

Summary and Prospects of Digital Transformation for Production Management

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Abstract

In the steel production process, we aim to achieve large-lot production in each process (maximization of productivity, quality stabilization, and minimization of cost) for small-lot orders of a wide variety of products, while satisfying product specifications and delivery dates for each order. It is a process of making different products from natural raw materials. We have developed an integrated production planning platform, an integrated production planning simulator, and a steelmaking and rolling scheduling system as systems that support the formulation of production plans that are quick and accurate, and are optimal overall, even in today's rapidly changing market environment. This paper describes the functional overview and prospects.

1. Introduction

The production system in the steelmaking industry, one of the primary material industries, features different manufacturing processes that use various materials such as iron ore and coal that are employed in several fields; for example, automotive, maritime, civil infrastructure and electrical appliances. Depending on the intended use, product specifications consist of several conditions such as material quality like strength and toughness, steel material surface grade and internal quality grade and dimensions such as thickness and width. Therefore, depending on product type, there can be several thousand to several tens of thousands of products available. Furthermore, the manufacturing conditions required to incorporate such product quality according to customer demand consist of the molten steel compositions in the steelmaking process and the combinations of rolling size, annealing temperature, type of coating and so forth in the processes after hot rolling. Such diversity of conditions is almost equal in scale to that of product specifications.

On the other hand, in the respective manufacturing processes, in order to maximize production capacity, create high quality products and lower costs, it is necessary to form groups to realize large-lot and continuous production, and additionally to determine the processing order within the group. In addition, since key items differ completely in the respective manufacturing processes, it is necessary to form groups different from each other.

Figure 1 shows the basic concept of the manufacturing process

and production planning. One of the major themes of production planning is the formulation of a production schedule in the integrated process, optimizing grouping and processing orders while meeting the delivery terms of the orders throughout the entire process from the material to the products stage. It is necessary, to promptly make comprehensive judgements which take into consideration various evaluation indicators such as quality, cost, delivery term and so forth in order to meet the changes in circumstances of the times. However, since the manufacturing process is large-scaled and complicated as the manufacturing conditions differ in each process, as do the delivery terms also, the business of production planning and

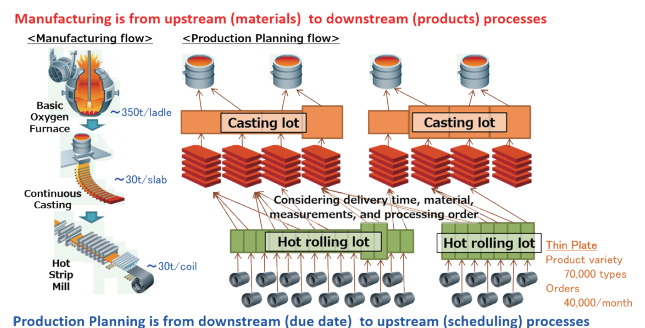


Fig. 1 Basic concept of manufacturing process and production planning

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scheduling is highly work load. In addition, amidst the needs for prompt and accurate response and judgement toward the rapidly changing market environment, as well as the problems of skill transfer and declining birth rate, the needs for support through information system technology are becoming increasingly important.

From the computer technology viewpoint, in addition to improvement in the computer main body capability, various calculation algorithms represented by Mathematical Optimization Solver are also making progress, and the system support for areas that previously had difficulty in practical application has become possible.

Under such circumstances, as the principal policy of DX strategy, Nippon Steel Corporation is promoting the development of an optimization algorithm to support the decision making in the production planning and scheduling business, and promoting its company-wide practical operation and sophisticated utilization. Introduced in Chapter 2 is the integrated production planning platform for prompt decision-making and sharing, based on the company-wide common database, of the judgement of overall optimized policy covering the entire area of integrated production and shipping, logistic control from order reception, production and up to delivery. Chapter 3 introduces the integrated production planning simulator capable of promptly responding to the changes in order amount and production status, and Chapter 4 presents the schedule optimization technology for the steelmaking – hot rolling process which is considered to be the starting point of product building.

