Productivity of the Japanese Iron and Steel Industry

—Technology for Manpower Saving—*

By Hiroshi TAKANO**

I. Preface

I am greatly honored to be awarded the “Watanabe Gisuke Prize”. I am deeply indebted for your guidance and encouragement.

Since a number of reports on Japanese iron and steel technology have been made by many predecessors in various sectors, to avoid repetition, I would like to talk about “Technology for Manpower Saving” that is resulting in increased labor productivity in the Japanese iron and steel industry.

The Japanese iron and steel industry is said to have the outstanding international competitiveness as well as superior technologies and facilities. Various reasons can be given for this. In my opinion, reasons are the high labor productivity and superior technologies to rationalize energy conservation and resources conservation.

In particular, as you know, Japanese iron and steel industry has made a great progress in technologies to rationalize energy and resources conservation since the first oil crisis. The high labor productivity also constitutes one of the greatest pillars.

Looking back to the past, as mentioned a while ago by Mr. De Lancey, the difference between respective iron and steel industries of Japan and U.S.A. was a bone of contention at the time of establishing the first Trigger Price Mechanism in 1978.

At that time, Prof. Hans Mueller and Prof. Kiyoshi Kawahito of Middle Tennessee State University jointly presented a report on respective steelmaking costs of Japan and U.S.A. According to the report, Japan's cost per ton of product is calculated to be lower by \$118, and out of this \$118, as much as \$87 is a result of the difference in labor cost between the two countries. This cost difference between Japan and U.S.A. clearly reflects Japan's high labor productivity because there is not much difference in the wage rates between the two countries.

Regarding the progress of manpower saving technology that has increased the labor productivity of the Japanese iron and steel industry, this has not only resulted in the increased labor productivity, but has also made an intangible and great contribution to the Japanese iron and steel industry. In other words, as will be elaborated later, the manpower saving technology has contributed greatly to the improvement of the working environment. The iron and steel industry has such undesirable working environment as high

temperature and hard physical labor, which cannot be avoided, although such environment is on a rapid decrease.

Elimination of such undesirable working environment results in the qualitative improvement of labor in the Japanese iron and steel industry, and the high level thereof enjoys a high international reputation.

In addition, this improvement in working environment results in friendly relationship between the labor and management. Thus, this even further improves the superiority of the Japanese iron and steel industry.

Now I would like to explain about the labor productivity and technology for manpower saving.

II. Evolution of Labor Productivity

To begin with, let us take the labor productivity in Japan in retrospect. Figure 1 shows the evolution of labor productivity of major advanced countries during the last twenty years. Due to the difference of outside order ratio, it is problematical to discuss the differences of absolute values of respective countries as they are. As to how much the Japanese labor productivity has increased, however, this can be well understood by comparing Japanese labor productivity with the labor productivity of other advanced countries. In other words, today, compared with 1960, the labor productivity increase in Japan shows as much as five times as against about 1.5 to 2 times in

Fig. 1. Evolution of labor productivity (production) in respective countries.

(Source: Statistical Handbook of the Iron and Steel, ed. by The Japan Iron and Steel Federation, (1980).)

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other advanced countries. The continued increase in Japan can still be seen, notwithstanding the slow-down due to the decreased production after the first oil crisis in 1973.

In the iron and steel industry, when we discuss the labor productivity, the quantity unit as shown in Fig. 1, *i.e.*, tonnage per man (t/man) is generally used as the standard in order to clarify the technical effects (*i.e.*, to counteract the effect of commodity prices *etc.*).

For your reference, Fig. 2 shows the evolution of labor productivity based on sales volume. Figure 2 shows, for example, the sales volume per manpower of each one company in Japan, U.S.A. and F.R. Germany. This shows the same trend as in the labor productivity based on the production shown in Fig. 1 and superiority of the Japanese iron and steel industry over other advanced countries can be clearly observed.

III. Technology That Contributed to Manpower Saving

1. Classification

Now, I will explain the manpower saving technology that provided the basis for such a high labor productivity as mentioned earlier.

