Discussion on Advanced R&D Topics (Two-part series: 2)
True Coexistence with Technology through R&D of Practical Human Use
Discussion between Professor Y. Sankai of the University of Tsukuba and Executive Vice President B. Futamura of Nippon Steel focuses on the proper nature of humankind’s fusion with technology, the future direction of assistive technology in manufacturing industries, and the qualifications required of researchers.

Munemichi Myochin: Born in 1942 in Hyogo Prefecture. In 1983 when he was named the 52nd head of his artistic lineage, he received the Skills and Meritorious Service Award of Hyogo Prefecture and was designated by Hyogo Prefecture as a “Traditional Craftsman.” In 1997, he was selected as a “Master of Japanese Sound” by the Japan Audio Society. Other major awards include the Great Prize and the Special Prize presented at the Japan Cultural Design Awards (2003) and the Arts & Culture Prize of Himeji City (2004).

Financial Results for the First Half of Fiscal 2008
Consolidated net sales increased ¥285.8 billion year on year, to ¥2,602.1 billion. However, owing to rising materials costs and other factors, operating profit decreased ¥16.0 billion, to ¥248.4 billion and net income was down ¥14.7 billion, to ¥161.6 billion.

Participation in POSCO’s New Cold-Rolling Mill in Vietnam
To further enhance the strategic alliance between Nippon Steel and POSCO of Korea, the two companies commence the joint study on Nippon Steel’s participation in the new cold-rolling mill in Vietnam, being constructed and owned by POSCO.
With high-grade steel products as its core business, Nippon Steel seeks to extend its competitive edge in technology in order to become the world’s leading comprehensive steelmaker. The foundation of its business operations is supported by rapid research and technological development that accurately grasp the needs of the market.

A face-to-face discussion was recently held between Professor Yoshiyuki Sankai, Graduate School of Systems and Information Engineering, the University of Tsukuba, and Bun’yu Futamura, Representative Director and Executive Vice President of Nippon Steel Corporation. Professor Sankai is an advocate of a new area of research known as “cybernics”*-1—the fusion of man, machines, and information systems. He is a leading explorer in this field and has successfully developed a robot suit

Yoshiyuki Sankai
Professor, Graduate School of Systems and Information Engineering
The University of Tsukuba

Bun’yu Futamura
Director, Technical Development Bureau
Representative Director and Executive Vice President
Nippon Steel Corporation

*1 Cybernics: This is an area of study that integrates such diverse fields as neuroscience, robotic engineering, IT, system integration technology, perceptual science, psychology, physiology, economics, law, and ethics. Its core fields are cybernetics, mechatronics, and informatics.
named HAL (hybrid assistive limb)\(^2\) that is designed to detect the wearer’s intentions and support his activities.

Their discussion focuses primarily on the proper nature of mankind’s fusion with technology, the future direction of assistive technology in manufacturing industries, and the qualifications required of researchers.

*Nippon Steel News* (nos. 368 and 369) presents a two-part series that recounts this discussion:

**Part 1: Questions of Why?; the New Field of Cybernics; and the Comprehensive Confluence of Technologies in HAL**

**Part 2:** Identity between a Steelworks and the Human Body; Closed Communications with the Production Floor; Spiral-ing Innovation; and Visionary R&D

The current issue (No. 369) highlights Part 2.

---

\(^2\) HAL (hybrid assistive limb): HAL is expected to be applied in various fields such as rehabilitation support and physical training support in medical field, ADL support for disabled people, heavy labor support at factories, and rescue support at disaster sites, as well as in the entertainment field.

**Yoshiyuki Sankai:** Having graduated with a Dr. Eng. in 1987 from the Graduate School of Engineering at the University of Tsukuba, Prof. Sankai currently serves as a professor of the Graduate School of Systems and Information Engineering, the University of Tsukuba, and is a member and director of the Robotic Society of Japan.

Because of his view that it is necessary in robotic development to study the living human body in cooperation with medical researchers in a wide range of fields, he has fostered a new area of learning called “cybernics” that integrates such diverse fields as neurological science, behavioral science, psychology, physiology, and IT. A direct achievement of this effort is the development of a robot suit known as HAL (hybrid assistive limb). In June 2004 he established CYBERDYNE, a venture business that manufactures and markets HAL products.

Among his many awards are the World Technology Award in 2005, the Good Design Award in 2006, the Japan Innovator Award in 2006, the Minister of Economy, Trade and Industry Award (distinguished service award for cooperative operations between industry, government and academia) in 2007, and the Tsukuba Venture Award in 2007. He also received awards from the Robotic Society of Japan, the International Federation for Artificial Organs, the American Society for Artificial Internal Organs, and the International Society of Rotary Blood Pumps.
Futamura: Now that we have shown you our Kimitsu Works and the Technical Development Bureau, what is your impression?

