FANUC NEWS

2022 Roundtable Discussion Special Issue

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2022 Roundtable Discussion

We invited the professors who advise us on our day-to-day operations to view our products at the New Products Open House Show on May 20. Afterwards, we held a roundtable discussion.





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(Listed in speaking order)

FANUC CORPORATION

■ Representative Directors
Yoshiharu Inaba, Representative Director, Chairman
Kenji Yamaguchi, Representative Director, President and CEO (Moderator)

■ FA
Hiroshi Noda, General Manager, FA Business Division
Yoshiki Hashimoto, General Manager, Hardware Research & Development Division
Yasusuke Iwashita, General Manager, Software Research & Development Division
Masamoto Fukuda, General Manager, Servo Research & Development Division
Yuji Nishikawa, General Manager, Laser Research & Development Division

■ ROBOT
Kiyonori Inaba, General Manager, Robot Business Division
Kenichiro Abe, General Manager, Robot Mechanical Research & Development Division
Seigo Kato, General Manager, Robot Software Research & Development Division

■ ROBOMACHINE
Satoshi Takatsugi, General Manager, Robomachine Business Division
Zheng Tong, General Manager, Robodrill Research & Development Division
Tatsuhiro Uchiyama, General Manager, Roboshot Research & Development Division
Akihiko Fujimoto, General Manager, Robocut Research & Development Division

■ Administrative Staff
Shunsuke Matsubara, General Manager, Research & Development Promotion/Support Division
Masako Sudo, Assistant General Manager, Research & Development/Support Division

(Positions are as of May 20)

President Yamaguchi

President Yamaguchi: Thank you for taking time out of your busy schedules to join us today.
We have held roundtable discussions every April to coincide with our New Products Open House Show. Amid the COVID-19 pandemic, however, we canceled the Open House Show and the roundtable discussion scheduled for April 2020, and in 2021, both events were held online instead in June. This means that the Open House Show and today's roundtable discussion are the first to be held face-to-face in about three years.
For this Open House Show, to prevent COVID-19 infection, we limited the number of visitors to one-third of the normal capacity, divided them into groups setting a maximum visiting time of two hours per group. Since some people had busy schedules in April, which is the first month of the fiscal year in many companies in Japan, we decided to postpone these events for a month, until May.
We regret that we could not welcome many more visitors, but those who did attend generally gave us positive feedback, saying that this year they were able to take more time than usual to view the exhibits and listen to the explanations of the booth staff. About three years have passed since we last held a roundtable discussion following your visits to the Open House Show, and I am not completely confident as to whether you think we have made much progress. As the global economy recovers from the COVID-19 crisis, our R&D divisions have been implementing countermeasures for parts shortages as their top priority. Together with the factories and purchasing departments, we have been devoting considerable time to addressing this issue. Nevertheless, we have continued to exert our utmost efforts in R&D, so we hope to hear your frank opinions and advice. We would appreciate your cooperation.

■ General Review of the New Products Open House Show

President Yamaguchi: First, Professor Emeritus Higuchi, would you start by giving us your general feedback about the Open House Show?

Professor Emeritus Higuchi

Professor Emeritus Higuchi: Three years have passed since the last face-to-face Show, so I was glad to see and experience your products in person. I was also very happy to hear the details about specific challenges and to speak directly with the developers. It has been a long time since I have had such a satisfying experience.
One of this year's noteworthy achievement for FANUC, which was announced in the newspapers and other media, is that your cumulative CNC production reached

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five million units in March. As described in detail in the company history (History of FANUC) published last June, the company started development activities in 1955 and production in 1958. In addition, cumulative shipments of Robodrill have reached 300,000 units. It has been 50 years since the company first released a Robodrill under the name of “FANUC-DRILL” in 1972. Both of these are excellent achievements. I would also like to touch on Chairman Inaba's "My Resume," which is a series of articles featured in the Nikkei Newspaper in January. I had a wonderful time reading these articles, which included a summary of the company’s history and many pieces of information I had never heard before.
As for robots, last year you won the "Main Prize" at the Best 10 New Products Awards of the 63rd Nikkan Kougyo Shimbun, the "Nikkei Business Daily Award" at the Nikkei Superior Products and Services Awards, and the "METI Minister Award" at the 9th Robot Awards. This year, you won the "JATES Chairman’s Award" at the 10th Techno-Economics Innovation Award. Congratulations.
Overall, you have been continuously making steady efforts. You make sure to carefully assess and address users’ needs, and your efforts materialize as actual products. I can see that the rapid improvement in computing performance has supported your hard work. In particular, simulation technologies are making remarkable progress, and I cannot wait to see how FANUC will apply them to products in the future.
Though not relevant to the Open House Show, allow me to express my opinion on education in control engineering. The foundation of control engineering was established by the efforts of wise men and women who sought to develop practical methods for control system design at a time when computers did not exist. In control engineering classes, students learn how to use Bode plots to assess whether control systems are stable and to adjust gains. This makes for excellent exam questions, but I have never implemented this technique in actual use. That is because it is easy to identify stability through numerical simulations. Many students struggle to understand the Laplace transform and begin to dislike control engineering. Given that there is a concerning trend that students’ competence in mathematics, particularly their analytical skills, are declining, I think it is necessary to first teach the essence and interesting aspects of automatic control in a straightforward way by utilizing numerical simulations without making use of the Laplace transform.
Among the various exhibits this year, I was attracted by the collaborative robots. Their performance has been steadily improving, and I found the white CRX robot to be particularly interesting. In this year's demonstration, the robot used its own sensing technology to dexterously grip objects with its chuck. Since there are many similar tasks that can be automated, the CRX can be expected to contribute to future developments.
I would also like to talk about the all-stainless-steel delta robot. The shining body seemed sterile, and I can see that the round shape allows the robot to be cleaned easily. I think those who work for food-related companies will highly appreciate it. I remember saying at a roundtable discussion over 10 years ago, "There are a food machinery exhibitions, so you should exhibit your robots there and continue to expand their applications." Together with the "washable robot" that was featured at the previous New Products Open House Show, I believe that your delta robot will play an active role in the food industry, which places great emphasis on hygiene management.

President Yamaguchi: Thank you very much, Professor Emeritus Higuchi. This year's roundtable discussion will consist of three sessions on FA, Robot, and Robomachine.

FA

President Yamaguchi: Let’s begin by focusing our discussion on FA. Professor Emeritus Tojiro Aoyama, could you please share your comments?

Professor Emeritus (Tojiro) Aoyama: To begin, thank you for inviting me here today. I was looking forward to seeing the face-to-face product exhibition and participating in the roundtable discussion that hadn’t been held for a long time.


Professor Emeritus Tojiro Aoyama

Before speaking about FA, I wanted to ask about the measures you are taking to address the major issues of the shortages in semiconductors and parts, as well as rising energy costs due to social instability around the world.
Regarding energy costs, such increases have always driven companies to reduce energy use from the past. However the renewed focus on energy saving is increasingly becoming a priority. The energy cost issue is not easy to solve. FANUC is taking various initiatives in product development, such as the FA Divisions’ initiatives to reduce energy use as well as initiatives to reduce the impact on the environment by utilizing underlying and digital twin technologies. Such efforts, along with the exhibited new green logo, are testaments to FANUC’s motivation and active engagement. I think these initiatives will become even more important. Digital twin technology is improving in terms of accuracy and performance, making telecommuting much more possible than before. Although there may be security issues to address, infrastructure is rapidly developing that will enable us to telecommute from the office and home rather than working at production sites. Such progress will indirectly contribute to reducing environmental burdens significantly.
In addition, the various devices that make up FA systems have been fitted with very user-friendly new features. FANUC’s CNC used to be associated with extremely complicated features that required expertise, proficiency in G-code, and a wide range of first-hand knowhow, In response, the latest achievements show the various approaches you have taken for improvement.
I found the collaborative robots area to be extremely interesting. Collaborative robots are becoming more diverse and their

CNC exhibit

movements are becoming more sophisticated. Looking at the robots on display, I expect that such robots will be introduced to production sites in a wider variety of ways than before, such as being used in combination with machine tool functions. In addition, by establishing a production system in which robots collaborate with machine tools, a variety of benefits can be attained such as the reduction of environmental impact when changing the production line configuration, lower energy consumption, and so on. It would be appreciated if you could elaborate on this topic.

President Yamaguchi: Thank you very much, Professor Emeritus Aoyama. General Manager Noda of the FA Business Division, would you like to respond?

Noda: Thank you very much, Professor Emeritus Aoyama. For this year's Open House Show, the FA divisions focused on five key areas: "real," "digital," "automation," "energy conservation," and "IoT."

Energy costs were mentioned in your comments. The FA Division will place strong emphasis on this area going forward. In fact we have continued to do so from the past. In a direct manner, the power consumption of motors, especially amplifiers, has been reduced. The shortening of the cycle time and machining time led to the decrease in the time the machine was operating, which reduced energy usage. Furthermore, IoT improved efficiency, which further conserved energy. In relation to digital technologies, as mentioned earlier in reference to digital twin technology, analyses of various data in the digital world has led to drastic improvements in the real world in recent years. In the exhibits, there was a demonstration of machining in digital space which used a simulator to create a dynamic model of a real machine. For example, compared to the long time required for trial and error in the real world to achieve the desired machining level, simulations enable virtual tests for machining, which can be performed in a much shorter time. By combining such digital technologies, total energy costs will be reduced significantly. This trend toward digitalization is exactly what will bring about energy conservation and energy cost reduction.

Noda
(General Manager)

Last with regard to collaborative robots, I would like to speak a bit from the perspective of FA. Demands to connect machine tools with robots is increasingly considerably. In the past, there was much talk about whether people or robots were better in terms of cost, but now automation is inevitable because it is hard to secure human resources. We strongly feel that the situation is changing, as the focus is becoming more and more on where automation can be most efficiently and successfully implemented. In this context, the development of collaborative robots with a high level of sensitivity to their external surroundings, has had a very positive impact. Since older machine tools were designed long ago, they lack robot interfaces. However, by utilizing collaborative robots and vision systems, the robots can detect and learn where machine tools are positioned, and approach them. For example, robots are being applied for an increasing variety of purposes by combining their human-like abilities, such as the ability to open automatic doors by pressing a control panel button. This trend is leading to a wider range of applications for collaborative robots. Major trends such as these were kept in mind in this year's exhibits. Thank you for your feedback. We intend to develop a variety of technologies, including those for energy cost reduction as well as real, digital and, of course, IoT.

President Yamaguchi: Now, Professor Shirase, please share your views.

Professor Shirase: First, thank you very much for inviting me to the Open House Show and roundtable discussion today. It is very enjoyable to meet face-to-face for the first time in three years. Last year, during the online meeting, we were shown many videos and materials, but they presented only your achievements. Today, however, in this face-to-face meeting, we are able to directly hear about your efforts to achieve those results and what issues you encountered, which is sparking a lively conversation.


