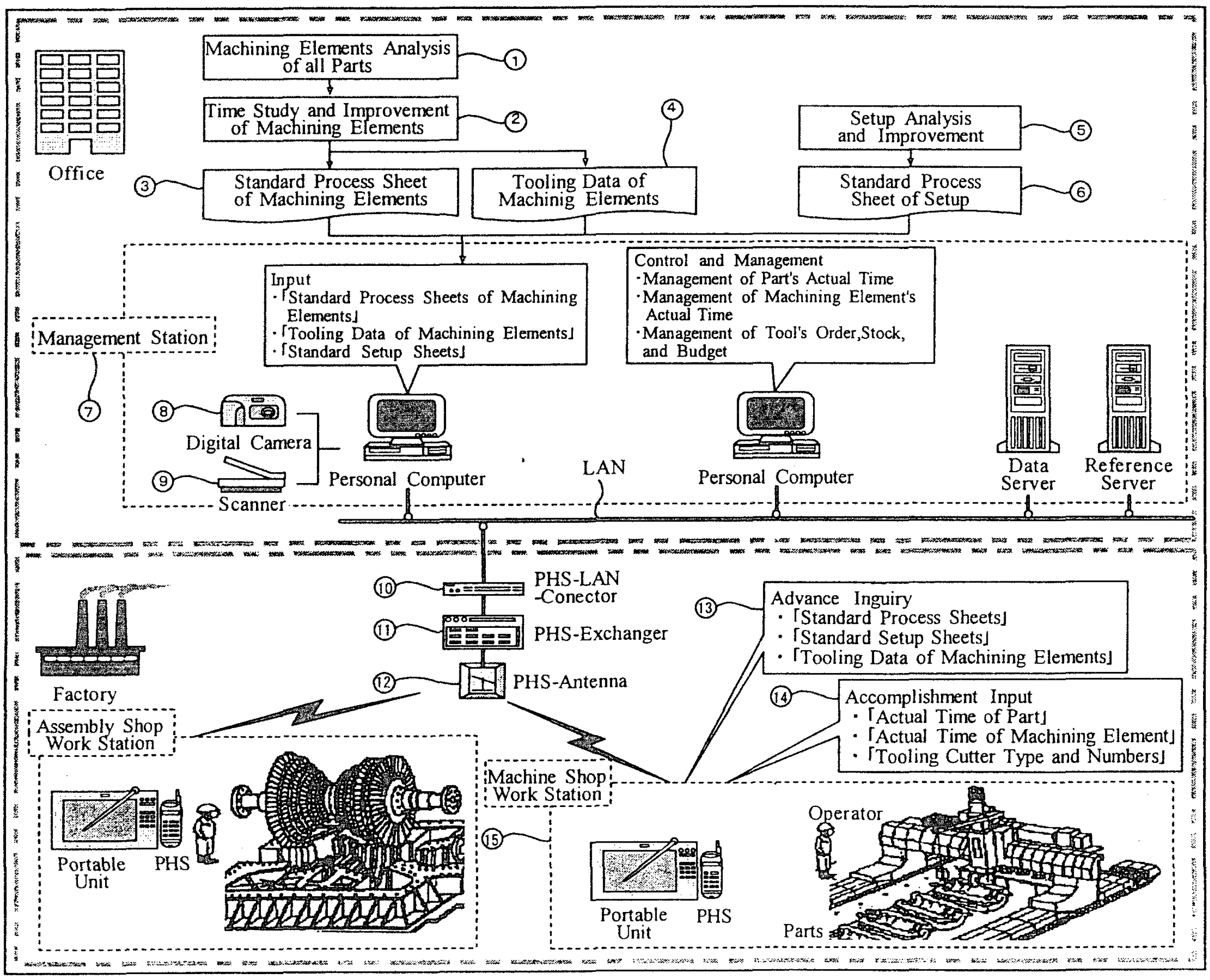

Fig. 6 IT-Outline of Parts Machining Improvement System

database and for retrieval) which are connected to each other via a LAN. The work stations ⑮ in the machining shop and the assembly shop have portable terminal units and mobile communication appliances (PHS), and the data can be transmitted/received via PHS. Transmission/reception to/from the work station are performed through the connection to the LAN via a PHS antenna ⑫, a PHS exchanger ⑪, and a PHS-LAN connector ⑩. The workers at the work stations can connect to the personal computer and the server of the management station, and can transmit/receive the work improvement information.

When starting the work, workers can make the portable terminal unit display the "standard process sheet of machining elements", "standard setup sheet", or "tooling database of machining elements", etc. ⑬, and read them as necessary before or during the work. After the work is completed, "actual machining time of part", "actual machining time of machining elements", or "kind and number of tools used", etc. ⑭ can be input from the terminal unit.