The manpower saving technologies consist of various factors. Here, however, we will classify the technologies into five factors:

- 1) Adoption of larger facilities and higher speed: Manpower saving resulting from increase in productivity due to adoption of larger facilities and higher speed.
- 2) Mechanization: Manpower saving as a result of mechanization in lieu of conventional operation by manpower.
- 3) Automatization and systematization: Manpower saving resulting from automatization of opera-

tions, computerization or systematization of control.

- 4) Adoption of continuous processes: Manpower saving due to continuous processes, and elimination of processes.
- 5) Others: Items that cannot be classified in any of the above categories, *e.g.*, manpower saving due to technological advances made by industries other than the iron and steel industry.

2. Effects

Now, effects of those factors on manpower saving will be reviewed here.

Notwithstanding the difficulty in accurately calculating the contribution ratio of respective factors, in order to get a general hold of the situation, comparison of labor productivity was made by taking, for example, the three departments of blast furnace, converter (excluding ingot making and continuous casting), and hot rolling (excluding slab scarfing), of the former Mizue Works and the present Ohgishima Complex within NKK's Keihin Works. In all cases, such high increases in labor productivity as 2.0 to 3.5 times are observed. Analysis of manpower saving by those factors classified as mentioned before shows results as shown in Fig. 3. This indicates that the effect of respective factors considerably varies depending on different departments. In other words, the effect of larger facilities is very high both for the blast furnace and the converter, of which respective effects are 65 % and 45 %. As against those percentages, the effect is only 10 % for the hot rolling department. In addition, the effect of automatization shows fairly high ratio for all the above departments. In particular, hot rolling department shows a high ratio of as much as 60 %.

3. Description

The following explanation is given as to the respective manpower saving technologies by taking examples.

1. Adoption of Larger Facilities and Faster Speed

Adoption of larger facilities and higher speed is said to be the greatest feature of the Japanese iron and steel industry and this trend has continued after World War II.

Figure 4 shows the evolution of furnace volumes of the blast furnace and the converter. In both of these facilities, a rapid growth in the adoption of larger facilities is seen and it can be observed that this has

Fig. 2. Evolution of labor productivity (sales volume) in respective countries.

(Source: Analysis on Operations of the World's Enterprises, ed. by the Ministry of International Trade and Industry, (1979))

Fig. 3. Contribution ratio of various manpower saving technologies.

Fig. 4. Evolution of adoption of larger blast furnace and converter.

greatly contributed to manpower saving.

In the case of converter, for example, the required manpower for the present converter of 300~350 t capacity compared to that for the initial converter of 50~60 t capacity, is less than 1/2 in contrast to the larger furnace capacity. This reminds us of how great the manpower saving effect is, notwithstanding the fact that the effects of mechanization and automa-tization are also included. However, as you can see from the evolution of maximum furnace capacity, the adoption of larger facilities are slowly decreasing. In other words, from the viewpoint that the cost advan-tage of installing and operating larger facilities is near-ing the marginal point, and that blast furnace, in par-ticular, has little flexibility at the time of relining or for production adjustment at the time of economic fluctuations *etc.*, development of such technology in line with the adoption of larger facilities is essentially considered to have come to the end of the chapter, though the average furnace capacity will increase due to so-called “scrap and build” in the future.

As examples for rolling departments, Fig. 5 shows the evolution of production capacity and rolling speed per mill in hot rolling and cold rolling. Although the progress of the adoption of larger facilities shows the value lower than those in the cases of the iron and steel making departments, the hot rolling mill shows the value of almost 2 times that of the initial hot roll-ing mill and this also means a great effect on man-power saving. Slowdown of the adoption of larger facilities is seen also in this sector as well as in iron making and steel making departments. Not much progress can be expected in the future in this respect.

2. Mechanization

Table 1 shows the mechanization examples in re-spective departments. Characteristics of mechaniza-tion place emphases on operation under such undesir-able working environment as high temperature and hard labor, or on the simple repetitive operation. It is worthy of mention that for the former, mechaniza-tion of operations at the top of coke oven, cast house, as well as mechanization for steel-making and ingot making is making advancements and that for the latter, mechanization of such operation as sampling and product binding are also making advancements.