Professor Shirase

I will mainly speak about FA. Last year, when you shared with us that the CNC processing capabilities had improved dramatically, I had the impression that you had energetically proceeded with the development of digital twin for CNCs and made definite progress.
To me, the most impressive was CNC GUIDE 2. This is a technology that faithfully imitates reality by modeling the servo and machine, as well as simulating mechanical movements. Using this technology, the machine's dynamic behavior can be reflected in a manner that also takes into consideration acceleration and deceleration in simulations for machined surface estimation. Last year, you explained the process of machined surface estimation. You had to idle the machine to obtain servo information from the CNC, and used this information to simulate machined surface estimation. But now all this can be performed by simulation alone. This not only elimates test cutting, but also idling. Furthermore, trial-and-error to obtain the optimal machining conditions can be conducted through just simulations. Therefore, there is a much greater impact than the year before.
I myself have some own thoughts about future developments. What we used to call "simulation" has recently come to be called "digital twin." However, these two terms refer to the same thing and merely changing the name is not enough. What is important is still how information on reality is fed back to the simulation technology. Models are used for simulations, but I think the key is how to express the so-called "factor X," that is, those which cannot be expressed by models. In other words, when the result of simulation and that of reality are checked for inconsistencies, any difference that cannot be explained is due to factor X. With regard to this, there should be a mechanism to make adjustments per machine. If this can be achieved, individual differences and differences in each machine's usage environment will be expressed as factor X. In addition to improved simulation accuracy, visualizing the individual differences of machines and differences in each machine's usage environment would be interesting.
I have also thought that improved simulation accuracy may make it possible to diagnose the degradation of machining performance. Specifically, being able to compare simulation results with real results at all times to check if they are any differences, and if there is a sudden large difference, being able to make judgments, such as there must be trouble, or that something is wrong with the fixture of the workpiece. If the difference increases slowly, assumptions may be made, such as the tool is wearing down or the machine has started to age, though the interpretation of such states presents a challenge. Anyway, such developments can be expected. I look forward to future progress in simulation of machine motion, as in the development of CNC GUIDE 2 and others, as well as in machined surface estimation.
In recent years, for energy-saving to achieve carbon neutrality, you have engaged in various initiatives, including reducing the number of operating hours and reducing power consumption of peripheral devices. As another approach, I suggest you think about energy saving when creating an NC program. For example, if you change the workpiece's mounting orientation or position, the machine's energy consumption will change greatly, especially in five-axis machining. When CNC GUIDE 2, which I just mentioned, acquires the ability to measure energy consumption, you will be able to compare changes in energy consumption according to the workpiece's mounting orientation or position. In addition, though I cannot come up with a specific method, I suggest making it possible to automatically generate an NC program that exhaustively searches for the way to move the machine that minimizes energy consumption based on the CAD data of the machined shape and the motion characteristics of the servo and machine. I believe it will be possible to create a totally different concept from the conventional CAM. This will be a dream come true.
I think digital twin will further evolve. Today's exhibits encourage me to dream of new horizons. I heard that FANUC will be celebrating its 50th anniversary this year. I hope you will continue to explore innovative technologies for world-leading manufacturing toward the next 50 years, namely your 100th anniversary.

President Yamaguchi: Thank you very much, Professor Shirase. Next, Professor Hideki Aoyoma, please share your thoughts with us.

Professor (Hideki) Aoyama: Hello, I am Hideki Aoyama. Thank you very much for inviting me to the Open House Show and roundtable discussion today. I highly appreciate and am thrilled by this opportunity to see actual exhibits onsite and to meet all of you face-to-face. Last year, your exhibits, despite being viewed online, exceeded my expectations, and I was able to see the exhibits in detail. However, being able to view in the real world had a much more powerful impact, and questions could be asked dynamically, which I think has led to a higher degree of understanding.

Professor
Hideki Aoyama

In addition, although I felt that the entire industry had stagnated due to the COVID-19 pandemic, I was quite reassured when Chairman Inaba made his presentation during the party of the Japan Machine Tool Builders' Association held the other day, and announced that he was expecting great sales.

In my position, I am interested in digital twin technology. This technology allows a real model to be converted into a digital model with a higher degree of accuracy by using servo information, which is one of FANUC's areas of expertise. This is a tremendous advantage for FANUC. I noticed at the Open House Show that you intend to aggressively promote this technology, and see it as being extremely promising. I think that die mold users in particular have high expectations for SERVO VIEWER, which accurately simulates a machined surface based on the modeling of the servo machine, including the characteristics of each axis. If a mechanical model for tool deflection, tool wear, and tool vibration is implemented to the simulation in addition to the servo machine model that I saw at the Open House Show today, I believe that ultra-high precision can be achieved in the simulation of an actual machined surface. In a joint experiment with the die mold division of an automobile manufacturer, I investigated the aspects of machined surfaces the die mold division pays attention to. It goes without saying that the shapes must be formed accurately. However, rather than decreasing deviations at a 50- or 100-micron level on free curved surfaces, die mold polishers are trying to identify the causes of scratches and fog lines on machined surfaces that are unrecognizable to the human eye, and to eliminate such defects. Using SERVO VIEWER to find the cause would be very much appreciated by those engaged in die molds. I hope that you will continue to enhance the functionality of SERVO VIEWER and add a mechanical simulation function with a tool deflection model in particular, as I have just mentioned, since this would be quite effective.

Another functional enhancement that impressed me was the increase in the operating speed of CNC GUIDE 2. By using CNC GUIDE 2, and modeling a servo machine to make a digital twin simulation, machining can be optimized and CNC parameters can be adjusted automatically, enabling even workers with low machining skills to perform advanced machining. In this respect, I realized that processing can be performed at a very high speed due to the introduction of a CPU with high functionality. Compared

Digital Twin

to the machine tool that I currently use at my university, CNC GUIDE 2 reduces the block processing time to one-tenth, which considerably reduces the block length, while making machining both fast and highly precise. Up to now, machining data for CAM had been created based on the concept of extending the block length as much as possible. However, because it is now understood that so long as block processing can be done in time, minimizing the block length will increase machining speed and precision. I felt that such an enhancement in CPU functionality would be quite effective.
Furthermore, with regard to machining of the die mold design surface, I am focusing on fine surface technology. Here, the tool path optimizer and machined surface estimation functions were introduced as the latest features. Presently, the tool path optimizer corrects the machining point using CAD data and the machining data for a single line. However, as CAD data has already been entered, it may be possible to correct machining points for multiple lines instead for a single line by perceiving the machining data as surface data.
Moreover, as energy-saving efforts, FANUC is committed to various initiatives to reduce power consumption. In today's environment, it seems it is no longer possible to do business in Europe without taking energy-saving measures. ISO as well as JIS have clearly defined processes to measure the environmental impacts of machine tools. As such, adding a function that enables a machine tool's environmental impact to be measured automatically simply by pressing a button on the controller would be a welcome feature for machine tool users. This would encourage them to select that machine tool, though implementation may be burdensome for the machine tool builder. To conform to ISO and JIS processes, experiments were conducted. In some cases, the power consumed by the machine tool and the cutting process merely amounted to about 15%. Most of the energy was used by coolant pumps. What was surprising was that much power was consumed merely to prevent compressed air from leaking in factories.
I would like to finish my comments by speaking about robots. FANUC has been developing yellow, green, and then white robots, which gives me a very strong impression that you are focusing on collaboration between robots and humans. I believe that further developing such collaboration will lead to robots autonomously going to processes that are experiencing problems to help deal with such problems. This will require dynamic combination with a scheduling system, and if that becomes possible, I can imagine a robot mounted on an AGV automatically moving to the problematic area to help solve the problem.

President Yamaguchi: Thank you, Professor Aoyama. Now, General Manager Iwashita, may we hear your comments?

Iwashita: I am Iwashita from the Software Research & Development Division. Thank you for your many valuable comments today, mainly concerning digital twin technology. We are implementing initiatives to improve performance, especially that of high-speed CPUs, with the aim of refining the conventional real-world technologies, which we consider to be very important. At the same time, we realize that simulation technology, namely digital twin technology, is necessary to make the most of real-world technologies, and that is why we launched relevant initiatives last year.


Iwashita
(General Manager)

Last year, we received a number of comments emphasizing the use of actual machines, and that such technologies were not helping to reduce actual machining times and so on. In our efforts to respond to such comments, we introduced the servo machine model, and we plan to develop this model focusing on high-speed simulation.
The servo model will of course, simulate the characteristics of the servo machine, including, for example, torques and errors. The data of the simulation will be compared with real-world data to support machine diagnosis, as Professor Shirase mentioned, or calculating energy consumption, and other such improvements. This year, we have gotten a lot of homework as usual. We would like to not only simulate movements but also improve performance by using AI to optimize parameters, to estimate and compensate for deflection and deformation with our knowledge of tools, and so on. As we are still mid-way in approaching these goals, we appreciate your continued support and guidance. Thank you very much for your time today.

President Yamaguchi: Next, Professor Takagi, could you share your views with us?

Professor Takagi: Thank you so much for inviting me here today. There is something special about attending presentations in person, and I have really enjoyed meeting the FANUC staff.


Professor Takagi

I would like to briefly speak about two points. My field is analog integrated circuits, so allow me to briefly introduce the situation globally as well as in Japan. The semiconductor industry's growth rate worldwide was estimated as being slightly more than 26% in 2021. Though the growth rate has been fluctuating, 26% is a large percentage. The industry is growing nearly every year. Last year, the market size amounted to nearly 600 billion dollars. Of that amount, analog semiconductors are said to account for approximately 100 billion dollars, which is about 20%. Although analog semiconductors recorded a record-high growth rate of 33.1% in 2021, Japan's semiconductor industry unfortunately is stagnant. As Professor Aoyama just mentioned, semiconductors are in short supply around the world, and this has presented a somewhat contradictory situation in Japan. Being involved in the semiconductor industry, it is a matter of concern, and I am wondering what can be done

to remedy this situation.
Given these circumstances, the National Institute of Advanced Industrial Science and Technology (AIST) has proposed minimal fabs. As some of you may know, a minimal fab does not require a cleanroom, and the manufacturing cost for a single line is about 1/1000th that of a conventional facility. A prototype was completed in 2009. With minimal fabs, The previous trend of monolithic integrated circuits was mass production in small varieties, but we are trying to change this to small volume production in wide varieties. The idea is very Japanese, in being rather adaptable. The delivery time is short as well, and takes only a few weeks, instead of a month. At the current level, wafers of 0.5 inches up to a little larger than 1 cm with a minimum line width of 6 μm can be manufactured. From this information, I thought it may be possible to machine semiconductors with FANUC's machining technology. As someone involved in the semiconductor industry, it would be delightful if FANUC's machining technology could be introduced to a minimal fab, to start a semiconductor revolution originating from Japan. There is a small part of me that has expectations for this to happen.
I have been working with you on collaborative robots, and this is another topic I'd like to bring up. This year, the lineup was enhanced with additional models. The weight of the green robot was reduced by 62% and a collaborative robot with a payload of 35 kg was released as well. Though I am an outsider in this field, even I found this to be an amazing technology.
Another impression I had when looking at a white robot was that the movement of screwing is close to human movement, and the white robot is becoming similar to humans. This is probably because sensing is applied to the movement of screwing. The important point about collaborative robots is that they can move without colliding with people and can stop immediately when they come into contact with a person. I have heard that sensing vibration is critical. We have been working with you on this, though unfortunately during prototyping, a problem was found in the proposal we presented last year. However, this problem was not theoretical but rather was in a section not shown in the circuit diagram. We proposed a solution, and I have heard that the matter has already been resolved, and development has proceeded to the next step. Regarding this point, analog circuits implicitly require empirical knowledge, and I think that is one of the difficulties of analog circuits. Still, as an academic, I must establish a theory that doesn't require tacit knowledge, so I am thinking about how to handle this better next time.
I hope we can continue to support your company in such areas where experience is needed.