As described above, all workers can easily and quickly review the latest technical information, contributing much to the shortening of the machining time.

The following countermeasures can be taken based on data input from the work station.

(1) The man-hour control, i.e., comparison of the standard time with the actual time can be obtained immediately, and future countermeasures can be considered through analysis.

(2) The technical skill level of workers can be determined immediately by comparing the time for the machining elements. If the actual machining time is shorter than the target time, the workers have achieved a more efficient method than the standard machining method, and their machining method can be reflected in the standard method through interviews. If the actual machining time is longer than the target time, the production engineer must instruct the worker appropriately. The technical skill level can be quantitatively and immediately determined in this way, and the "how to" information and the machining method which achieved greater efficiency can become known among all workers and engineers.

(3) The service condition of the tools can be understood, and the tool stock and budget control can be performed in a timely manner by including the tool makers in the information network.

As described above, the shop control can be performed relatively easily. A practical example is described based on a machining shop, an assembly shop, foundry shop, or welding shop would be equally applicable.

Manufactures in general contract out about 40% of work, and therefore the number of contractors is very great. Thus, the exchange of technology information to/from the contractors is important for improving cost competitiveness.

Many special tools are used in manufacturing a large product, and in order to eliminate any lost time caused waiting for a tool, close cooperation with the tool makers is necessary.

Figure 7 shows the outline of a network of contractors and tool makers.

Information is exchanged between the tool makers and the contractors through the Internet via routers connected to a LAN. Regarding the technology information described above, access is made only to the required information, and the methods used by the contractors can be improved by supplying the required latest technology information.

The cost competitiveness can thus be reinforced by co-operation with the contractors through use of such an information network.

In addition, regarding the information exchange with the tool makers, the tool situation from the in-shop work station is received by the tool makers. When the tool stock is less than the allowable value, an order instruction is automatically displayed on the personal computer, and the name, quantity and delivery time of the required tools are transmitted though the personal computer of the tool maker. The number of workers involved in such as inventory

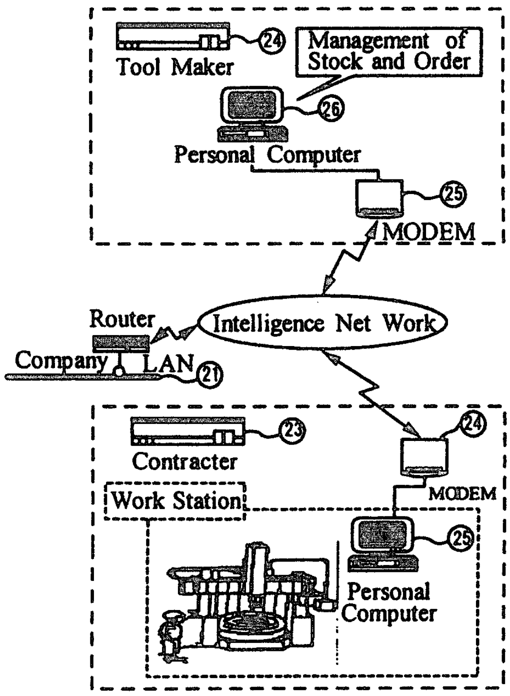

Fig. 7 Network Outline of Tool Makers and Contractors

can be decreased, the machine operation time is also increased by eliminating or reducing waiting time, resulting in productivity improvement.

5. Database of Standard Process Sheet

Preparation of a standard process sheet etc. for basic data required by the machining improvement system is described as follows. Specifically, a description is provided regarding how the database is established, and how the improvement result is reflected in the estimated machining time for "following parts" in the case of machining of a steam turbine.

Figure 8 shows the flowchart of the database.

Firstly, the total parts to be machined in the shop are listed up ①, and elements of each parts are classified into common machining groups ②. Next, the machining elements are analyzed ③, and summarized as a machining elements table ⑦.

Next, the production engineer performs the time study and the work analysis for each element, and carries out various improvements as necessary ⑧. These improvements are spirally achieved to devise more efficient methods, and the latest technology is summarized for the standard process sheet ⑩. In addition, the database is also established so as to be able to retrieve data regarding problems or mistakes in the past for each machining element. The tool database pertaining to the machining element ⑪ is established so that the workers can perform a tool based retrieval, and then utilize the tool stock and budget management functions.

In addition, the work analysis is performed regarding the setup of parts, and summarized as the standard setup sheet ⑫. The thus-prepared "standard process sheet for machining elements", "tool database by the machining element", and "standard setup sheet" are input in the personal computer, and transmitted to the server, and stored.