Sankai: While I was surprised by the fact that the molten steel stored in the steel refining vessel, the basic oxygen furnace, is equivalent to about 300 cars, my first impression about the Kimitsu Works was that the scale of the plant is huge. Such huge plants, in a sense, are identical to the human body. The human body is controlled by the central nervous system, itself an enormous system, so that even minute sections of the body are not left alone to act independently.

For example, blood pressure and temperature are peculiar to each person, and the human body uses chemical reactions to maintain a dynamic balance suitable for each individual and condition. While diverse kinds of minute changes in operating conditions occur in the giant plants of a steelworks, there is a point of dynamic balance where these changes can be optimized for the entire system. I think an operating system that allows such complete optimization is required for a steelworks.

Even if a highly advanced system were to be incorporated in a certain section, it would be useless in isolation; just as food distribution is a basic requirement for humankind, the establishment of basic systems leads to control over plant health, or optimized operational control, doesn’t it?

Futamura: Systemic balance is indispensable for integrated steelworks operations, as it is for the human body. That is, the digestive system of a steelworks not only produces iron from iron ore, it also yields finished products from the extracted iron. The resulting products enter the vascular...
system, which generates slag, dust, CO$_2$, and other by-products that are then appropriately treated and recycled. An important consideration of equipment design is how to balance these two systems.

A huge amount of energy is required to reduce and melt iron ore in a blast furnace and to produce the reduction material in coke ovens, but these processes also generate gas. The gas thus generated is used as an energy source for in-plant power generation and the operation of downstream processes. In certain steelworks, all necessary electricity is supplied by such in-plant power generation. In terms of energy consumption, an important factor in steelworks operation is how to balance the operation of upstream and downstream processes. This ensures that every equipment in the works functions in synchronized fashion with every other equipment in the loop.

**Sankai:** In the case of the human body, not all of the cells that compose the body are deeply involved in overall health maintenance; such cells play only their assigned role. Similarly at a steelworks, each process and equipment carry out the precise role given to it, and then the operations control system, like the central nervous system, manages overall operations and controls reciprocal interaction between the upstream and downstream processes to achieve a state of complete optimization. I think this is the best system of operation for a huge steelworks.

**Futamura:** You are right. Acting on the information given to it about the kind of product being produced, each equipment, or each cell, accomplishes its particular role. For example, when multiple rolling mills are used to continuously roll thin steel sheets, each mill carries out individual role. However, all the independent roles of the respective mills are controlled by an integrated control system that functions like the central nervous system. Operations of giant steel plants are thus controlled by such integrated production control systems.

**CDQ (coke dry quenching) equipment**

At an integrated steelworks, the by-products, waste heat, and by-product gases generated in the iron and steelmaking processes are appropriately treated for recycling. For example, in cooling red-hot coke, the CDQ equipment quenches the coke using inactive gas instead of water, and the sensible heat of the red-hot coke is recovered to generate electricity and to reduce CO$_2$ emissions as well.
Futamura: At enormous steelmaking plants, certain operations are not yet automated or mechanized. When we examine these operations, it is regrettable to see that in many cases heavy human labor is required because of technical difficulties. One of our goals in taking you on a tour of our steelworks was to elicit from you some suggestions for remedying these unsolved problems.

It is a mission and a hope of mine to realize a working environment in which each worker engaged in product making on the production floor can grapple with tasks that add meaning to their lives. Of course, I doubt that a technology like HAL (hybrid assistive limb) can be adopted as is, but I do feel that you can offer some useful hints to our company that are based on concepts and elementary technologies rooted in your research methods and in your hope for the coexistence of human beings with machines.

Sankai: The basic direction of my R&D procedures is “to be of use to people.” I feel joy in managing technology by creating methods suitable to an objective without adhering to current technology—in this sense, I am someone “who thinks that the end justifies the means.”

One of the processes that I inspected was the removal of iron ore that had fallen from the conveyor belt during transport. I have had some ideas regarding automation of the process and how the current removal work might be replaced with more expedient technology. I was also deeply intrigued by the refractory repair robot you showed me at the research laboratory and the sensors that can serve as substitutes for human eyes. I have thought over that with some improvements, we can make even these machines and technologies easier to use.

If I serve at your company for about two weeks to gain an intimate understanding of practical steelworks operations, I might be able to make some contributions to your company. I believe that new ideas will result from a process by which the production-floor staff can communicate with the engineers engaged in equipment technology development about emerging tasks and by repeated direct discussions regarding the effect of contend-
ing technologies.