As mentioned before, elimination of labor out of

Fig. 5. Evolution of adoption of larger facilities and high speed facilities for hot and cold strip mill.

Table 1. Mechanization examples by departments.

Department	Mechanization examples
Harbor and Raw materials	Auto-sampler
Iron making	Mechanization of operations in cast house (Opener rod exchanger and charger), Repair of runner (Pouring method and automatic stamper), and Operations around coke oven
Steel making, Slabbing, and Blooming	Slag skimmer, Sub-lance, Rotary nozzle, Cleaning machine for base plate, and Spot scarfer
Hot strip mill	Roll related equipment (Automatic changing equipment and chock in-stalling/removing equipment), Auto-matic hanger for crane, Automatic binding, and Automatic packing line
Cold strip mill	Width gage, Length gage, Detectors for defects, and labeling/stamping machine
Test and Analysis	Test specimen working machine and Test specimen installing/removing e-quipment
Maintenance	Automatic lubricator (oil/grease)

this section results in not only the manpower saving effect but also greatly contribute to the qualitative improvement of labor in the iron and steel industry, and it can be safely said that such elimination pro-vides the basis for the high efficiency of the technical workers that attracts international attention.

Taking the steel making shop as an example, some mechanization cases will be introduced (Photos. 1 to 3).

Photograph 1 shows the teeming operation in ingot making using rotary nozzle. The conventional stop-per operation of ladle by manpower has been con-sidered as one of the rigorous operations in terms of working environment and a difficult operation be-cause of the larger ladle size. With the development of rotary nozzle mechanism, however, this operation has been replaced by the easy pendant operation as shown in this photograph.

Photograph 2 shows the cleaning machine for bot-

Photo. 1. Teeming operation in ingot making with rotary nozzle.

Photo. 2. Cleaning machine for bottom pouring base plate in ingot making.

tom pouring base plate in ingot making. The base plate operation in ingot making has been regarded as most problematical in terms of working environment and personnel, and are rapidly decreasing as a result of increase in continuous casting. This operation still remains, however, for the purpose of special steel ingot of large size *etc.*

This equipment enables to speedily carry out cleaning of base plate through remote control, and settles the severe environment problem.

Photograph 3 shows the partial scarfing equipment for slab (spot scarfer). Mechanization of overall scarfing has been adopted as hot scarfer and cold scarfer since the early stage. The partial scarfing, however, greatly depends on manpower even at present, and is one of the subjects for study in manpower saving. This equipment is of a partial scarfing type, operated through remote control to carry out scarfing of defective portions that has been inspected ahead of

Photo. 3. Spot scarfer for slab.

Table 2. Automatization examples by department.

Department	Examples for automatization computerization, and Systematization
Harbor and Raw Materials	Centralized control system of raw materials
Iron making	Combustion control of coke oven, Charging in BF, and Blast control
Steel making, Slab- bing and Bloom- ing	Dynamic control of converter and Auto- matic pouring for continuous casting
Hot strip mill	Reheating furnace combustion control, AGC, Unmanned operation of slab yard and coil yard, and NC opera- tion of roll grinder
Cold strip mill	Cold rolling on-line system (Systemati- zation of scheduling) and NC opera- tion of roll grinder
Transport, Products inventory and delivery control	Centralized control system of locomotives, Unmanned crane, Automatic warehouse, and On-line system for products inventory and delivery control
Test and Analysis	Automatic Testing machine and Auto- matic analyzing machine
Maintenance	Systematization of repair equipment control and Computerization of repair planning
Utilities	Centralized control system of energy

time. This scarfing equipment is expected to further advance to such stage of development as completely automatic, integral system including automatic flaw detector, automatic marking, and automatic scarfing.

3. Automatization and Systematization

Based on the progress of control technology from both software and hardware aspects, and on the development of computer utilizing technology, the Japanese iron and steel industry has expeditiously proceeded with the systematization of control method as well as with the automatization of production method.