Further, as a result of the improvement, it can be estimated how long the next part will take to machine. The parts machining elements table ④ is summarized so as to understand at a glance the machining category and elements for each part. The ratio of machining

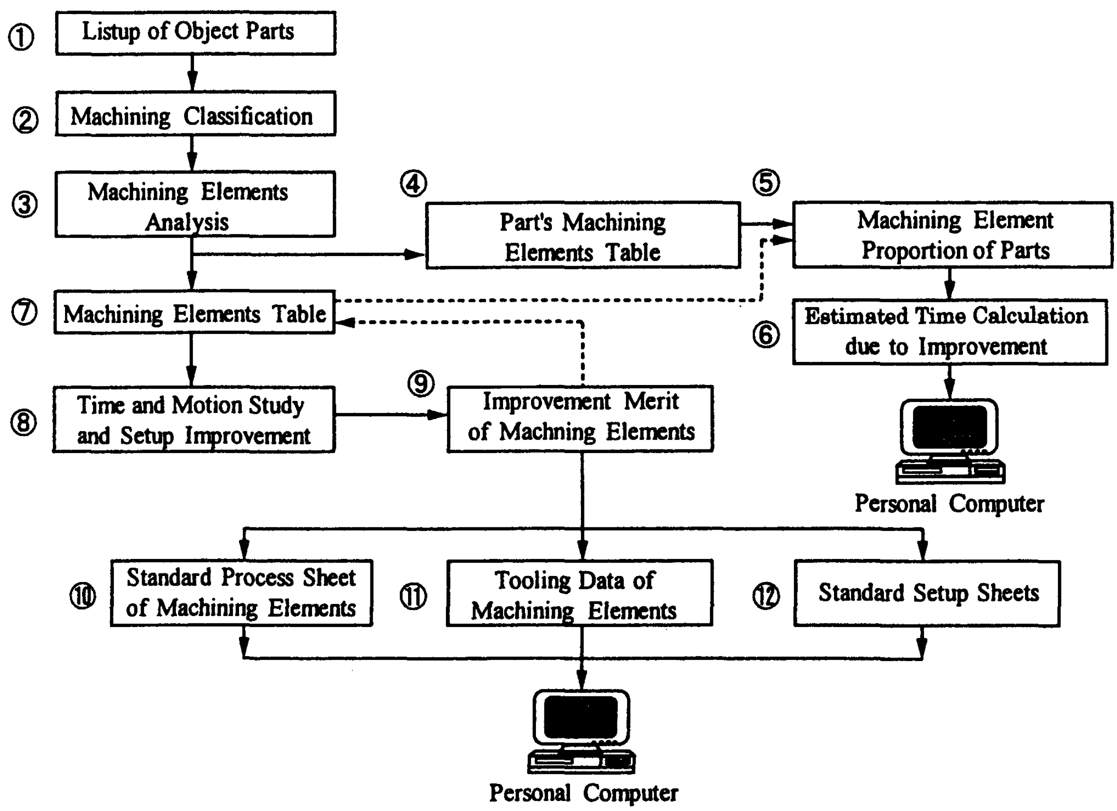

Fig. 8 Flowchart of Machining Elements Analysis, Estimated Time due to Improvements

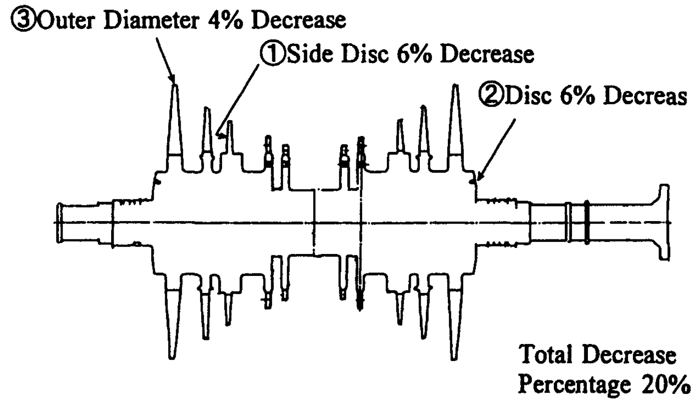

Fig. 9 Estimate of Increased Machining Efficiency for Rotor

element time to the total number of man-hours is calculated, and tabled for machining elements proportion of parts ⑤.

If the improvement result of a certain element ⑨ is obtained, and input in the machining elements table ⑦, the result is transmitted to the table of machining elements proportion ⑤, and the decreased percentage of the parts is calculated. Thus, the man-hours required to manufacture the following parts can be estimated. If the estimated values are accumulated for the total parts, the current number of man-hours can be understood, and utilized for the estimation of new orders.

