FANUC NEWS

2023
Roundtable
Discussion
Special Issue

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2023 Roundtable Discussion

We invited professors who advise us on our day-to-day operations to view our products at the New Products Open House Show on May 19. Afterwards, we held a roundtable discussion.

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(Listed in speaking order)

FANUC CORPORATION

■
Yoshiharu Inaba, Representative Director, Chairman
Kenji Yamaguchi, Representative Director, President and CEO

■ FA
Hiroshi Noda, General Manager, FA Business Division
Koji Hada, General Manager, CNC Hardware Research & Development Division
Yasusuke Iwashita, General Manager, CNC Software Research & Development Division
Masamoto Fukuda, General Manager, Servo 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, Chief Technical Advisor, FA Business Division

(Positions as of May 19, 2023)

President Yamaguchi: Thank you for taking time out of your busy schedules to join us today. We have held this roundtable discussion every year to coincide with our Open House Show. Last year, despite the COVID-19 pandemic, we were able to hold a physical Open House Show. However, we still had to limit the number of visitors considerably, and there were no visitors from overseas. This year, in conjunction with the relaxation in COVID-19's classification from Category 2 to Category 5, we were able to welcome about three times more visitors from Japan than last year. We also had visitors from almost all countries around the world, who were able to see our latest products and technologies.

President Yamaguchi

We believe that we have made great progress compared to a year ago, and we hope to receive your frank opinions and advice at today's discussion.

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 New Products Open House Show?

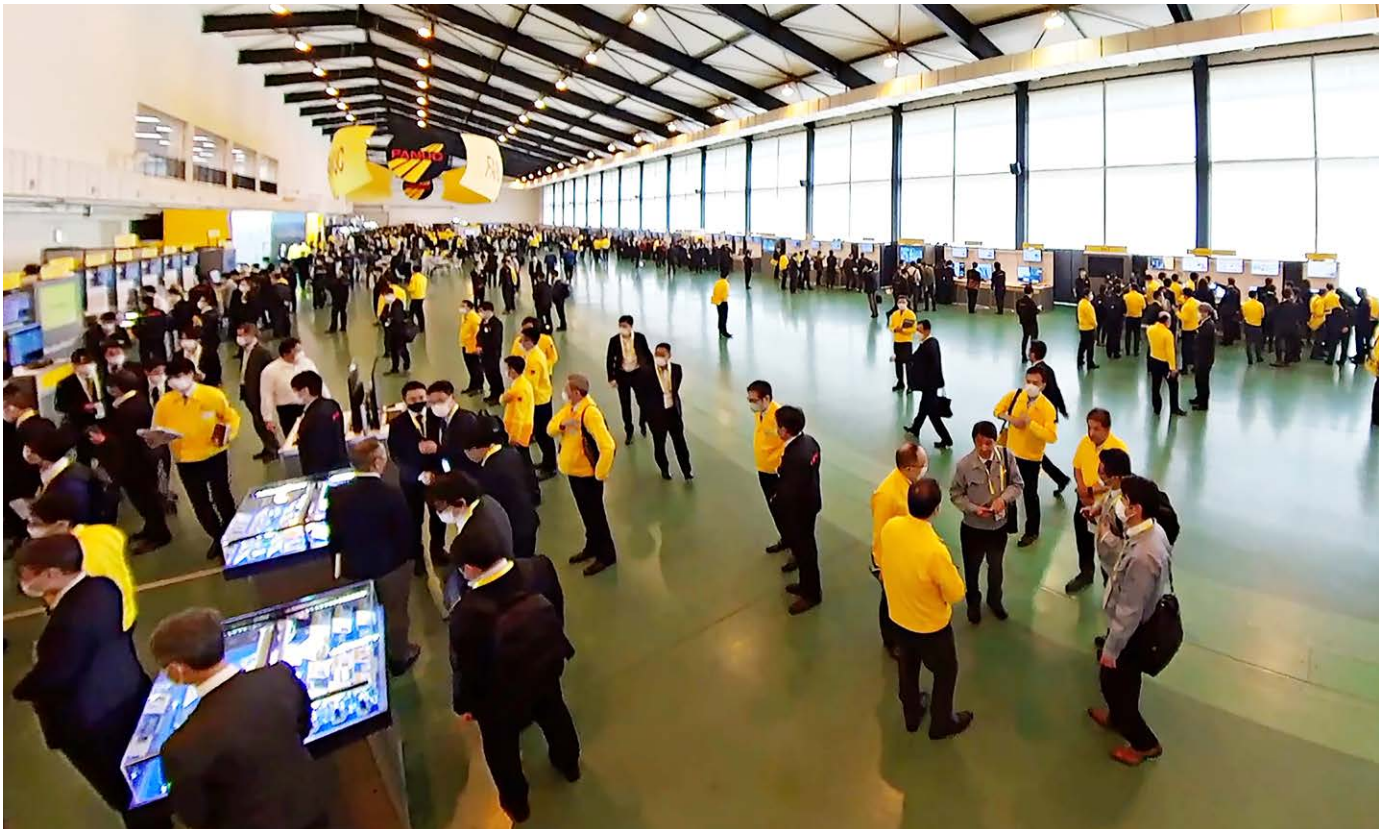
Professor Emeritus Higuchi: The opportunity to see this year's Open House Show gave me a true feeling that the COVID-19 pandemic was finally over and full recovery is underway. As usual, I would like to start by introducing the awards FANUC has received.