President Yamaguchi: Thank you, Professor Takagi. Next, Professor Sasahara, please share your views with us.

Professor Sasahara: Thank you for inviting me to this roundtable discussion. Today, I came here early and viewed the entire Open House Show. I was finally able to see actual exhibits and communicate with FANUC staff face-to-face, so I enjoyed my time and am very satisfied with today's visit.


Professor Sasahara

Let me outline some topics with a focus on FA. First, I got the impression that major technical advancements have been made with regard to digital twin and hardware sophistication. I took a look at the faster minute line segment program, tool posture turning, machined surface estimation that takes into account servo characteristics, AI-based servo tuning, and other exhibits with great interest.
Regarding the faster minute line segment program, the demonstration showed a program for a line segment with a length of 5 microns, which resulted in accurate machining without reducing the speed. That is amazing, but from the standpoint of actual machining, an NC program for a line segment with a length of 5 microns cannot normally be developed for general machining. It is necessary to set a very small tolerance in tasks for CAM, so I think a tolerance at a submicron level will be needed to achieve a line segment with a length of 5 microns. Generally speaking, this is difficult to do. This is because the operation time in CAM will be too long and the volume of NC data itself will also be quite large. In addition, the speed may not increase due to the CNC block processing time becoming a bottleneck. Still, for dies having free curved surfaces and similar dies, I strongly support an NC program for a short line segment length in an allowable range for the block processing time. I have the same view as Professor Hideki Aoyama, who just spoke, and there is no doubt that both higher speed and higher accuracy can be achieved by shortening the line segment length within a range that fits the new CNC, which features a markedly short block processing time.
I think it would be best for FANUC to not only promote the faster program and shorter block processing time but also to communicate to users how to create an NC program that actually makes the machine run more accurately and faster. I say this because there are still many users who believe that a large tolerance and smaller program size will lead to faster operation. I hope that FANUC will provide information such as: "These are tips to create programs that make full use of FANUC's high-performance NCs."
As CNC GUIDE 2 now enables simulations to also consider the servo characteristics of each axis of a machine tool, this development is advantageous to machine tool builders, and in some cases, to users as well. For machine tool builders, this can also be beneficial to set and adjust servo-related parameters. As exhibited, for users, machined surface estimation that takes into consideration the impacts of taking shortcuts at the corners and more realistic machining time prediction are possible. This is greatly advantageous in that more detailed information can be obtained compared to a machining simulator for general NC programs.
Another thing I wish to discuss is the change to the NC I/O unit, which may seem unexceptional but is very significant. When a long-used unit is replaced by a new I/O unit, the new unit should be used continuously for many years. Based on the concept, I

Servo device exhibit

think you have given deep consideration to compactness, maintainability, and workability. As I examined the new unit, I could imagine that you have taken great pains to develop it because it is likely to be used for several decades, and I felt that this is a very beneficial change for users as well as machine tool builders.

President Yamaguchi: Professor Sasahara, Thank you for your comments. Next, General Manager Hashimoto, please respond.

Hashimoto: I am Hashimoto from the Hardware Research & Development Division. Professors Takagi and Sasahara, thank you so much for your comments. As some of the professors have pointed out, there have been numerous improvements in software functions as a result of improved hardware performance and fast CPUs, among other factors. As the person in charge of hardware development, I feel that we must always work to enhance hardware performance.

Hashimoto
(General Manager)

In addition, during this Open House Show, some applications that make use of the sensing functions of the collaborative robots, especially the white ones (CRX series), have attracted attention. As Professor Takagi mentioned, we also believe that analog sensing technology, specifically the technology for sensing minute signals, will become extremely important. Thanks to Professor Takagi's guidance, we were able to solve some problems, and we achieved the desired accuracy. However, even higher accuracy is required as well as stabilizing the circuit and detection, since minute signals are handled. We look forward to receiving further guidance from Professor Takagi on various matters, including such points.
Professor Sasahara mentioned improved processing speed. In connection, when I was explaining that CPU performance had been enhanced to such an extent, I was asked a question from a visitor. The question was, "How does that enhancement affect machining results?"
In the end, I realized that we must carefully consider what machining results can be achieved by our improved performance from the user's viewpoint, and promote this as a function not only of the hardware but also of the software.
In addition, thank you for mentioning that the FANUC Slice I/O has been made smaller. We think we have created a compact I/O unit with good maintainability as a result of careful examination, so we will now focus our efforts on increasing sales. We will continue to strive to improve the hardware's performance level, and we very much appreciate your continued cooperation.

President Yamaguchi: Thank you. Next, Professor Matsubara, please let us hear your comments.

Professor Matsubara: Thank you. I would like to truly thank the

FANUC staff who kindly presented explanations at the Open House Show today.


Professor Matsubara

The key point of interest among the exhibits that I saw is digital twin. In the old days, when the field of die machining was growing, Professor Yoshiaki Kakino, who was my superior, launched a study meeting to solve an issue in which CAM, CNC, and the machine were not connecting smoothly. The meeting was called the CCM Study Meeting, from the initial letters of CAM, CNC, and Machine. According to the Open House Show that I saw today, CAD, CAM, CNC, Machine, Machining (process), and Measurement have all been connected, the first letters which form "CCCMMM." Since it is a bit difficult to pronounce, I think the shortened "(CM)3" is better. Because production technology will advance little by little, conceptual things rarely take shape. However, I could clearly see the connection this time, which expanded my imagination.
I often used to design new machines and tune the servos. However, at that time, we could not predict the resulting path and the machined surface. Today, we can simulate a machined surface digitally, and I think our own design and tuning results can be obtained very easily. Recently (or rather, still now), friction has been a problem to me. With regard to sliding friction, the step accuracy changes even with a slight change in the oil additive. Although I apply Teflon to the surfaces of sliding guideways, I have no idea which element affects what. For that reason, it is difficult to create a model. On the other hand, once a model has been created as a servo model, you can see what the machined surface will look like. I do hope that you will make progress in research and development of digital twin. I did take a look at a digitally machined surface, but I am the type who would rather measure it. A French associate professor at our university often finds interesting sensors in Europe. One such sensor was a displacement sensor with considerably high precision, and you can perform on-machine measurements at high speeds and ultra-high precision by mounting it onto the machine. However, even if it can perform measurements, it cannot be used for post processes without the position data of CNC with address information. Therefore, if you can connection this part, a process chain can be formed.
Another point is robots. First, let me speak about a recent experience of mine related to robots. Robots are working in our Katsura Campus library. Their job is to deliver the books carried in from other libraries by a vendor to a gate. I watched how these robots do their task, and because they do not have hands, when they had to go down in an elevator, a staff member had to accompany them and press the button. This means that a human has to takes care of the robots.
According to the concept of IoT, if the elevator control and the robots could communicate, the staff will not be required to take care of the robots, and I think the world is advancing in that direction. However, what I saw at the Open House Show today was analog-like operation, in which a robot opened the Robodrill door using its own hand. I thought that perhaps this kind of analog-like interface is rather important. The servo amplifiers of old CNC servo systems received analog commands, which enabled us to do many things. If we continue to keep analog interfaces in the environment on purpose and consider robots as being a generic term for various distributed devices instead of a single unit, it may be possible to think more flexibly about the relationships between other devices, robots, and humans in the environment. I think it is quite interesting to consider this as coexistence rather than automation.

President Yamaguchi: Thank you, Professor Matsubara. Next, Professor Fujimoto, could you please share your comments?

Professor Fujimoto: I am Fujimoto from the University of Tokyo. This is my first time to join the roundtable discussion. Thank you for inviting me.


Professor Fujimoto

From the academic year from 2010 to 2020, I belonged to the Hori/Fujimoto Laboratory. Following the retirement of Professor Yoichi Hori, I became head of the laboratory last year. I work both in the Faculty of Electrical and Electronic Engineering and the Graduate School of Frontier Sciences at the Kashiwa Campus, where the laboratory is located.
My research includes control engineering and power electronics, including motion control, vibration suppression, and wireless in-transit power supply for electric vehicles, as well as servos for machine tools, lithography equipment, and robots. I also study servo technologies for collaborative robots at the academic level. In the automotive field, I am a member of the Society of Automotive Engineers of Japan, which has about 45,000 members. It has a technical council that oversees around 50 technical committees, and I will be chairing it soon. If any of you are involved in automotive engineering, I welcome any criticism as it will be my job as the chair to address complaints.
In the servo field, I have been working for the Institute of Electrical Engineers of Japan and IEEE for a long time. I took a former member of the Fujimoto Lab, who joined your company in April, to the international conference on power electronics that was held until yesterday in Himeji. His research at the university focused on suppressing torque ripple by utilizing harmonic current control which has current wavebands above kilohertz, suppressing sound and vibration, and reducing copper and iron losses at high frequencies. Today, at the Open House Show, I was reassured to learn from the displayed panel and explanation from the staff that such technologies are available, thinking that the new employee I just mentioned may be able to play an active role.
Now, allow me to share with you my feedback on today's exhibits. I have been studying servos for machine tools for many years. I

have always hoped that your servo amplifiers will become easier to use and tinker with for academic research. I think that it is possible to change the feed forward gain of the P and PI controllers, but more than that, for some time I have wanted to change the controller starting from the structure, and introduce a new theory. As mentioned by Professor Emeritus Higuchi, control theory has been promoted at recent academic conferences, and servo theory has been developed with the aim of achieving greater utilization of linear encoders, load-side encoders, and load-side acceleration, while the vibration suppression theory has also changed considerably. Technologies are advancing rapidly, but I believe that the conventional P and PI structure and feed forward have their limits when it comes to incorporating these technologies.
In particular, since industry-academia collaboration is very active in Europe, I am concerned that we may fall behind in such collaboration with regard to applying the latest servo academic research.
Given such circumstances, I have high expectations for the digital servo adapter that we saw today, because it will allow machine manufacturers who are familiar with mechanical characteristics to participate in motion control to some extent.
I was also interested in the chatter suppression and vibration control, which was exhibited as a new feature, because a former member of the Fujimoto Lab, who now works in FANUC's Servo Research & Development Division, studied this subject as a student. For a second, I thought his work had finally come to light, but this feature was actually different, so I was a little disappointed. I am really looking forward to the future of this project, as I am sure that it will continue to make progress.
Finally, it was wonderful to see that CNC GUIDE 2, which we had been discussing, now allows the input of all mechanical frequencies and servo characteristics of each axis, and calculation is reduced to about one-tenth of the machining time. The new system identification theory has been developing rapidly recently, and the full-closed control theory has emerged. I hope a framework for open innovation will be developed among universities, servo manufacturers, such as your company, and machine tool builders.