**Futamura**: I agree with you. Simply looking at a specific operation does not allow one to understand the different layers of elements or factors that constitute the tasks to be solved. As a basis for promoting R&D aimed at problem solving, it is important for researchers to gain an accurate understanding of what is needed on the production floor by closely observing the series of movements that occur in the specified operations.

**Sankai**: In steelworks operations, it seems essential to transport not only the steel products but also refractories for iron- and steelmaking equipment and other heavy items. For operations where mechanization is difficult and manual labor is necessary, I think it is feasible to apply technologies such as HAL that transport goods by lifting them.

**Futamura**: In order for the steel industry to attain sustainable development based on product making, it is imperative not only to succeed in the production-floor skills that constitute the genesis of product making, but also to solve emerging issues such as reducing the workload of the production-floor workers.

In manufacturing industries such as the steel industry, many operations remain that currently cannot be programmed or automated. In particular, with regard to the tasks of maintaining an arterial system and inspecting, diagnosing, maintaining and repairing equipment—tasks that play an important role in improving equipment operating rates, I detect many useful suggestions in your concept of “man-machine fusion technology triggered by and premised on information transmitted from men,” rather than in robots that work as programmed.
Futamura: I would like to hear your views pertaining to the nurturing of human resources. In the course of our discussion, I think that a key to nurturing human resources lies in your statement that you are not anxious about the challenges posed by any goal. Accordingly, you might say that if one encounters a good purpose that would be useful to humankind and if one is engrossed in and enthusiastic about attaining that purpose, his talent will grow.

Sankai: In R&D, my approach is not to promote research randomly, but after determining an objective. The nurturing of human resources is the same. I usually tell my students to draw a tree-shaped diagram of what is required to attain an objective. When the researchers working on a project are deadlocked, I suggest that they take a step back and redraw the tree. In addition, in order for students to feel a sense of leadership, I strongly believe that it is important to have them experience success.

Futamura: The main objective of enterprise R&D is to meet a diverse array of emerging needs ranging from the broadly social to the concerns of a single customer. When a researcher has gained a general understanding of a problem and is engrossed in R&D, his skills and his passion and enthusiasm for obtaining the objective grow. As a result, it becomes possible to anticipate market needs and to speed up development work. I truly believe that this leads to further enhancement of our company’s competitive edge in technology while at the same time enriching the researcher’s life.

Sankai: In cybernics, we are involved in upgrading basic research premised on clear objectives to applied research that will result in precisely those products that, through their production, will contribute to society. Also, I think it is important that the task-solving objectives discovered in the above process be fed back into basic research. In university research, it is important to maintain the viewpoint that researchers remain attached to the technology that they, themselves, bring forth and that they be involved in its further development. In the future, I wish to promote an upward spiral in innovation through inventive challenges, capital-
izing on new industrial opportunities rooted in cybernics and nurturing human resources.

**Futamura:** The Japanese steel industry supports the operational infrastructure of the Japanese manufacturing industry and, concurrently, continues to create eco-friendly, high-performance steel products and processes that accurately meet social needs. In order to tackle such needs and to enhance the development of human resources, I intend to further strengthen the ties between industry and academia.

**Grappling with Visionary Research and Technological Development with Exciting Incentives**

**Futamura:** Parallel with your promotion of research at the University of Tsukuba, in 2004 you established CYBERDYNE, a venture business with the immediate aim of manufacturing and marketing HAL (hybrid assistive limb) products. Please tell us about your development activities and your aspirations for the future.

**Sankai:** Our ultimate goal is the development of human support technology. We also plan rehabilitative support whereby temporary physical disabilities are overcome by employing the standard two-way communications system contained in HAL to transfer control over one’s movements to another person. HAL makes it possible to provide rehabilitative services that deliver experience and bodily sensations to the patient when both the patient and the medical therapist are wearing the
Feature Story

suits. This has never been done before and it is now the case that equipment capable of sending commands to all nervous systems has been completed.

Futamura: When handling heavy structures and equipment, there is always an artful or proper way to do so. A veteran can conduct such operations with minimum force. A pressing task on the production floors of the manufacturing industry is how to succeed veteran’s skills. By having a veteran wear a HAL to transfer his movements to a younger worker, it is now possible to effectively conduct advanced training through repetitive motion in a separate room, isn’t it?

Sankai: Really, I would like to preserve such a HAL in a museum. If prominent athletes were to wear a HAL and thereby store enough relevant data, it would be possible to bodily acquire their movements even 300 years later. I get excited just thinking of it. And this excitement is an excellent source of motivation for research.

Futamura: I gather from today’s discussion that you have proven within your own experience that, when one enthusiastically grapples with a research project, even if a successful conclusion seems distant, one’s viewpoint will expand and talent grow as part of the process and that ultimately the means to realize one’s dreams will be found.

Thank you, Prof. Sankai, for your valuable comments.