2. Integrated Production Planning Platform

2.1 Background of construction of integrated production planning platform

Even in the business environment where energy and resource prices, and demand for steel materials vary greatly, in order to promptly and accurately respond thereto, and in order to optimize manufacturing of products and the supply system in the integration from material procurement, production and up to shipping, as well as in logistics, it is necessary to construct a business process which can shorten where possible the lead time between order reception and product shipment, and be executable within a short cycle and timely. Upon shortening the lead time, it is also important to shorten not only the time required for the actual flow of articles, but also the time required for the formulation of plans. On the other hand, upon formulating a plan, in order to formulate an optimized plan by organically linking the information of various conditions such as that of delivery term and/or of materials, enormous efforts and time are required for the formulation manually and/or with a bucket-relay type information transfer means such as via Excel data delivery and/or oral message delivery. Therefore, a timely response to such a major change in business operation circumstances as mentioned above is difficult.

While demand and/or needs directed toward the production planning business are growing increasingly sophisticated, Nippon Steel is now formulating production plans and production control in the following manner.

- ① Formulation of a sales plan and policy based on the amount of orders estimated through sales activity and demand prediction and the production capacity parameter values (inclusive of construction/maintenance plan) of the respective processes
- ② Formulation of a production plan, coordination and issuance of directions per the manufacturing processes as per steelworks involved in the sales plan
- ③ Progress control of actual production and delivery term of or-

ders in the respective manufacturing processes of respective steelworks

- ④ Shipment control for customers and relay stations, and the control of the related stock yard and logistics

Conventionally, the respective business has been conducted using dedicated systems in the respective businesses in the steelworks concerned due to constraints in computer capacity and network technology. Furthermore, as the key information (hereinafter referred to as “granularity”) differed in systems, and therefore, inter business information linkage relied on manual work and was highly work load, there has been an inability to respond promptly to the changes in needs and/or operation. Then, such information was all “linked” with the smallest identical granularity, and the company-wide common database and the company-wide common platform were constructed. Furthermore, the company-wide sharing and visualization of the simulation of production planning and effect evaluation were realized by the integrated production planning platform.

2.2 Outline of the integrated production planning platform

The integrated production planning platform consists of four major business functions in the aforementioned production planning business and production control business and the functions required for the control of various parameters required for these business functions.

The concept of the integrated production planning platform is shown in Fig. 2.

The first business function is the mechanism which supports the formulation of sales plans and policy. With this, the aggregation and sharing of the data of the major product specifications of customers and of products based on the information obtained through sales activities in the respective sales divisions, and the data containing the amount of orders and delivery term are possible. Furthermore, depending on customers, type of products, product specifications and so forth, certain restrictions exist in steelworks and the manufacturing process. Therefore, this function conducts simulation based on the forecast production amount corresponding to the order amount and the order mix, and ascertains that the balance is within the manufacturable quantity, and thus this function has the ability to realize the formulation of sales plans and policy.

The second business function is the integrated production planning simulation function to conduct production planning formulation, coordination and issuance of directions per the respective steelworks as per the respective manufacturing processes concerned in the sales plan. This function constitutes the core of the integrated production planning platform, the details of which are described in Chapter 3 and Chapter 4, and only the outline of the function is described here in this chapter. This simulation function is equipped with a function which enables by simulation the determination of the production balance and the production timing of every order in all integrated manufacturing processes in the entire company from the steelmaking process, the starting point of building product specifications, through the processing of materials to incorporate quality, size and so forth, and down to the final process of packaging to make products ready for shipment. As mentioned in the previous chapter, as the optimization grouping condition, namely the optimized production lot condition, in the respective manufacturing processes differs, independent formation of the largest lot in the respective manufacturing processes impedes the synchronization of the production timing in relation to the upper process and/or to the subsequent process, possibly causing an increase in in-process in-