Table 2 shows such examples. Great strides in manpower saving have been achieved through automatization and systematization in transport method

as well as in combustion control of coke oven, automatic pouring of continuous casting, and in automatization of processes such as AGC of rolling and further through systematization of control system such as process control, maintenance planning and energy control.

NKK's Ohgishima Complex is considered to provide typical examples in this respect and so my explanation will be based on a few examples of the Complex. I hope this view will not sound one-sided.

To begin with, hot strip mill will be used as an example for the explanation of the production process.

This shop has been planned and constructed using only the best of NKK's manpower saving technologies. Table 3 shows comparison of personnel between Ohgishima's hot strip mill with that of an ordinary hot strip mill (here we have used NKK Fukuyama's hot strip mill as an example). This comparison shows that the new Works enable manpower saving of as much as 60 %.

Technologies permitting such a high manpower saving consist of the following.

- ① Ideal layout
- ② Completion of unmanned yard (slab yard and coil yard)
 - i) Development of unmanned crane
 - ii) Development of unmanned equipment for incoming and outgoing deliveries
 - iii) Development of yard control operating system
 - iv) Development of on-line products controlling system
- ③ Other technologies
 - i) Completion of production control system
 - ii) Development of rolling control model
 - iii) Automatic acceptance for quality performance
 - iv) Modernization of roll shop
 - v) Development of coil cooling equipment

As can be determined from the comparison of personnel shown in Table 3, the greatest feature of such technology is to unman the slab yard and coil yard that heretofore had been mostly behind automatization. Therefore, in this respect, a little more detailed explanation will be given.

Figure 6 shows the comparison of layout between Ohgishima hot strip mill with that of a conventional hot strip mill the feature of which is the slab yard and the coil yard.

The layout of the conventional yard consists of two to three buildings whose widths are several tens of meters long. Each building basically has a parallel layout with several travelling cranes mounted.

As against this, the layout of a new yard has buildings of shorter widths and a number of buildings are transversally arranged in a row for operation with a travelling crane per building, to avoid interference between cranes. Furthermore, the unmanned yard has been realized by the development of control operating system of each yard through the technology for unmanned operation of those cranes and delivery cars to and from the yard. Pictures have been taken of the slab and coil yards for your information. (Photos. 4 and 5.)

We will now take up the centralized control system of energy as an example of systematization of control method.

Figure 7 shows the centralized monitoring control system of Ohgishima Energy Center. This system allows unmanned operation of energy facilities in about 30 different locations throughout the Works. In this way, all energy data to be transmitted (such as power, fuel, water, etc.) are processed by the on-line

Photo. 4. Slab yard, Ohgishima Hot Strip Mill.

Photo. 5. Coil yard, Ohgishima Hot Strip Mill.

Table 3. Hot strip mill—Manpower saving effect.

		New mill	Existing mill	Balance
Personnel (men)	Slab yard	12	64	52
	Reheating furnaces~ Down-coiler	60	84	24
	Coil cooling yard	8	88	80
	Finishing	56	108	52
	Products yard	4	44	40
	Shipping	36	52	16
	Roll shop	40	84	44
	Total	216	524	308
Productivity (t/man·month)		1 250	700	550

Fig. 6. Layout comparison of hot strip mills.

computer in the energy center, and the comprehensive demand and supply control of energy is carried out. The system allows, with only a small number of personnel, to successfully carry out the efficient energy control that is considered to be one of the biggest problem at present.

4. Adoption of Continuous Processes

Adoption of continuous processes, in parallel with adoption of larger facilities and higher speed, is considered to be one of the greatest features of the Japanese iron and steel industry. While the adoption of larger facilities and higher speeds have somewhat slowed down with the start of low economic growth brought about by the first oil crisis, the adoption of continuous processes is on a conspicuous increase. This trend is expected to continue throughout this decade.

Table 4 shows examples of continuous process technologies. Herein included are elimination of a mixer resulting from the progress of technologies for blast furnace and converter and elimination of such process as hot charge resulting from the progress of slab production technology (*i.e.*, elimination of slab scarfing). Nevertheless, continuous casting and continuous annealing can be mentioned as typical examples for the essential technology towards continuous processes.