Using a practical example, a description is made in detail of the estimated time calculation for the low pressure rotor shown in **Fig.** 9. For example, the ratio of the side disc machining ① to the total number of man-hours is derived from machining experience and assumed to be 20%. If the machining element time can be decreased by 30%, the percentage decrease of the man-hour total is 20%×30%=6.0%. Similarly, the percentage decrease for disc grooving ② is assumed to be 6.0%, and the percentage decrease for outer diameter machining ③ is assumed to be 4%, respectively. If the accumulated total percentage decrease for every machining element leads to be 20%, man-hour totals of all parts must also decrease by about 20%. As described, when the percentage decrease is calculated for each improvement of the machining elements for the total parts, the number of man-hours required for new orders can be better understood in advance.

In addition, by comparing and analyzing the differences between the estimated time and the actual time for each part, problems that occur in "which machining elements" of "which parts" in "which station" can be easily traced. If the actual time is longer than the estimated time, the production engineer instructs the worker appropriately. If the actual time is shorter than the estimated time, the workers method is better than the method of the production engineer. The method used by the worker is understood, analyzed, and reflected in the standard process sheet. The productivity efficiency can then be repeated by those concerned so as to pass down the improved technology and higher level of efficiency leading to improved performance.

In order to prepare the standard process sheet for machining elements, the kind of machine, the name of the objective parts, machining category, machining elements, machining shape, tool name, cutting condition, machining path, machining procedure, etc. are checked for the observation data. In addition, the observation form is prepared so as to understand the countermeasures to be taken for improvement, presence/absence of practicability thereof, and the checking method thereof. The standard process sheet includes the machining elements code, machining elements name, machining shape, machining path, work contents, service tools, cutting condition, and the machining time. Also, for preparing the standard setup sheet, the name and size of the service tools can be understood at a glance by including an image from a digital camera, setup remarks and setup times are also clearly described.

6. Outline of the Screen Composition of a Network System

The network system is explained briefly. The operating steps that appear on a terminal unit consist of "machining start/finish processing", "standard setup sheet", "standard process sheet for machining elements", "tooling waste management", and "introduction of new technology".

First, if "machining start processing" is clicked by the worker before the work, drop-down lists will appear. Bar-code numbers of the worker, group number, and machine number are chosen from the lists. Then the order, part, and machining process are directed. When the worker understands the task, "standard setup sheet" is clicked. And a parts list is shown. If a predetermined part is chosen, various outside figures of the part appear on the screen. When the most similar part is chosen, the machining process is displayed. Thus the machining process is chosen, and setup pictures taken by a digital camera, and notes of the setup appear. When the setup of the part is completed, "standard process sheet for machining elements" is clicked, and the table of machining categories appears. When a predetermined machining category is chosen, the machining element shapes are shown visually in a table. When a machining element is chosen, the standard process sheet of the element is shown. The operating process, operating time, and tooling paths for roughing and finishing are shown in this sheet. Since the part has various elements, the machining of the part is completed by repeating the various machining elements. When the work is finished, workers input the actual time taken and tool usage information, etc.

The above is a general operation process for the network system.

7. Conclusion

As described above, any part consists of a combination of machining elements. There is very little production processing data concerning these machining elements. When the introduction of IT is aimed at using this database, a simple system that workers can easily adapt to has been built. Since the data outlining how improvements have been achieved is immediately input to a computer, anyone can view the latest production method data through a network. Improved efficiency has been achieved using this system.

(1) By construction of an IT network using the idea of a machining elements method, productivity has increased by 135% in one year. The same work was achieved by half the number of production engineers previously required (from 20 to 10 men).

(2) The concept of "machining elements" is a method applicable to the general manufacturing industry world wide. In the case of machining of a steam turbine, the machining elements were summarized to 63 categories. Thus, the database was small, the input was simple, and retrieval by workers was easy. This system could easily and automatically make not only the passing down of "how to" technology but also the sharing technical information.

(3) By utilizing IT which has progressed significantly in recent years, the technology information is communicated to all workers and engineers through the network. Everybody can review the screen of the terminal unit "anytime", "anywhere" and "easily", and the new technology can be applied to manufacturing work immediately.

(4) By comparing the actual time to the estimated time on a personal computer, problems regarding "which machining elements" of "which parts" in "which station" can be quantitatively understood, and a strategy for improvement can be established.

(5) The technology information can be easily and rapidly disclosed by contractors through the network. Therefore, cost competitiveness can be achieved together with contractors.

(6) The present system can be applied to assembly, foundry, welding, tests, operation works, etc. in addition to machining, and significant improvements in productivity efficiency could be expected.

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