President Yamaguchi: Thank you, Professor Fujimoto. General Manager Fukuda, would you like to respond?

Fukuda: I am Fukuda, General Manager of the Servo Research & Development Division. Professors Matsubara and Fujimoto, thank you for your comments. Today, I took a tour of the Open House Show with Professor Matsubara. As we viewed the main exhibits, he gave me positive feedback on our achievements and shared some insights, reassuring me that we are providing what the market needs. However, I felt that we still have a long way to go in some areas. The question, "Is that a machine manufacturer's perspective or a user's perspective?" is asked frequently. I was made aware again that this distinction must be made in our development process.

Fukuda
(General Manager)

As for digital twin technology, as you stated, we have introduced the servo model and measurements into our concept. We would like to continue to research how to digitally feedback measured values. It is very intriguing to think about how to model machines including friction. It will likely take a long time to find a solution, but I want to start thinking about it soon.
Professor Fujimoto, thank you for joining our discussions from this year. We are very excited to have such talented employees join our team through you. Energy efficiency is definitely an important topic for servos, but we must continue to make steady improvements in order to achieve energy efficiency that is higher than that of existing electric machines with servo motors.
In addition, Professor Hori advised us to enhance our approach to academia in his remarks last year. Your research is very informative, so we would appreciate your guidance in our efforts to promote energy conservation for control systems. I look forward to our continued collaboration.

Robot

President Yamaguchi: At this time, let's shift our focus to robots. We will start with Professor Sugano. Professor, please share your comments.

Professor Sugano: Thank you for inviting me here today.
I had an opportunity to see many things at the International Robot Exhibition in March, and today, I learned more new details from the exhibition staff. Since the other professors have already spoken about robots, I think we are running out of things to say as a team on robotics, but I would like to talk a bit about something very specific to robots.

Professor Sugano

I have always been an advocate for controlling robots with force/torque sensors mounted on each joint, rather than with the conventional six-axis sensor on the wrist. The white robot controlled by sensors mounted on each joint was moving much more smoothly than before. Six-axis force sensors on the wrist cannot respond to force applied to the forearm or upper arm, and I think it is important for future collaborative robots to be able to sense with their entire bodies.
At the last roundtable discussion, I said that although the current focus may be on the capability of robots to stop, I wanted to see R&D efforts toward developing products that can follow and mimic human movements as much as possible. Mounting force/torque sensors on each joint is essential for achieving such capabilities, and the fact that the new robot is controlled in this manner means that it will have no problem moving alongside people. In other

words, the robot can move in closer proximity to people, and even if the robot comes into contact with a person, it can follow, avoid, or stop without problem. Going forward, I hope to see R&D efforts toward creating industrial robots that can work close to people.
Just two years ago, the Cabinet Office launched the Moonshot Project, and I was appointed as the project manager for Goal 3: "AI-driven Robot for Embrace and Care ," so I have been engaged in R&D to create a robot that can work together with people. In this project, we engage in R&D to adapt robot motions to human movements by utilizing AI to predict human movements, and we are working to create a robot with joints that move flexibly. I believe that this feature is common to your white robot, and I hope that you will actively advance R&D of your white robot in order to demonstrate its superiority to the world.
In fact, I am launching a new research theme for the Moonshot Project. For robots to work in close proximity to people in the home or in medical care, nursing, in factories, and so on, the key is not just to adjust the robot's motions in consideration of people, but also to change how people feel about robots. This means that we must examine social acceptability, so I have teamed up with sociologists in order to start studying ELSI (Ethics, Legal, Social Issues) for robots.
When we discussed how robots may be accepted, particularly in Europe and in the US, I was asked why my robot was white (the robot I made was also white). Unlike robots in science fiction, for real robots that move alongside people, color matters because color may connote racism.
Naturally, different cultures have different views on what is perceived to be appropriate in movements and manners. Industrial robots focus on efficiency and energy conservation, but it has been pointed out that efficiency may not always be prioritized because when robots move near people, their movements may be interpreted as being rude. Therefore, even if a robot is created in Japan, it must be acceptable to the entire world — to that end, social acceptability is a very important factor to consider.
At present, our research focuses not only on the design and colors of robots but also on how humans should adjust their movements to be in tune with robots. Eventually, if not today, robots may be introduced to production sites, where they may learn human skills and work with humans. Therefore, we must consider social acceptance in our research on programming, controlling, and AI. Since your company has also released a white robot, I hope to continue our discussion on this topic.

President Yamaguchi: Thank you, Professor Sugano. Next, General Manager Abe, who works closely with Professor Sugano in his day-to-day work, can you comment?

Abe: I am Abe, General Manager of the Robot Mechanical Research & Development Division. Professor Sugano, as always, I appreciate

Lineup of collaborative

your valuable advice.
First, I will talk about the white robot with sensors mounted on each axis. The green robot is similar to the yellow industrial robot, except for having a six-axis sensor. Although the green robot stops when touched, it does not have the flexibility that you repeatedly referred to. In contrast, the white robot has a sensor on each axis, which enables it to mimic movements and flexibly move its joints as you described earlier today. This has expanded the robot's range of application, and we will continue to develop this feature since both FANUC and our customers have positively evaluated its scalability.


Abe
(General Manager)

Also, regarding social acceptability, at present, robots look like robots in appearance and are seen as automatically moving, non-human beings. However, when robots work with humans, human emotions will become important. You presented insight into the near future, so I would like to explore options, including colors. I appreciate your continued support.

President Yamaguchi: Thank you. Now, I would like to hear a few words from Professor Asama.

Professor Asama: I am Asama. Thank you for inviting me here today. When I joined online last year, I was reminded of the limitations of online participation. As many of the professors already mentioned, through face-to-face communication, we can interactively talk about a variety of things. I am glad that we could discuss a wide range of topics, making this physical experience quite different than online. I as well have learned many things.


Professor Asama

Many of the professors have already addressed many topics, so there may be a great deal of overlap in what I have to say, but please allow me to speak briefly about what particularly impressed me.
First is the improvement in usability. In addition to vision sensors, force sensors are employed as a standard feature in collaborative robots, and I think this greatly helps to improve usability. Of course, this leads to improved reliability, but I think the main achievement is the feature that enables the robot to act autonomously and appropriately with only quick and easy system configuration.
FANUC's traditional robots are made exclusively for experts, but your recent models have gradually come to be equipped with features for small- and medium-sized companies as well as the general public, including non-experts. I think this shift can dramatically expand and diversify your user base.
This indicates that industrial robots are on track to become more and more common. Nowadays, when you visit a DIY store, you can find a range of tools. People make a variety of things using DIY tools, and skilled people make use of construction equipment to work on their own gardens. In this context, I hope that one day, the general public will be able to use FANUC's robots to make things at home. It would be great to see FANUC's robots become available at DIY stores someday.
The second thing I want to speak about is digital transformation. It is extremely important that with the increase in the use of robots, a wide variety of data can be acquired. This will lead to the development of digital twin technology and cyber-physical systems. I think the industry is heading in a direction in which new business potential can be developed by utilizing the value created by such data, and this trend is accelerating.
I have been very interested in the FIELD system for quite a while, thinking it would be the core of a major new business. To me, one highlight is that the FIELD BOX, which was on display today, can centrally collect data from a variety of IoT devices, as well as enable various types of control and operations in real time.
As a third topic, I would like to touch on social initiatives. Like other industries, the manufacturing industry is expected to contribute to achieving SDGs and carbon neutrality, so companies must demonstrate that they are contributing. As usual, I was impressed by the various initiatives toward energy efficiency you have dedicated yourselves to.
I will also briefly mention trends in the robotics industry. I consider this year to be a milestone for robots.
One reason is related to the Japan Robot Association. This year marks the Association's 50th anniversary. I am currently creating a vision for the robotics industry as the chairman of the committee in which Mr. Morioka represents FANUC. We are now having intensive discussions to create a vision for 2050.
Another reason is the Robotics Society of Japan, which celebrates its 40th anniversary this year. The Society is scheduled to give an academic lecture in early September at the University of Tokyo. As a chair of the steering committee, I would like to ask FANUC to participate.
The third subject is the Japan Robot Awards. Recently, this contest has been held once every two years, and this year marks the 10th time the event has been held. FANUC has won various awards in this contest, and this year a special commemorative award will be presented. I believe this is another major event of the year.
In terms of academic and technical trends, probabilistic and statistical methodologies are dominating the field and being incorporated into various papers. AI, machine learning, and deep learning are also being actively adopted and applied in academia. In terms of hardware and other aspects, soft robotics is becoming a trend, and the use of drones have advanced tremendously. However, it is very regrettable that this technology is being applied for military purposes.
Also, as Professor Sugano mentioned, the Cabinet Office has launched the Moonshot Project. This is a major academic project which is more a basic research project. The concept is to use robotic technologies to transform society by 2050, and there are

currently four ongoing projects in the Goal 3 category.
I think the general key word is "connect." As mentioned earlier regarding FIELD system, the connection initiated in Industry 4.0 has enabled robots to collaborate with each other as well as with people, thereby realizing a variety of functions and services. I believe that is why we are seeing developments and social implementations accelerating in various areas.
In this context, decentralization and protocols are considered important, and I think that FANUC's current initiatives align with this trend.
In addition, there are three challenges to overcome. The first concerns "coexistence with humans." I am the head of the new Research into Artifacts, Center for Engineering, and I think that the trend is more toward coexistence with humans than toward automation.
In this light, when discussing how people and systems can coexist, human-related issues surface. Among such issues as labor shortages, aging societies with declining birthrates, diversity, work style reforms, and other matters, we must consider what is required of robots and what functions they should perform.
The next challenge concerns social aspects. To be specific, social acceptability, ELSI, and Safety 2.0, which Professor Sugano mentioned earlier. The focus is on functional safety, and I believe this will become extremely important and is being discussed at the EAJ and the Science Council of Japan. At the Science Council of Japan, Ms. Sudo and I have been continuing discussions, and we are attempting to put together a vision of what should be done for robots to join human society and coexist with humans from the viewpoint of social acceptability.
Lastly, I would like to mention resilience. As another professor stated earlier, as can be seen in the effects of semiconductor shortages in the manufacturing industry, supply and engineering chains are globally connected. If a problem occurs somewhere, it affects everywhere else.
In this context, how can we achieve resiliency in manufacturing to survive social changes? I believe this is an extremely important challenge. I am sure that FANUC is struggling with this challenge as well, and I would like to discuss this with you in the future.