As you well know, the continuous casting has recently shown a conspicuous growth, what was less than 10 % in 1970 has increase to 64 % in 1980 as regards ordinary steel, and further growth to 85 % is predicted for 1985. Since the manpower saving ef-

Table 4. Examples of adoption of continuous processes by departments.

Department	Examples of continuous processes and Elimination of processes
Steel making, Slabbing and Blooming	Elimination of mixer and Continuous casting
Hot strip mill	Hot charge, Direct rolling, and On-line heat treatment
Cold strip mill	Fully continuous type tandem mill and Continuous annealing

fect of continuous casting varies greatly depending on respective cases, it is hard to generalize such effect.

If the continuous casting is completely substituted by ingot making, slabbing and blooming, then manpower saving of about 50 % is considered to be possible and fairly large manpower saving effect is considered to be attainable.

The continuous annealing is a typical technology that has been researched, developed, and applied in Japan for industrial purposes. This is widely attracting the international attention, as well. At present, this is one of the topmost technology being exported.

Figure 8 compares the conventional batch annealing process with the continuous annealing process. With continuous operation of five processes (from electrolytic cleaning to recoiling), transport of products has been mostly omitted, the conventionally employed number of cranes reduced from 10 to 2, and

Fig. 7. Total energy control system.

the manpower saving of as much as 73 % has been attained.

5. Others (Effects resulting from technological progress made by industries other than the iron and steel)

The manpower saving technologies consisting of technologies towards larger facilities, mechanization, automatization, and continuous processes have been explained in the foregoing based on respective examples. What I would like to emphasize here is that those technologies could not have been achieved solely within the iron and steel industry, but was possible in

part because of the technological advances in various other industries.

For example, technological advancement in the heavy industry, engineering and construction enabled installations of larger facilities with high reliability. The technological advancement in instrumentation, controlling, computer, *etc.* allowed development of iron and steel industry's technology towards automatization.

At this time, I would like to explain about some of the items not included in the previous classification in

Fig. 8. Manpower saving resulting from continuous annealing process.

regards to the effects of the technological advancements made by other industries on the manpower saving.

One of them is related to the extended lives of furnaces and ladles as a result of improvement in the quality of the refractories. Since the iron making and steel making which are the upper stream processes in the iron and steel industry, deals with the molten metal of high temperature, the refractories play a very important role. Recently the quality of refractories has been improved dramatically and consequently, the life of blast furnace, converter and various ladles has greatly increased.

Figure 9 shows evolution of manpower for furnace repair of a converter at NKK. This clearly shows the effects of longer life along with the effect of larger converter on the reduced manpower for the furnace repair, and it can be understood that the improvement in the quality of refractories constitutes one of the factors in manpower saving.

What can be mentioned next is the decrease in anomaly of equipment as a result of technological progress made on electrical and mechanical parts. Figure 10 shows the developmental evolution of electrical equipment for rolling facilities.

The decrease in the amount of anomalies and ease of maintenance, *etc.* allows manpower for repair to be decreased, notwithstanding the increase in the electric control related facilities along with automatization resulting from evolution of logical element, for example, from magnetic elements to transistors, and further to ICs and LSIs.

IV. Future Prospects

I have thus far explained the evolution of labor productivity in the Japanese iron and steel industry, and the manpower saving technologies in which the labor productivity is based. Finally, I would like to add some of my own considerations with respect to prospects in the future. To begin with, regarding respective technologies, the adoption of larger facilities and higher speed have almost reached the marginal point as mentioned before and I do not think great expectations can be held for the future in this respect. However, such newer technology as continuous cast-

Fig. 9. Evolution of manpower for furnace repair for converter.

Classification	Year					
	1955	1960	1965	1970	1975	1980
Main motor by insulation classes		B class			F class	H class
Main circuit		D.C. generator			Under special circumstances	
D. C. power source		Mercury rectifier			Thyristor	
Field power source		D.C. generator + Rotating amplifier			Thyristor	
Cooling type of main motor					Unit cooler	
Computer control						
Sequence control		Relay sequence			Sequence controller	
Logical element		Magnetic logical element			IC logical element	
			Transistor logical element		LSI element	

Fig. 10. Developmental evolution of electric equipment for rolling facilities.

ing *etc.*, for example, still have room for further development. The capacity for continuous casting of slab that has until quite recently been said to be 100 000 to 150 000 t/month is now being rapidly improved with the aim of 200 000 to 300 000 t/month, and the manpower saving effect can be greatly expected in the future.