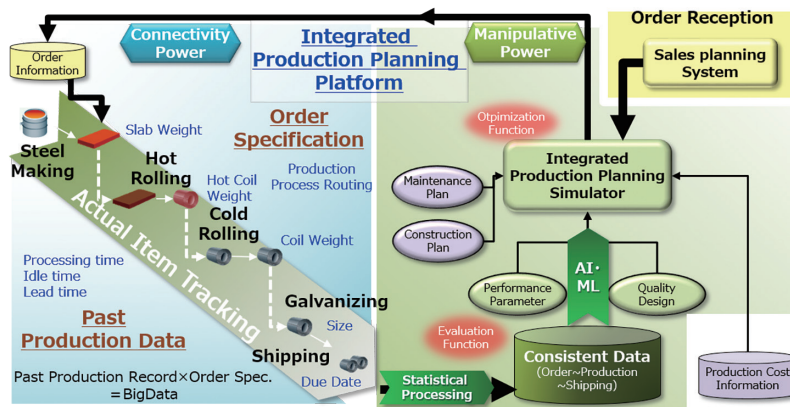


Fig. 2 Concept of integrated production planning platform

ventory, variations in production term and delay in delivery. Then, in the integrated production planning simulator, the manufacturing date in the respective manufacturing processes of each of the production units of slab or coil (hereinafter referred to as the “actual article”) is predetermined based on the delivery date in the final process, and by backdating so that the delivery term is secured while maximizing and optimizing lots in the respective manufacturing processes. At that time, the simulator takes in the information of the manufacturing progress status and the actual result of inventory of actual articles as well in the respective steelworks, and determines the production amounts of all manufacturing processes and the manufacturing timings of the entire actual articles, taking into consideration the construction/maintenance schedule in the respective manufacturing processes, and the production capacity and the manufacturing term, which differ depending on the actual article.

In the steelmaking process wherein the production lot increases in size as it moves to the upstream process, in order to derive an optimized solution effectively, the simulator consists mainly of two simulators so that it is capable of formulating the production plan optimized respectively for the upstream process and the downstream process. One simulator is the integrated production planning simulator dedicated to the downstream continuous lines and the ancillary processes after hot rolling, and is described in Chapter 3. The other is the steelmaking and rolling scheduler, a scheduling system that optimizes the upper stream of steelmaking for the hot rolling process. In the steelmaking process, molten steel of several hundred tons in a molten steel ladle is continuously cast to a continuous casting machine and then cast, and therefore, it is important to form a lot by appropriately aggregating the actual articles having identical or similar compositions and size specifications. Furthermore, since it must be taken into consideration that certain products require hot rolling to be applied immediately after the completion of casting, this simulator is equipped with the simulation function employing a technology called mathematical optimization as described in Chapter 4.

The third business function controls the order delivery term required by customers and the progress of manufacturing of the materials of the order and the products. Based on the manufacturing schedule for the respective actual articles formulated by the integrated production planning simulator, it is possible to grasp the manufacturing status per customer and/or per order unit.

The fourth business function is the integrated control system for ship allocation and berth availability for the transportation of prod-

ucts according to the delivery term required by customers. Since scheduled days for ready-for shipment (termed as date recorded) of the products are calculated by the integrated production planning simulator, by allocating ships according to the date recorded, shortening of the standby state term for shipment is possible. Furthermore, for this, this business function is also equipped with a function for managing and controlling the stock status at relay stations, real time movement of each ship and berth availability.

Lastly for these major functions, the mechanism for managing production capacity parameters and shut down plan of construction/maintenance, all required as the prerequisites for formulating an integrated production plan, is described. In the respective manufacturing processes, scheduled shutdown is applied for implementing regular cyclic maintenance, modifying equipment to enhance its performance and so forth. The shutdown due to construction/maintenance is scheduled in advance, selecting a timing at which the opportunity loss of the integrated order-manufacturing capacity is minimized, and from the viewpoints of availability of construction/maintenance workers and the procurement of materials. The production plan is formulated incorporated with the increase of inventory, taking into consideration the operation and the shutdown timing of the respective manufacturing processes. Furthermore, in the respective manufacturing processes in the respective steelworks, as the production capacity parameters, the ratio of material passage and the inter-process term differ depending on the product type and/or size, by taking into consideration these differences, the forecast of minute ready-for shipping date is enabled.

By linking the above functions with the data of appropriate granularity, and by promptly conducting reformulation of the production plan, effect evaluation and modification of the plan at a proper frequency, corresponding to the changes in the contents of customer orders, changes in the material procurement circumstances and operation variations in the respective manufacturing process, flexible and optimum product supply is enabled. Also, business that does not have to rely on the tacit knowledge and/or knowhow of experts has been realized. The system to realize these functions utilizes the recently advanced digital technology and the system-development method in addition to the standardization of the previous supportive systems for respective business.

In the next chapter, details of the integrated production planning simulation function which constitutes the core function of this platform is described.