President Yamaguchi: Professor Asama, thank you for your comments. General Manager Inaba, do you have any comments?

Inaba: Thank you, Professor Asama.
I think that the position of automation changed significantly during the COVID-19 pandemic. As General Manager Noda of the Business Division, mentioned, previously the main purposes of automation were to improve quality, reduce costs, and so on, but we now receive more requests for consultation on the introduction of automation as an essential element of business continuity. The purposes of introducing automation are expanding to include making up for the lack of skilled workers and preventing people from clustering as an infection prevention measure.
As such, the industries in which automation is being introduced and automation applications have also been expanding. Continuing from last year, we have been promoting reliability in automation as well as ease of use, while working to increase the model lineup to support a wider range of applications.


Inaba
(General Manager)

As the professors have commented, the CRX payload lineup has been expanded to include 5 kg, 20 kg, and 25 kg. We exhibited applications for high-torque tightening, polishing coated surfaces, palletizing cardboard boxes, and battery transport using the M-1000iA with a 1-ton payload. We also exhibited the SCARA series, which are used for 3C-related applications, computers, mobile phones, and home appliances, and the DR-3iB STAINLESS for handling primary food in the food industry, which was complimented by Professor Emeritus Higuchi. It seems the range of applications is unlimited, due to the expanding range of purposes in the background.
While increasing models in this way, we are further pursuing ease of use with respect to software, sensors, and usability, as the professors have described. We exhibited an interactive UI for launching the Vision Sensor, teaching and matching in a CAD model for bin picking, an AI error proofing function, and a cardboard box detecting function. The areas for applying force sensors have also been expanding and they are used for high-torque tightening, polishing of coated surfaces, and lathe centering in the exhibits.
Digitalization and the use of digital data are important Open House Show themes. In the area of digital twin, teach-less technology that makes use of simulation and cyberspace is being implemented. Moreover, more flexible operation has been enabled by using sensor information to further absorb differences between physical space and cyberspace.
At the Open House Show, spot welding operations generated by offline simulation in cyberspace are replayed in physical space without checking with actual operations. The Vision Sensor is used to recognize misalignments between cyberspace and physical space in order to correct the generated operation. In addition, using a mechanism similar to that of bin picking, in which the situation is different every time, a welding operation is performed without teaching. By extracting the position and orientation information from physical space and reflecting this information in cyberspace via the Vision Sensor, the optimal operation is generated.
The autonomous generation of such optimal operation is realized not only by the optimal path creation technology in cyberspace and sensor data processing technology, but also by FANUC's technology for industrial personal computers called "*i*PC" and related technologies that support arithmetic processing. Though *i*PC is a PC product, FANUC's lifetime maintenance is offered, which is one of the differentiating advantages of our company.
Going forward, we will proceed to carry out product development with reliability as the base axis and ease of use as another axis. Although developing "a robot that can understand the situation"

Palletizing with 25 kg payload CRX

DR-3*i*B STAINLESS

as mentioned by Professor Asama may not be easy, we will enhance autonomous functionality. In addition, we would like to maintain the perspective of considering how we can contribute to issues of sustainability, including carbon neutrality.
We very much appreciate your continued guidance. Thank you.

President Yamaguchi: Next, Professor Okatani, would you share your comments with us?

Professor Okatani: Thank you for this opportunity. As usual, my tour of the Open House Show centered on robots. Your collaborative robots especially caught my attention.


Professor Okatani

Three years ago, I recall that there were only a few green robots, but this time there were many white robots. I believe that collaborative robots will be very useful in expanding the range of robot applications. I have no doubt that the combination of vision and AI technologies will make robots easier to use than ever before as they come to be applied for new purposes.
Although I heard that the robots are not the most advanced in terms of technology, I was very impressed by the fact that they move properly as products, and that the actual products are close to what we see in laboratories.
This direction will probably continue in the future, but since vision and AI technologies are the realm of computer science, our neighboring countries are now number one in both quality and quantity. At international conferences, these countries attract overwhelming numbers of participants, presenters, and corporate sponsors.
It was mentioned that FANUC is probably the only robot manufacturer that produces vision technologies in-house. I hope you will continue with this effort.
Considering the future of vision and AI prediction, AI has progressed tremendously over the past decade, following the invention of deep learning. Some people have the pessimistic view that we may be heading toward another cold winter season for AI. In reality, however, from a researcher's perspective, we see exciting developments every day, and progress that exceeds our expectations. One example of the most advanced technology is AI that uses language. As far as the area of language is concerned, the latest AI models can talk at a fully human level and have extensive knowledge, so we can speak to them as if we are talking to someone who is very intelligent. Some researchers even say that general-purpose artificial intelligence is close to completion. However, this only applies to the area of language, and does not necessarily apply to the real world.
Therefore, in terms of vision technologies, it is difficult to academically study only images because these technologies are already capable of performing what can easily be done in general. Our lab is also studying AI combined with language capabilities, and after seeing the exhibits today, I realized that there are actually many things that we would like to try for on-site operations by utilizing vision technologies. While this may be inherently difficult, there may still be areas that we can develop by taking creative approaches.
In conclusion, we hope that our joint research will be of some help to you, and we ourselves would like to address important issues experienced in actual operations on-site that may not be readily noticed in the academic world.

President Yamaguchi: Thank you, Professor Okatani. General Manager Kato, please comment on that.

Kato: Hello, I am Kato from the Robot Software Research & Development Division. I would like to thank you for always providing us with advice. Leveraging the professors' remarks and advice, we have exhibited many new functions; automation of welding teaching, bin picking in which a path is automatically generated by finding items based on CAD data, box detection using AI, and a new function for the collaborative robot CRX in which a workpiece is placed while following the chuck.

Kato
(General Manager)

As Professor Okatani noted, AI is advancing rapidly. A controller with the mechanical ability to implement the results of such advancements for industrial applications, and new sensors that facilitate ease of use are now available. By incorporating AI, control, and the latest sensor technologies, we will begin by developing a robot that can be used by anyone. Then we will engage in development that expands the scope of robot applications to make it possible to achieve things that cannot be done by conventional robots or vision systems. We look forward to continue receiving your advice.

President Yamaguchi: Thank you for your comment. We will now conclude the part of the discussion on robots.

■ ROBOMACHINE

President Yamaguchi: Next, we will continue the discussion by focusing on Robomachine and machining technology in general. First, Professor Shamoto, could you share your ideas with us?

Professor Shamoto: I am Shamoto. Thank you for inviting me to this roundtable discussion today. As expected, it was better to look at the exhibits in person as I could get the actual feeling. Also, it was good to be able to discuss things directly with FANUC engineers.

Professor Shamoto

Let me speak about my general impression of Robomachine. FANUC has always been making machines with an extremely high level of basic performance, and this time I found that performance has gradually improved.
Performance has improved step by step, such as high speed, high efficiency, high precision, high rigidity, and high throughput, and cost performance is outstanding as you place high importance on cost. Although I had noticed this from before, I felt there was further improvement.
In addition to basic performance, Robomachine has steadily made progress in various directions, including energy saving, network support, ease of use, and automation.
Next, I would like to talk in more detail about Robodrill, which is close to my field. First, I heard that the cumulative total is 300,000 units which is an amazing figure. Previously, I thought of machine tools as mother machines that are not mass produced, but 300,000 units of a single model is a tremendous figure that is beyond belief. Excellence in cost performance that I just mentioned, is likely to be the reason.
This time as well, I realized the high basic performance of Robodrill. I had seen it demonstrated several times before, but seeing it again reconfirmed my impression of how great it is. From the demonstration of machining that runs briskly, and heavy cutting such as processing steel at high torque, it can be acknowledged that the basic performance is extremely high.
I also found the tapping spindle that you have newly developed to be a very good improvement. I originally thought that the advantages of Robodrill are its compact size and brisk movements with quick acceleration/deceleration. The performance has been improved further not only with quicker acceleration/deceleration, but also with low heat emission, which I think is excellent progress.
I would like to comment further on the brisk movement. Generally, the shortcomings of compact machines are low rigidity and the tendency to chatter, which are said to be an eternal challenge for machine tools. Chatter vibrations of machine tools is one of my specialties, and as a method to suppress chatter, there is SSV (Spindle Speed Variation), which is a function that changes the spindle speed.
SSV allows for quick acceleration/deceleration, and identifies the magnification; that is by how many times the scope has changed in the spindle rotation position and spindle speed of one rotation compared to that of the next rotation. This contributes to stabilizing chattering. As such, high acceleration/deceleration is highly advantageous for SSV, and leads to chatter vibration stability. This may compensate for the weaknesses of compact machines, which are considered to have low rigidity.
As for SSV, despite the fact that many research activities have been conducted at conferences, some of its mechanisms have long been unknown. Recently, however, these have become clear. Previously, conditions such as the amplitude and frequency were adjusted by trial and error, but today we know the optimal conditions. I hope you can apply such information and facilitate its use under good conditions. I made this comment at the Open House Show to those in charge as well as an FA staff member.
Another topic is higher precision. When I looked at the fine surface machining samples, I was impressed by the excellent mirror-like surface created by a machine in this price range. I am also interested in the direction of making considerable enhancements to surface quality. Because various underlying technologies have been improved, we have almost reached a stage in which any machine tool can create a mirror-like surface. Since I believe Robodrill is a machine that has the potential to do so, I hope you will proceed with research and development in this direction.
With regard to underlying technologies in which FANUC excels, for example, the company has created smooth surfaces with its fine surface technology, has reduced the vibration level of elements such as linear guides, and has developed a technology for instantly

sharpening sharp cutting edges using a laser, which is close to conventional scaife polishing, so I have high expectations for FANUC with regard to such peripheral technologies as well.
As for energy-saving technologies, which have recently increased in importance, you have been promoting visualization, which I think is a good thing. It would be even better if you can separate the amount of energy used for machining. For example, in the case of a spindle, I believe the torque used for machining can be isolated based on the difference in torque between when the spindle is merely rotating and when the machining is started with a G1 or G2 command. If you could isolate the net energy used for machining from the energy for other usages, visualization will advance further, leading to the improvement of energy-saving. I hope you will engage in research and development in that direction as well. That's all from me.
Thank you.

President Yamaguchi: Thank you, Professor Shamoto. General Manager Takatsugi, could you respond to that?

Takatsugi: Thank you for your valuable comments, Professor Shamoto.