On the other hand, mechanization and automa-

zation in particular—by using robots, for example—is rapidly gaining ground recently in various industrial sectors and is now most conspicuously widespread in the automobile industry *etc.* In the iron and steel industry, however, environmental conditions for operations and objects for operation are multifarious. Therefore, utilization of robots for general purpose is very limited and not as popular in this industry.

For example, according to the research carried out by Japan Industrial Robot Association, 13 800 industrial robots were employed in 1979 throughout Japan, of which 2 200 robots were employed by the automobile industry and only 58 robots were employed by iron and steel industry. Development of mechanization is considered to be required in the future through development of special technologies in a manner to meet the requirements of respective cases.

In addition as for automatization, emphasis has been placed on the main line of production process rather than elsewhere. The manpower saving effects is expected to continue in the future, with the trend to place emphasis on such auxiliary sectors as finishing, inspection, checking and repair.

As regards continuous processes, further development can be expected as the emphasis are presently placed mainly on this area from the viewpoints of not only manpower saving, but also resources and energy conservation. “Adoption of continuous processes” was used as one of the greatest themes of technological development in a report “Future Problems of the Japanese Iron and Steel Industry and Measures to Be Taken” recently prepared by the Ministry of International Trade and Industry. Examples taken herein are “Direct Connection of Continuous Casting and Hot Rolling,” “Adoption of Fully Continuous Operation of the Entire Cold Rolling Processes,” or “New Refining Processes with Elimination of Coke Oven and/ or Sintering Processes,” *etc.* In the future, research and development of those new technologies for the continuous processes can be expected to further advance and greatly contribute to the manpower saving.

Furthermore, since the smooth flow of materials and products and rationalization of transport result in a very great manpower saving effects, research on the plant layout through sufficient utilization of technologies for automatization and continuous processes, is a very important task. In the future, when constructing new plants, the up-to-date layout with emphasis placed on flow of materials and products is expected to be further adopted.

Now, apart from the individual technology, looking at the iron and steel works in Japan from overall aspects, quite a few differences can be observed in introduction of new technologies depending on respective sectors though they are newly equipped powerful works.

In the future, through development of the lagging-behind-areas by respective works, the labor productivity in Japan will continue to increase as a whole, and in my opinion, the Japanese iron and steel industry will be able to maintain the international superiority.

Improvement in productivity has so far been explained with emphasis on technologies and facilities, but aims to grasp the processes in relation to technologies and facilities as well as to create conditions in which the capabilities of personnels can be fully realized. Researches on both aspects of hardware and software are collectively achieving the results in those respects. Researches on this sector, *i.e.*, so-called “software” researches by Committee on Industrial Engineering, the Japan Iron and Steel Federation, and others, have attained a number of achievements. Further achievements can hopefully be expected in the future.

Last but not the least, I would like to add a few more words on the concept of labor productivity. As mentioned before, in the iron and steel industry, the labor productivity is expressed based on the quantity unit, *i.e.*, t/man. In the future, however, I think it will become necessary to collectively express the labor productivity also in value unit, *i.e.*, yen/man. In other words, as explained before, the labor productivity up to the present time has shown almost the same evolution whether the productivity is based on production (t/man) or sales volume (yen/man). In the future, however, considering addition of processes along with sophistication of products, or increases in fabrication degree, the tendency may not necessarily be in the same status. Therefore, the productivity should be reviewed not only from the quantitative aspect but also from or collectively with the viewpoint of value with considerations given to sales volume or added value.

At this occasion of receiving the prize, I have so far explained about the productivity in the Japanese iron and steel industry, with emphasis placed on the manpower saving technologies. In concluding my speech, I hope that further technological development in this sector will provide the basis for the progress of the Japanese iron and steel industry.