3. Integrated Production Planning Simulator

3.1 Problem in formulating integrated production plan

Nippon Steel manufactures tens of thousands of products through several to a dozen processes in order to satisfy the product specifications that satisfy the respective grades ordered. To this end, the formulation of integrated production plans is required which, while maintaining the production of high quality products and securing the delivery term, satisfies various evaluation indicators such as maximization of production amount, stabilization of quality and minimization of cost in the respective manufacturing processes. Conventionally, production planning was conducted in the following way. The work of about one month was divided up among persons in charge who are highly knowledgeable of the restrictions and/or features of the respective plant and process from upstream to downstream, and the work was conducted through the exchange of information. Based on the delivery term, the transportation period of time to customers and so forth per order, and the date of the completion of manufacturing of the products at the final process are determined. Starting at the said date and backdating toward the upstream processes from the final process, and by further taking into consideration the inter-process transportation period of time and the preparation period of time for manufacturing, the manufacturing completion date in each process is predetermined per product. After conducting this business to the utmost upper end process, based on the restrictions in grouping and processing orders, the production schedule of the respective manufacturing processes is coordinated. When this business is conducted down to the utmost down end process and completed, the entire work is completed as an integrated production plan.

Furthermore, the persons in charge of the respective plant and process formulate the schedule, taking into consideration the grouping and processing orders pursuant to the characteristics of the respective manufacturing processes; however, there are dozens of groups, each having different sheet thicknesses, sheet widths, compositions and so forth, and the processing orders in a group in the case of the cold-rolling process can number as many as about 3.0×10^6 at the least. Furthermore, sound relationships with the preceding process and/or the subsequent process must also be secured; therefore, it is obvious that the business is very complicated and highly burdensome, and that it far exceeds the manpower available.

Up to the present day, aiming at the optimization and the sophistication of the production planning and scheduling business, the introduction of a visual and/or intuitive user-interface and the development and introduction of the function for determining processing orders within a group have been promoted. However, the previous system foundation and the development style were unable to catch up with the rapid changes in circumstances, and there are still a wide range of areas that rely on the knowhow of experts. Thus, extensive time and load were required for the formulation of an integrated production plan, and the timely decision making and response were insufficient.

3.2 Development of integrated production planning simulator

In order to solve the aforementioned problem, the formulation of a production plan in the integrated process within a short period of time is required. However, since data accumulated company-wide over a long period of time have to be dealt with based on the actual article granularity corresponding to orders, upon the execution of simulation, sufficient computer capacity is required as the data amount several ten times larger has to be managed. In the meantime,

as the simulation does not need to be executed all the time, possible intensification of the computing resources at appropriate timings is desirable. Hence, by constructing the integrated production planning simulator on the foundation of cloud computing, and by using high performance CPU and large capacity memory at appropriate timings, and by enabling parallel processing, simulation within a short period of time was realized.

Furthermore, there are a number of special conditions attributed to specific facilities in the respective steelworks, and since they interact with one another in a complicated manner, unlike the study by the conventional water-fall type system, it is difficult to establish the system specifications in advance by sorting out all conditions in advance in order to obtain the intended simulation results. Then, this time, the Agile type method was employed, wherein the base simulation function is constructed at first, and on it, system specifications are added sequentially, and accuracy evaluation is repeated. In order to effectively execute frequent release of program modifications and the review of the program structure, by utilizing the container technology (a technology which groups together the application software and the environment required for the execution thereof, facilitation and expediting of construction of the environment are possible), the Agile development under the cloud environment was supported, and the realization of the required simulation function was achieved.

The developed integrated production planning simulator can automatically formulate the integrated production plan for all steelworks manufacturing processes, taking into consideration the number of special conditions of the respective manufacturing processes and the complicated conditional restrictions between such processes. The simulator consists of the following three functions. First is the pretreatment function of aggregating all of the detailed product specification information of each actual article based on the order and sales information, facility shutdown plans of all processes of the entire company and all of the production productivity parameter values. In addition to the product specifications of the respective actual articles, applied manufacturing processes, processing time of the respective manufacturing processes, delivery term between the respective manufacturing processes, and so forth are also determined. Second, by using all of the actual article information, the operation and shutdown plan of the respective manufacturing processes and the production productivity parameter values corresponding thereto, the schedules of all processes are formulated by the automatic scheduling function which also takes into consideration the delivery term and lot size. The result of the scheduling is quantitatively evaluated as to whether or not it is satisfactory as being wholly optimized relevant to the pluralities of indexes of delivery, cost and productivity. Furthermore, this scheduling function is equipped with a function which enables the change and/or the coordination of schedule patterns of all processes in the entire company by human will and/or judgement. Details of the respective functions is summarized below.