Takatsugi
(General Manager)

On the Robomachine team, our mission is to build actual machines using our CNC and servo system, to propose concrete solutions for customers' production sites, and to feed back the knowledge gained from customers' production sites into the development of FA products and robots as well as Robomachines.
At this year's Open House Show, we introduced our initiatives on carbon neutrality, energy conservation, and IoT, which are in high demand in society. In addition, we unveiled new models of Robodrill, Roboshot, and Robocut, which were released last year, for the first time at the face-to-face Show, and visitors were able to see our dedication to enhancing basic performance.
For example, Robodrill is commonly used in machining of automotive parts and IT-related parts such as those of smartphones. The automotive sector is seeing a shift in machining parts in tandem with the transition to EVs. In the IT field, the trend toward larger, thinner smartphones is leading to an increase in machining of wearable devices, and we must respond quickly to these changes. As you mentioned, we need to make steady efforts to improve the machines' basic performance. The new technology will enable us to machine previously unmachinable objects, to finish machined surfaces with higher precision and quality, and to reduce machining time. We appreciate your continued guidance as we strive to achieve smart development practices so that we can accelerate improvements of such basic performance.

President Yamaguchi: Next, Professor Matsumura, would you share your comments with us?

Professor Matsumura: Thank you very much for inviting me here today. I was able to further deepen my knowledge by attending the face-to-face Open House Show and hearing various information while standing beside the actual machines.


Professor Matsumura

The latest key words for the development and progress of Robodrill are "social environment" and "responding to customers."
Regarding social environment, I noticed that you have enhanced the feature for visualizing energy consumption in order to promote achieving the SDGs toward a sustainable society. In other words, I strongly felt the necessity to remind users of the need to conserve energy and reduce energy consumption through visualization. I think this is a wonderful application because the feature provides clear operational guidelines for users as well as design guidelines for equipment designers. In particular, in cases in which an entire factory must be managed, the function can be integrated into the production lines to obtain some ideas about how to streamline operations, which I believe will bring about significant impacts.
In terms of customer service, Robodrill was developed to be highly user-oriented, and I realize that you have made many efforts. Last year or the year before, I mentioned the shift from “usability” to “effective use.” I believe that the proprietary G-code that you introduced this year shows precisely that you have realized an approach to “effective use.” Specifically, it is a wonderful achievement that this feature enables the stable drilling of many very small holes without breaking the tool, and I felt that the development of this G-code itself is significant. In the future, I hope to see further advancements through, for example, efforts to encode cutter paths to prevent damage to tools, as in the case of roll-in machining. I think this will involve digitalizing or packaging machining knowhow, and I am hopeful that this feature will lead to the digitalization of craftsmanship. This proprietary G-code is a package of movements and programs, but it would be more interesting if you could also apply your knowhow on movements, such as where to decelerate, and develop this into a tool to differentiate from others. Converting craftsmanship into code, however, requires thinking about how to correlate with craftsmanship. I believe that by bringing together your various existing peripheral technologies, you can digitalize such correlation and incorporate this into Robodrill’s control system.
As for automatic adjustment of control parameters, as Professor Shirase already said, these parameters may change due to the aging of the machine. If this is the case, it may be possible to apply this in the opposite direction. What I mean is that changes in parameters could be used to quantify age-related deterioration. If aging deterioration can be estimated based on past parameters for machine movements, this would become useful information for maintenance and new installations.
With regard to machine tool hardware, as Professor Shamoto

mentioned, the tapping spindle is a revolutionary technology. He emphasized how this spindle is light and fast, which helps to increase the hardware's energy efficiency. As I noted earlier, this is another technology that helps to address environmental issues. Though not related to the introduction of Robodrill, the FA team introduced machined surface estimation utilizing Servo Viewer, machine simulation, and cutting load simulation. I believe further development is possible if these achievements can be utilized for Robodrill. I heard that some issues remain to be solved in terms of machining, but given that your company has come so far in development, I am sure that this can be more than just a dream.

President Yamaguchi: Professor Matsumura, thank you very much for your valuable comments. General Manager Tong, could you respond to that?

Tong: I am Zheng Tong, General Manager of the Robodrill Research & Development Division. Thank you for your time today. At the previous roundtable discussion, you mentioned that we should focus on promoting "effective use" rather than "usability." This is exactly what we have achieved by the functionalization of Robodrill's machining technology.
For example, drilling small diameter holes is especially difficult, and cutting tools often break after drilling only a few holes when using conventional G-code. In developing our latest functions, we aimed to provide customers with a consolidated G-code that would enable non-skilled users to achieve craftsperson-standard performance by bringing our existing machining knowhow together.
We did this because people were having difficulty in effectively utilizing and maximizing the performance of Robodrill, making it difficult for them to assess the Robodrill fairly. We aimed to solve this problem by making Robodrill easier to use.
As for your last comment regarding the latest FA features, such as machined surface estimation, Robodrill has an aspect of being a showcase for FA products, so we will continue to actively implement such features and introduce them in application examples not only to Robodrill users but also to other machine tool builders. We will continue to do our best. Thank you.

Tong
(General Manager)

President Yamaguchi: Thank you. Next, Professor Kunieda, please share your thoughts with us.

Professor Kunieda: I am Kunieda from the University of Tokyo. Today, I took a look at many of your technologies that focused on wire electrical discharge machining. Thank you for showing them. Speaking of things other than wire EDMs, I was astounded by your

Robodrill on display

services' range of development. I was also deeply impressed by your efforts aligned with users' requests, such as repair services, preventive maintenance to help users, and integrating a robot to a machine without changing the control unit of the machine.

Professor Kunieda

Regarding wire electrical discharge machining, it is a great feat to have achieved a precision of one micron with such a soft tool as soft as a wire electrode. I presume that this is the result of tremendous efforts to make technological improvements one after another. Today, I heard explanations from the engineers about some of the improvements and concepts which were convincing and gave me insight.

As many machining parameters need to be set, I wonder how you can achieve a precision of one micron with a wire electrode that easily vibrates for several microns just by emitting machining fluid even when machining is not being performed. I presume you have achieved that level of machining precision through trial and error in experiments, and using the database obtained from such experiments. But, to what extent do you acquire machining conditions theoretically? I suppose it is still quite difficult to obtain the discharge reaction force of the electrical discharge generated in a narrow machined groove and the resistance that the wire electrode receives from the fluid in a narrow groove just from calculations. I am very interested in knowing to what extent you can gather such information theoretically.

Next, as for machining speed, companies used to compete intensely with one another regarding machining speed. While I have not heard much about such competition in recent years, are today's machining speeds good enough? Though I comment on this every year, only 1 to 2% of the area melted by discharge marks become debris in electrical discharge machining. This means that there is still sufficient room for improving machining speed, but in reality this cannot be achieved as expected. I viewed the exhibits wondering how you are attempting to approach machining speed enhancement.

President Yamaguchi: Thank you, Professor Kunieda. General Manager Fujimoto, do you have any comments?

Fujimoto: I am Fujimoto from the Robocut Research & Development Division. I would like to thank Professor Kunieda for his frequent guidance on clarifying the discharge phenomenon.

Professor Kunieda just asked how we ultimately achieve a machining precision of the order of one micron with a wire electrode that vibrates significantly just by emitting machining fluid.

Currently, we have been working on identifying wire electrode behavior through simulation, but this is extremely difficult and we are not making much progress. At present, to achieve such precision, we gather a tremendous amount of data on machining conditions by actually cutting the test shape by wire electrical discharge machining for each workpiece thickness and material type of wire electrode, and then adjusting the parameters for electrical discharge machining to obtain the target machining precision. As such, because it is very important to theoretically identify the behavior of wire electrodes and to enhance the simulation accuracy to the extent that it can be used to obtain data on machining conditions, we consider this to be a challenge that we should continue to work on.

Fujimoto
(General Manager)

In addition, Professor Kunieda also commented on increasing the machining speed. Enhancing machining speed has been a challenge for us for many years. The other day, Professor Kunieda kindly presented us with a valuable observation result that most parts of a workpiece melted by a single discharge were resolidified without being removed. This was precisely an appropriate hint, and with it, we have just begun to consider means to make the water flow ideal and to optimize the discharge control. We will also continue to actively conduct verification, including whether our present approach of performing electrical discharge in water is the optimal solution.

In any case, it is an established view that wire electrical discharge machining takes an extremely long time, so we will strive to make improvements and search for ways to help the users of our wire electrical discharge machines.

We appreciate your continued guidance. Thank you.

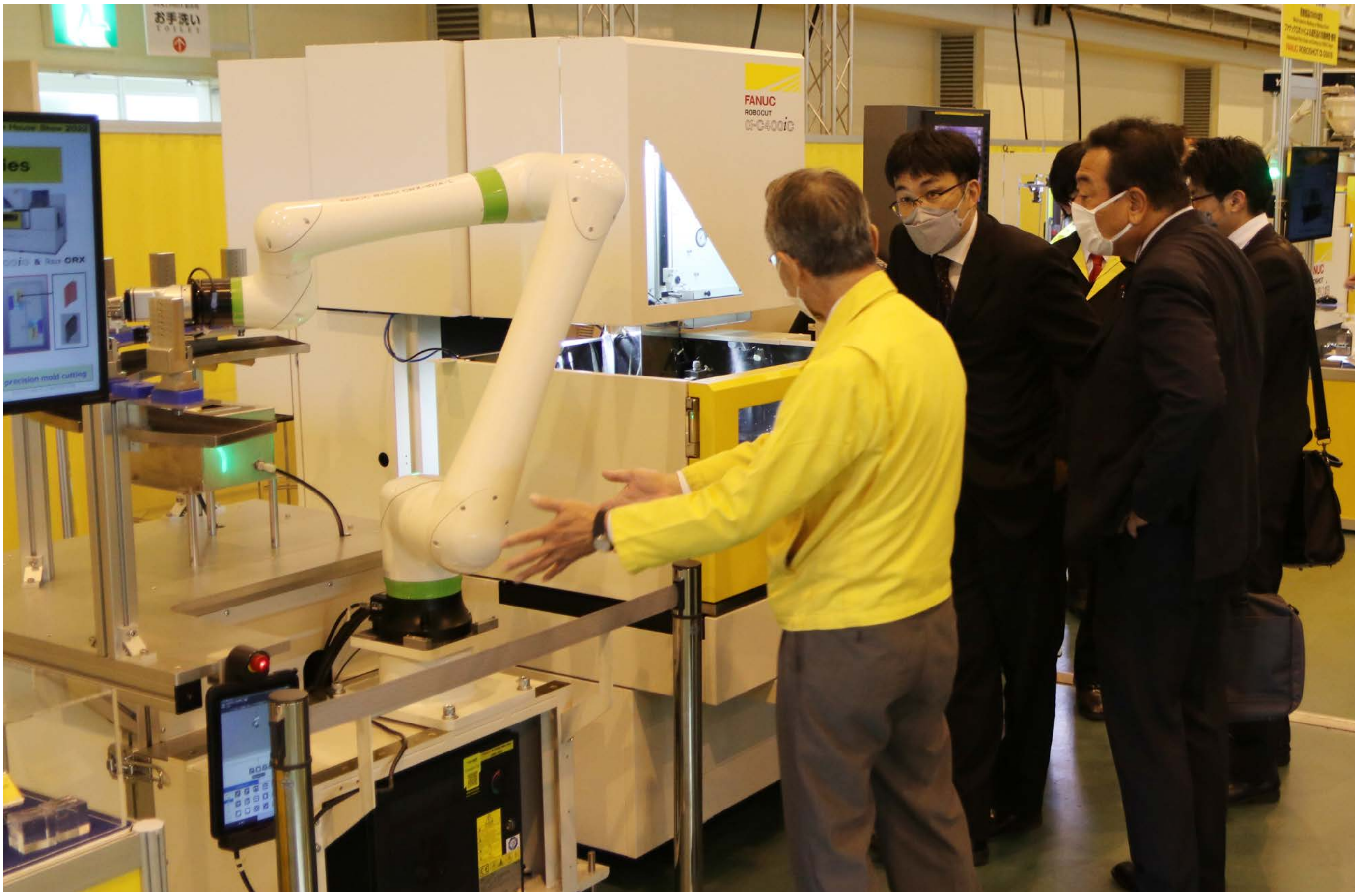
President Yamaguchi: Thank you. Next, Associate Professor Kajihara, please share your remarks with us.