Professor Emeritus Higuchi

As displayed today, Robot M-1000*i*A has received three awards, namely the "Main Prize" of the "2022 Nikkan Kogyo Shimbun Best Ten New Products Award," the "Nikkei Sangyo Shimbun Award" of the 2022 Nikkei Excellent Products and Services Award, and the "Best 100 Good Design Award" of the 2022 Good Design Award.

I believe that large robots such as the Robot M-1000*i*A will experience an increase in the variety of uses in production as we go forward. Up to now, in order to assemble large objects, cranes or chain blocks were used to raise or lower the objects, then assembled while making adjustments. However, this requires skill, and is dangerous. Contrary to such conventional methods, as shown in this exhibition, robots are versatile in how they work, such as grabbing parts and assembling them from the side. I think the awards were presented also in recognition that robots will come to be widely used in such applications.

Also, on the whole, phrases such as "complete renewal of the basic structure," "improvement in basic performance," and



May 15–17, 2023　FANUC New Products Open House Show

"total renewal," appeared quite frequently especially in the FA area.
The development of such innovative products probably had to be started about five years ago. I know that COVID-19 delayed many activities, but I think it was a good opportunity for you to go back to the basics and rethink sufficiently.
Up to now, you have been making improvements on existing products to gradually increase performance. This time, I think it was a good approach to go back to the drawing board and start over. One example of the results of these efforts is the 10% reduction in energy loss in the new generation of servos.
I have been involved in various R&D activities related to actuators, so I understand that development is very advanced with little room for further advancements. Improving performance by 10% is extremely difficult, but you have steadfastly worked on it and made it happen.
As in previous years, the robots were fun and interesting to see. Especially the collaborative robots on display were models with large payloads that work well in collaborative mode. When collaborative robots were first developed and put to practical use, I didn't think they would be able to handle such heavy objects. I was also concerned about the risk of serious accidents that could hurt people. However, to date, the newspapers have not reported any significant accidents. I believe collaborative robots being truly safe has been demonstrated in actual use. In the future, I expect that models with payloads of 30kg and 50kg will play a very active role in the field of logistics as well as applications in other areas.
In any case, I can see the results of your various development efforts. There is probably much more that you wanted to display at this year's Open House Show but were not quite ready to reveal yet, so I hope to see the results next year. Thank you.

President Yamaguchi: Thank you very much, Professor Emeritus Higuchi, for your very encouraging words.

FA

President Yamaguchi: Let's begin our discussion with FA. Professor Emeritus Aoyama, could you please share your comments?

Professor Emeritus Aoyama: Hello, I am Hideki Aoyama. Thank you very much for inviting me to today's Open House Show and roundtable discussion. Every year, I really look forward to participating in this event to see these new technologies being introduced.
With regard to FA, the improvement in CPU processing performance, digital twin technology including CNC GUIDE 2, AI servo tuning (acceleration/deceleration parameter adjustment technology), and technology for integrating robots into machine tools caught my attention.