(1) Scheduling pretreatment function

- 1) To aggregate and store the basic information such as product type, quantity and delivery term, and product specification information of all actual articles for the schedule formulation.
- 2) To aggregate and control all construction/maintenance shutdown plans and the production productivity parameter values of all processes in the entire company.
- 3) To determine based on the specifications of the respective actual articles, the applied manufacturing processes, processing

time at the respective manufacturing processes, delivery term between manufacturing processes and so forth.

- (2) Scheduling engine
 - 1) To formulate automatically the schedule of the entire processes by using the product specifications of the entire actual articles, operation and shutdown plans of the respective manufacturing processes and the corresponding production productivity parameter values, taking into consideration the delivery term of the respective orders, optimized grouping and processing orders in the respective processes.
- (3) User interface
 - 1) Expression in visual form and/or intuitively of the manufacturing schedule (scheduled manufacturing date and so forth) of the respective manufacturing processes determined by the above. Modification of the result of the automatic formulation is possible.
 - 2) Modifications of the manufacturing facility construction/maintenance schedule, grouping in the respective manufacturing processes, group arrangement orders, and the selection of setting of the priority mode regarding quality or cost are possible on screen.
 - 3) Realization of the confirmation of the result of the performance of the integrated production planning from the perspective of its capability to catch up with various changes in the environment and/or scheduling pattern by using the Self BI Tool (a software that contributes to business work by analyzing and visualizing data).

Owing to these functions, the formulation of the integrated production plan based on the actual manufacturing articles within a short period of time has been realized in all steelworks.

3.3 Effect of integrated production planning simulator

Owing to the realization of formulation within a short period of time of the integrated production planning which has been conventionally conducted by the great manpower of experts, the execution of simulation by changing the premises of the facility operation and/or the indexes of priority pursuant to the change at the time, and the selection of the best-fitted plan from among the simulation results have been enabled. Furthermore, the allocation of manpower and time to sophisticate issues like the study of problems in future scheduling becomes possible.

Three examples of application and their effects are introduced below.

- (1) By bringing the experience, knowhow and the tacit knowledge of experts to explicit knowledge, even inexperienced young persons in charge become able to formulate optimized plans equal to or superior to that of the experts, and the smooth alternation of the generation of persons in charge of planning becomes possible.
- (2) Reduction of the work of the study on the company-wide optimization of the facility shutdown is possible owing to the realization of the short term simulation and the verification, confirming the influence exerted as a whole by the change in the facility shutdown schedule.
- (3) As the verification and confirmation of the influence of the major change in order structure on the entire company by simulation are enabled, by using the results as evaluation indicators for the study on sales and order reception plans, it is possible to formulate sales and order reception plans that meet the environmental conditions of the times.

4. Development of Steelmaking and Rolling Scheduling System

4.1 Problem in steelmaking and rolling scheduling system

In the steelmaking process, molten iron supplied from a blast furnace is processed in converters and in the secondary refining equipment where compositions are adjusted, and the semi-products of cast steel are produced by a continuous casting machine. Molten steel is poured from the converter furnace to a transport vessel termed as the ladle after the completion of composition adjustment, and is then transported to a continuous casting machine via the secondary refining process. One ladle of molten steel is called a charge. Furthermore, a group of pluralities of charges continuously cast in the continuous casting machine is called a cast. As the composition adjustment in a steelmaking plant is conducted on a charge basis, it is desirable to increase the production lot by aggregating orders having the same compositions and product size. Furthermore, since a charge is produced in the unit of a predetermined weight, if the aggregated order does not reach the charge weight, the balance is produced as excess material that is not assigned to the order. Reduction of the excess material where possible is required as the excess material is stored in the storage yard until it is assigned to a new order, causing tightness in storage yard availability and prolonging production lead time. In the hot rolling process following the steelmaking process, slabs produced by the continuous casting machine are reheated in the slab reheating furnace, and rolled one by one to product size. Since slabs cast in the steelmaking process cool down gradually as time passes, to minimize the cost for reheating in the reheating furnace, rolling within a short period of time after the completion of casting to the extent possible is required. Furthermore, in a rolling schedule, the order of rolling from wide to narrow slabs, or what is termed as coffin restriction, must be taken into consideration.