Associate Professor Kajihara: I am Kajihara from the University of Tokyo. This is my first time to participate in this roundtable discussion, and it is nice to meet all of you, though I am somewhat nervous as I am surrounded by your company's top executives and prominent professors.

Associate Professor
Kajihara

The research that I am involved in pertains to direct bonding between metal and resin using injection molding. Put simply, it is research into creating textures on metal surfaces, pouring resin into the texture in insert molding, and creating a strong bond with an anchor effect, and others. Another of my research activities involves microscopes. I use your Roboshot for the research on bonding I just mentioned. Roboshot operates very vigorously and is helping us progress our research. Thank you.

Therefore, I will comment mainly on matters related to Roboshot. First, as for my overall impression of the Open House Show, I was very impressed with your high sensitivity to users' needs as well



Robocut on display

as your swift implementation of improvement measures and performance enhancements in response to such needs.
Regarding products other than Roboshot, I was quite surprised to hear that, for instance, CNC GUIDE 2 and digital twin, both of which have frequently been spoken about, have improved in terms of precision, and that Robocut can now create a tapered shape very quickly in a little over twenty minutes.
As for Roboshot, I was impressed by the many varied improvements that you have made, which have led to faster performance and finding new applications over the last couple of years.
In considering the performance of Roboshot itself, the first point is the 21.5 inch display panel, which received the Japan Society of Industrial Machinery Manufacturers' Award at the 51st Innovation & Inventive Design Excellence Award, "IDEA." From the start, FANUC's display panel has been large and easy to use, and for those of us who conduct experiments in particular, it is a welcome technology that enables us to carry out experiments in which we monitor sensor signals while experimenting such signals. You have also developed display panels that enables the use of browsers. With this, everything, including all LINK*i* conditions, can actually be monitored and I thought this technology will prove to be extremely important for the progress of IoT as well.
Although not part of the display panel itself, the temperature controller is properly linked according to EUROMAP standards, and it can also be operated from the main body of a Roboshot. Normally, a temperature controller and a molding machine are separated, so we need to go to the temperature controller to adjust the temperature. With the display panel, you can do it all from the main body.
As Professor Asama has already commented, the improved usability is superb, so users like us are thankful that such individual efforts have accumulated for our benefit.
With regard to performance, I witnessed automatic adjustment of clamping force by using a clamping force sensor. I thought it was wonderful that your high sensitivity to all kinds of things led you to focus on the clamping force sensor as an important parameter, which has led to improved performance.
Although this may be a minor point, you succeeded in saving energy with the well-designed barrel cover, which reduces energy consumption by 9% through heat control. Though it may be trivial, I think it is quite good that power is saved in such a simple manner. I truly hope that you will actively apply your technology enabled by your high sensitivity to such areas.
I recently realized that you are not only working on improving performance but also expanding applications through your focus on recycled materials. When I visited the K Show in Dusseldorf three years ago, what surprised me the most was seeing so many booths featuring recycling, and drawing much attention. They could hardly be seen at previous shows.
In Europe and the United States, great attention was already being

paid to recycling at that time, and circular economy trends have also gradually appeared in Japan. According to some green transformation (GX) scenarios for carbon neutrality, fossil fuels will no longer be used in 2050. If fossil fuels are not used, naphtha cannot be obtained, so this will prevent plastics from being produced.

In such a case, as one path, the trend of using recycled materials should emerge as a matter of course. I believe technologies to use recycled materials will become very important in Japan as well. Since FANUC has already started working on this and has gradually been producing results, I do hope you will continue to advance your activities in this direction.

Another thing I found interesting is two-component molding. General two-component molding, in which two materials are normally injected by rotating the mold, has been around for some time. In your case, the mold does not move, and the robot moves to pick up and inject the materials into the next cavity. I found such technology to be very interesting.

My question is, when the mold is usually rotated in two-component molding, are you using a robot to pick up and inject the materials because high precision in positioning and others are required during rotation? This has a very interesting visual impact, but I would appreciate it if you could share the reason.

My last topic is about your initiatives on IoT and AI. I am curious about your strategy for such initiatives with regard to Roboshot in particular. There are also many other things including FIELD system and LINKi, but they are applied to the relationships between molding machines and diagnoses of their operating statuses, which are so-called production technologies. Although AI is also used for many purposes such as preventive diagnosis, I would like to know if you are heading in the direction of applying such technologies to molding itself or considering doing so in the future.

For example, in the case I just mentioned concerning molding recycled materials, Hitachi issued a press release in March this year stating that they had enhanced molding precision by mounting sensors inside a mold and carefully controlling various information using machine learning. I would like to hear from you if this is also a possible direction for your company and under what strategy, including AI, you intend to improve molding phenomena and molding precision, or to improve the molding situation itself.

For example, a company in Europe optimized molding by installing more than 1,000 sensors in a molding machine to obtain and analyze big data, and then by applying machine learning to important data. I would be grateful if you could tell us about your future direction.

President Yamaguchi: Thank you Associate Professor Kajihara for

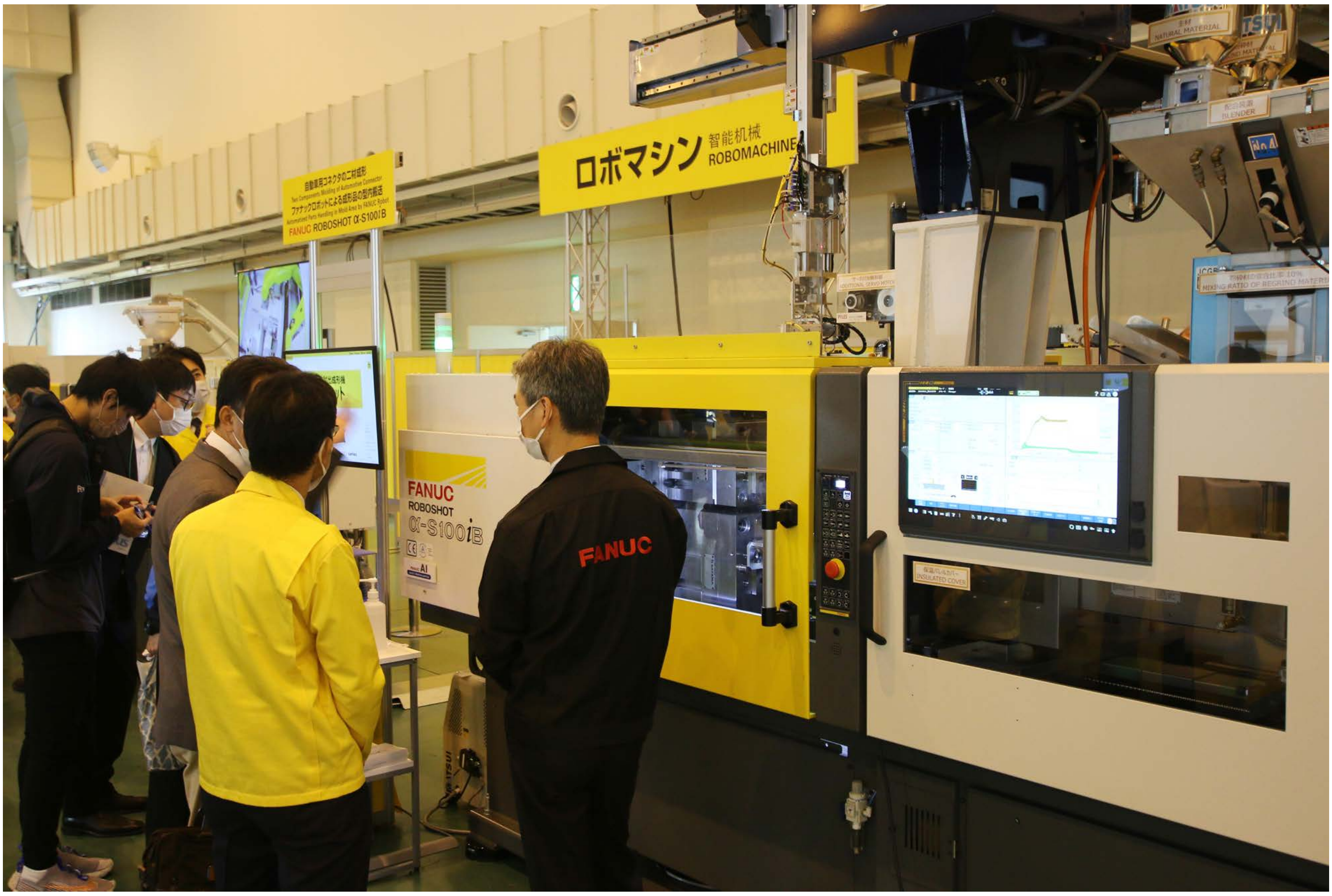


Exhibit of Roboshot

your questions. General Manager Uchiyama, how would you respond?


Uchiyama
(General Manager)

Uchiyama: I am Uchiyama from the Roboshot Research & Development Division.
Associate Professor Kajihara, thank you for joining us today.
As Associate Professor Kajihara commented on usability at the beginning, we have combined a large screen with the PANEL *i*H Pro and I believe that screen operability has considerably improved. We will further enhance this by using PANEL *i*H Pro to collect, analyze, and utilize various information. In the course of such processes, I think we will make use of AI-based enhancements.
In the case of injection molding machines, there are various molding conditions, but continuing to increase the number of screens without good reason is not a proper solution. We must consider how settings can be simplified from the viewpoint of customers, and this is where AI can exert its value.
Regarding the molding method for two-component molding that you asked about, as you noted, there is a method for performing two-component molding in which the mold is rotated on a rotary table. However, because there are issues with this method such as the mold becoming very complex, the requirement of precise positioning, and the mold becoming easier to break, we use a robot.
Next, as for your comment on recycling, we feel that saving energy and recycling will be major future challenges for plastics. Today, plastics face headwinds in some sense, so what we need to do is to turn these into tailwinds. Given this situation, our future large challenges include making good use of recycled materials and ensuring that precision is maintained even for recycled materials. As Associate Professor Kajihara commented, Europe is well ahead of other regions when it comes to recycling. Actually, in Europe's injection molding market, the rate of electric molding machines remains around 40%, which is rather low compared to Japan's 90%. We believe an approach that addresses recycling materials and emphasizes being environment-friendly as well as energy saving is needed to increase the use of Roboshots in Europe.
We will carefully consider the many comments we received from Associate Professor Kajihara today. We appreciate your continued support. Thank you for attending today.