Thus, in the planning business for the process from steelmaking to the hot rolling process, in addition to the consideration of various restrictions pertaining to manufacturing, the trade-off among minimization of heat loss, maximization of production lot and observance of delivery term must be considered. To date, the formulation of the plan has relied on experts. However, even if the formulation of the plan relied on the operation knowledge and the experience of experts, as it took several hours, prompt response to the changes in requirements and/or operational variations has been difficult. Then, the steelmaking and rolling scheduling system based on optimization technology is being developed, aiming at the support and/or the automation of the planning business in the process from steelmaking to the hot rolling process. The steelmaking and rolling scheduling system consists of pluralities of engines, and by incorporating into each engine the experts' knowledge of the restrictions in operation and the tacit knowledge such as expertise, even inexperienced persons can formulate very promptly an optimized plan equal to or superior to that of the experts, and sophistication of business, shortening of time and the intensification of the capability to respond to schedule changes in the case of operation variation are enabled.

The next section introduces how the engine of the cast frame, one of the constituent elements of the steelmaking and rolling scheduling system, is being designed.

4.2 Weekly steel tapping planning business

In the weekly steel tapping planning business, slabs scheduled for production are sorted and aggregated to a cast, and the continuous casting machine and the date of tapping are determined for the

respective casts. The business of sorting of slabs and aggregating to a cast frame is considered to be a cast frame design issue, and its engine has been developed. The representative restrictions which the subject engine should take into consideration are shown below.

- Slabs to be aggregated to an identical cast frame should be within the producible range of the continuous casting machine.
- Due to the upper and the lower limits of the number of the charges which constitute a cast, the total weight of slabs to be aggregated to an identical cast frame is restricted.
- Steel type of the respective slabs is predetermined, and slabs having an identical steel type can be aggregated to one charge.

Furthermore, minimization of the number of cast frames, integration of delivery term and the minimization of the amount of excess material are enumerated as the evaluation items in the cast frame design.

4.3 Development of cast frame design engine

With the approach method of building a cast frame one by one of the slabs given in the plan, wide slabs and/or narrow slabs which are difficult to aggregate to cast frames tend to remain. Due to these remaining slabs, cast frame of high evaluation cannot be formed, or formation of cast frame fails and some of the slabs remain; this is the difficulty with the cast frame design issue. With such greedy algorithm, the result oriented to obtain optimality as a whole cannot be obtained, and in this development, the cast frame design issue is formulated as a set partitioning problem. In the set partitioning problem, when any arbitrary subsets of a universal set bear cost, a universal set is segmented to subsets without duplication and/or omission in such a way that the summation of such costs becomes minimized. In the cast frame design issue, the universal set corresponds to the set of the subject slabs in the planning. The subset corresponds to the candidate cast frame with aggregated slabs. The cost is calculated per candidate cast frame based on the evaluation items. With the solution based on the set partitioning problem, upon selecting cast frames from among the enumerated candidate cast frames, it is possible to obtain an optimal solution as a whole while minimizing the remaining slabs. In order to solve the set partitioning problem with high accuracy, a great number of subsets, namely cast frame candidates having high evaluation, must be enumerated. However, in this problem, on the assumption of 1000 slabs in the subject plan, the number of combinations of the subsets can be as high as 10 to the power of 300, and therefore, it is impossible to enumerate all combinations within a practical computational time. Then, by aggregating in advance the slabs having similar manufacturing conditions to a group, the number of elements of a universal set is reduced to about 100, and the number of combinations of the candid cast frame to be enumerated is greatly reduced. Upon aggregating slabs to a group, in order to avoid damages where possible to the optimality of the solution which the engine outputs, slabs having a steel type, size and delivery term similar to each other are aggregated to the same group so that slabs with high probability of being aggregated to the same cast frame ultimately are aggregated. Furthermore, the number of the combinations of candid cast frame based on the actual operation has been reduced. Plans determined by humans have more or less common patterns to a certain degree, and the plans near to such and output by the engine are more readily accepted by humans. Then, the huge amount of actual operational data in the past has been compiled, and shortening of the computational time was attempted by excluding the operational patterns unused in the past from the enumerated candidates. Furthermore, con-

cerning the objective function similarly as well, it was designed so that the more times a pattern is operated in the past, the more readily the pattern is employed as the optimized solution.

4.4 Effect of cast frame design engine

We have started applying the developed casting mold design engine in actual operations. It has become possible to formulate plans with accuracy higher than those plans conventionally formulated by persons in charge. Reduction of the amount of scrap by about 10% at the joint section was confirmed. Furthermore, by adjusting the weighting factors such as that of productivity and cost which constitute the objective function of the optimization problem, a plan with the index changed to the one of greater importance can be formulated, thus enabling the employment of the plan appropriate for the operational environment. Since the computational time required for optimization, although dependent upon the number of the slabs and/or the order structure of the plan, ranges from several seconds to the order of several minutes, and since the speed is overwhelmingly high as compared with the case of the manual formulation of the plan by persons in charge who plan cast frame one by one, and even when the modification time for optimizing the position of the urgently needed material is taken into consideration, shortening of the time for formulating the weekly tapping planning by about 70% has been realized. The pursuit of optimality by comparing pluralities of plans and by refining the plan has become possible, and with sharing of the weekly plan at an early time among the sections concerned, time is now being spent on the coordination of issues which span the sections. Furthermore, by shortening the time required for the business of planning, even when variations take place due to operational problems, prompt restoration of normal operation is possible by restarting the engine and remaking the plan. Furthermore, by making the experts' knowhow explicit, and by incorporating it in the engine, even relatively inexperienced persons in charge can now formulate plans that are equal to those of experts.

4.5 Summary of steelmaking and rolling scheduling system

The prototype cast design engine was developed and completed for the first application to the plants in the Kimitsu Area of East Nippon Works. We are currently utilizing it in the routine operations of the weekly steel production planning, and it is demonstrating the aforementioned benefits. Furthermore, from the start of the development, evolution to other steelworks was targeted, and the packaging of the functions commonly required was conducted. The study on lateral evolution and introduction to other steelworks is currently under way. In order to use this type of engine continuously for business, it is important to appropriately adjust the parameters that the engine possesses, and to maintain the accuracy of the plan. In order to formulate and realize the plan incorporated with the human will of prioritizing production or cost pursuant to the market condition, and/or operational condition, development and the actualization of the screen display and function that allow for easy tuning of the respective parameters are also promoted, and a system environment that enables the control of production through the cooperation of human and system has been prepared. Furthermore, the steelmaking and rolling scheduling system consists of pluralities of engines, and presently, the actualization of other engines is also being promoted as well. In future, by executing the system with coordinated engines, we will enhance the operational real ability of the system throughout the whole of the steelmaking and rolling process by continually updating the entire operational schedule of steelmaking and hot rolling

processes so that the response to operational variations is enabled, and the risk of operation shutdown due to tightness in slab storage yard availability or shortage of inventory is avoided in advance. Furthermore, in order to break away from the individual partial optimization in steelworks, and to realize entire optimization across steelworks, a system structural plan is under construction in conjunction with the aforementioned integrated production planning simulator, which enables prompt decision making of optimized policy based on the entire integrated production planning platform.

5. Conclusion

The steel production process is a V-shaped, job shop type production process in which large-lot production in each manufacturing process (maximization of productivity) is intended for small-lot orders of a variety of products, and various products are manufactured individually from natural raw materials, satisfying the product specifications and delivery term of each product ordered. Furthermore, in the respective manufacturing processes, the formulation of a production schedule taking into consideration the number of manufacturing restrictions and/or evaluation indicators from the viewpoints of product quality and cost is necessary, and even for a process, ex-

perts' knowhow is required for the formulation.

In this article, with respect to such plan-formulating business, as the efforts to support promptly and accurately even under constantly changing circumstances, and to exert the actual effect of shortening of lead time, the construction of an integrated production planning platform, development of an integrated production planning simulator and the development of a steelmaking and rolling scheduling system have been described. Furthermore, the mechanism of formulating a production plan unattainable by humans or systems alone, and only attainable by the sophisticated linkage between human and system has been explained.

By utilizing organically the huge high quality data asset on the integrated production planning platform, by giving people awareness, and by enabling the prompt and accurate judgement of decision making, we aim to innovate the entire business process, to reduce drastically the business work load and shorten business working hours and business cycle. At the same time, with the reciprocal feedback, we aim to optimize the entire steelmaking business process in Nippon Steel, and to take on the challenge of new technology development so that Nippon Steel will continue to move forward as an advanced company leading the world.



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