President Yamaguchi: This concludes our discussion of topics with a focus on FA, robots, Robomachine, and machining technology overall.

■ Summary

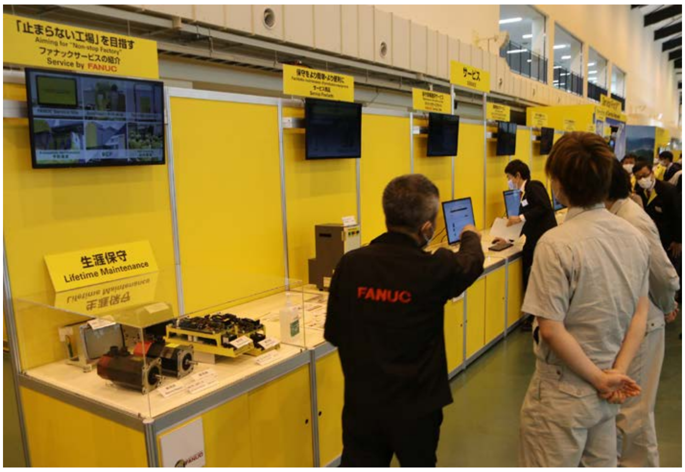
President Yamaguchi: Finally, Professor Shinno, could you please wrap up this discussion?


Professor Shinno

Professor Shinno: Thank you for inviting me to the Open House Show today. I met with FANUC's engineers for the first time in three years and had valuable discussions with those involved in the development of various new products.
In recent years, the environment surrounding Japan's manufacturing industry has changed dramatically with the emergence of an advanced information society, the aging of the population, and the declining birthrate.
This Open House Show featured specific R&D results related to various new products that enable us to respond to these environmental changes. As several other professors mentioned in their comments, FANUC has proposed new products of academic interest, such as collaborative robots with new color schemes and designs, methods for utilizing digital technologies to reduce environmental impacts, real-time simulation of machining processes, autonomous mobile robots that combine robots with AGVs, and optimization of machining processes utilizing digital twin technology. It is generally believed to be difficult to escalate R&D issues in the FA field in academic research, but by attending the New Products Open House Show and having discussions with those involved in development, I recognized that this is not necessarily the case. For example, AI Servo Tuning, which is one of your new products, has succeeded in estimating machined surfaces and machining parameters through modeling and process formulation, and I saw that many new academic findings have been obtained in the process. I think that the entire process and results of R&D could easily be summarized in an academic research paper. Moreover, with regard to digital twin technology, which was still somewhat in the conceptual stage at the previous exhibition, we saw concrete, practical R&D results at this year's event. Based on these observations, I strongly feel that the future development of new products related to digital twin technology should be directed toward realizing autonomy. As for FIELD system, which has been a focus of attention at previous exhibitions, although it appeared that the company was trying to promote its use as a platform, it did not leave much of an impression. Therefore, I think that more thought needs to be given to devise ways to present it to customers.
In light of the political, economic, social, and technological factors surrounding Japan's manufacturing industry, I strongly feel that the Japanese industry's competitiveness has declined significantly. Although the media is not so critical of this trend at this time, I personally am aware that the industry is in a precarious situation, and I would like to take this unique opportunity to emphasize the necessity of addressing this issue as soon as possible. We constantly study and sort specific issues that need to be solved in order to strengthen Japan's industrial competitiveness. At this point, I have roughly classified such issues into seven categories, each of which I will explain in turn.
The first category is about "ensuring the quality and quantity of human resources." The current government's package policy of

"investment in people" is obsolete and inadequate, and it will only generate limited ripple effects throughout the industry. Some manufacturing companies are currently experimenting with the U.S. originated reskilling (redevelopment and retraining of professional skills) strategy to strengthen their human resources in order to promote digital transformation, and are reporting some success in these initiatives. Japan's manufacturing industry is actively promoting horizontal division of labor, including the appointment of external personnel to internal positions, but it is questionable whether such initiatives are helping to strengthen companies' core competencies over a long period. Human resource strategies must be developed based on a long-term perspective.
The second category concerns "addressing product commoditization." Professor Asama referred to commoditization in his comments, but I would like to talk about commoditization from another perspective. As digital technologies develop, it becomes more difficult to differentiate products, making it harder to commoditize products. To avoid this problem, in the product development process, companies need to incorporate mechanisms that cannot be easily imitated, in a manner that is not apparent. I do not mean adjusting product structures so that competitors cannot easily copy them. For example, for products with a modular design, it is necessary to consider incorporating modules (components) into the product structure that only the company itself can easily recognize. This principle should be thoroughly applied to the new products featured at this year's Open House Show.
The third category is about "addressing increasingly complex and sophisticated customer needs." Even if you conduct market surveys in an attempt to identify customers' needs, you will probably obtain only conventional results. You cannot elicit new needs from customers that the customers themselves do not know of or are unaware of. The self-righteous belief that good seeds will naturally bring good needs does not necessarily lead to success. However, I believe that formulating future customer needs ahead of existing ones, and identifying and quickly capturing and nurturing seeds to address those needs is one of the prescriptions necessary for the manufacturing industry's future success.
The fourth category concerns "addressing process innovation and material innovation." This used to be Japan's strength. In the 1980s and early 1990s, both Japan and the rest of the world recognized that the country was foremost globally in the areas of production technology in the automotive industry, and in the competition to develop new materials such as ceramics and advanced composite materials, as exemplified by "Japan as Number One," a book that symbolized the county's rapid economic growth. Unfortunately, today it is said that Japan has fallen far behind the global mainstream economically and technologically, trailing both Europe and the United States. I hope that, without fear of failure, Japan's manufacturing industry will boldly engage in R&D to apply new technologies and materials as well as introduce new products to international markets, just as the industry used to do in the past.
The fifth category is about "addressing the digitalization of manufacturing sites." As the number of skilled workers and engineers with expertise working on the factory floor declines, it is once again becoming apparent that technical knowhow is attached to people, and is a serious matter. When an employee leaves a company, the company loses the skills and knowhow that the employee has accumulated over the years. Therefore, such skills and knowhow that are important to the company are not inherited by the next generation. Although there may a feeling that it is too late to take action in many manufacturing sectors, we are working to address this issue through digitalization of professional development. In the future, it will be essential to utilize digital technologies to formulate and systematize the accumulated experiences and intuitions of experienced technicians and engineers in order to systematically pass down their techniques and skills.
The sixth category pertains to "addressing carbon neutrality and resource constraints." At today's Open House Show, the themes of "energy conservation," "lighter weight," and "higher speed" were on display at the CNC digital twin and Roboshot booths, where specific initiatives to reduce environmental impacts were presented. In terms of carbon neutrality, it is necessary to reexamine the overall lifecycles of current products as to whether the materials which form their structure are the most appropriate and whether the products are used optimally.

Sustainability initiatives



Services featured in the exhibition

The seventh category is about "addressing risk management." Companies must prepare for uncertain events with measures to minimize risks to the maximum extent possible. In many cases, however, such measures are unsuccessful. The recent Russian invasion of Ukraine has exposed deficiencies in risk management in various areas, highlighting the importance of risk management. In the manufacturing industry, the business model based on horizontal division of labor is attracting attention for its effectiveness and becoming more common as companies aim to succeed in open innovation. On the other hand, some companies are returning to a vertically integrated business model to secure logistics in response to risks and to avoid country risk. The importance of managing companies calmly while assigning the right people to the right places and maintaining a balance within the system is increasingly being recognized.
These seven categories that need to be taken care of to strengthen Japan's industrial competitiveness are general issues that we should naturally be addressing in light of the environment surrounding Japan's manufacturing industry. FANUC may have already solved these issues. To strengthen Japan's industrial competitiveness, it is important for individual companies not to merely sell products, but rather to further expand fine-tuned services, which is a strength of Japan's manufacturing industry - in other words, to combine hardware and software as a package and to promote all functions and roles of such an integrated system as a business. I hope that FANUC will significantly develop its business by consolidating and engaging in the three pillars of product manufacturing, value creation, and personnel training.
Finally, thank you very much for inviting me to the New Products Open House Show, the first to be held in three years. On behalf of all the professors present here today, I would like to express our deepest gratitude to FANUC's employees for their efforts in preparing for this Show and roundtable discussion. We wish FANUC continued growth and success in the future. Thank you very much for today.

President Yamaguchi: Thank you for concluding the discussion, Professor Shinno. In ending, Chairman Inaba would like to express his gratitude.

Chairman Inaba: Thank you very much for your valuable comments and advice today. This was the first face-to-face Open House Show in three years, and I deeply appreciate that many of the professors said they were glad to have visited. As the organizer and operator of the event, our feelings are exactly the same. We hope that by touching the exhibits and directly hearing the sounds, feeling the movements, and interacting with the exhibition staff, you could experience the exhibits and understand them more deeply than through an online exhibition. I hope to make the most of the valuable advice we received today in our future product development.


Chairman Inaba

As usual, I would also like to thank Professor Shinno for his comments. In fact, I completely agree with him. While it may be true that Japan's manufacturing industry is currently lagging behind the rest of the world, I believe there is still a chance for us to win.
The rhythmic catchphrase "from the tangible to the intangible" has driven everyone to shift to the intangible while disregarding the tangible. However, we will never have the intangible without the tangible. In opposite terms, it is my belief that by making good tangible products, we can make even better intangible products. Therefore, we will continue to focus on tangible products while creating intangible ones. While other countries attempt to shift to the intangible while disregarding the tangible, I believe that Japan's strength and FANUC's strength lie in steadfast manufacturing practices. Based on this belief, we will continue to manufacture solid hardware for FA, robots, and Robomachine, and we will integrate software to be installed in this hardware, IoT technologies that connect them, and AI technologies that intelligently utilize them to contribute to the strength of Japan's manufacturing industry. These things are easy to say, but they are not being achieved today. However, this is the direction we want follow.
Finally, I believe that the members of the R&D Divisions were greatly encouraged by directly receiving advice from the professors who participated in this roundtable discussion. Thank you very much for today's contribution.

President Yamaguchi: Many thanks to the professors who joined us. We apologize for taking up much longer time than expected, but it has been a very valuable opportunity for us. Thank you very much.

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