Professor Emeritus Aoyama

The nearly threefold increase in CPU processing performance has improved various related processes or have raised their level. As a relevant technology, cycle time reduction was introduced, and I was very interested to find that the increased CPU processing performance also improves block processing performance. In our research, we calculate the block processing time of a machine tool equipped with a FANUC CNC and create NC programs suitable for that machine tool for machining curved surfaces. As a specific example, assuming that the feed rate is 8 m/min, the fastest speed for machining curved surfaces can be achieved when the distance between command points is 0.133 mm. As the point to point distance of the path is 0.133 mm, the machined shape deviates only slightly from the requirements, resulting in high precision machining. Since point-to-point distance depends on the block processing time, a nearly threefold improvement in block processing time may reduce the point-to-point distance in curved surface machining from 0.133 to around 0.044. Machining that is both fast and highly accurate is an approach that reverses the conventional basic way of thinking of identifying tool paths, and is remarkable.
At last year's JIMTOF, FANUC made a high-profile unveiling of digital twin technology based on CNC GUIDE 2. This attracted the attention of many in the industry. I believe that it was one form of a demonstration of digital twin technology for machine tools. It is inevitable that other companies will catch up, so I am very optimistic about your further advancements. The technology to estimate machined surfaces based on position data and predicted feed rate obtained from CNC GUIDE 2, and to correct defects in advance, will be a very powerful advantage for die and mold manufacturers. You have built servo models to correctly simulate acceleration and deceleration. If you could take this one step further and also consider machining loads, estimation of machined surfaces would become closer to reality.
AI servo tuning is a powerful tool to support machine tool manufacturers in tuning CNC parameters. In addition, a study group of the Society of Die/Mold Technology has confirmed through experiments that differences in the tuning of CNC parameters can make a significant difference in the quality of machined surfaces. Though it is important to optimize tuning according to the machine tool's intended use, it is difficult for general users to tune CNC parameters. For example, I am not sure whether this is an appropriate example, but in the case of a car, there are four to five levels of tuning available for engine power, suspension, the steering wheel, among others. Would a driver tune these parameters? Wouldn't it be enough to tune them by simply pushing but-

CNC Exhibit

tons that are pre-installed in the car, such as for comfortable mode, normal mode, sports mode, or extreme sports mode?
Likewise with machine tools, it is difficult for general users to tune a CNC. For example, if there were buttons to select pre-set tuning such as for machining press molds, design surfaces, die-casting molds, or functional parts of dies, tuning can be performed automatically with just a push of a button, thereby being able to machine more suitably for the intended use. At today's Open House Show, I could see that the ROBODRILL also had a function for selecting the tuning mode, such as for higher precision or higher speed. Still, it is difficult for users to decide whether to use high precision mode or high speed machining mode in machining.
Regarding machine tools and robots cooperating and collaborating to work together, in my opinion, this is an area that will become increasingly important from now. In this context, setting up an Ethernet connection between the CNC and robot and operating the robot with the G-code in the machine tool is a superb way to achieve ease of use. This is a very welcome feature for general users. In the times to come, machine tools will probably be used in combination with mobile robots, and in that case, I think the use of high-speed Wi-Fi and/or 5G will be necessary, rather than wired Ethernet.
Last, but not directly related to today's Open House Show, a company called Beijing Jingdiao drew a lot of attention at JIMTOF.
I heard that Beijing Jingdiao, which was originally a CAM manufacturer, was so enthusiastic about creating NC data suited to the characteristics of their machine tool that they manufactured their own machine tool in-house, including a CNC and machine elements. After understanding all the features of the machine tool, they created NC data suited to this machine tool and succeeded in ultra-high precision surface machining. FANUC manufactures both CNC and machine tools, and as I mentioned earlier about generating machining paths based on block processing time, I believe FANUC can create NC data that will make maximum use of the characteristics of machine tools. Currently, acceleration/deceleration exist which is believed to cause errors in shape. However, I feel it would be good to leverage the characteristics of acceleration/deceleration to be able to machine surfaces according to the intended curvature.
I may have been too free and varied in what I have said, but I believe that Japan needs FANUC to continue to grow and to remain a global leader in the manufacturing industry. I hope you will continue to do your best going forward. That is all from me. Thank you very much for having me today.

President Yamaguchi: Thank you very much, Professor

Emeritus Aoyama. General Manager Noda of the FA Business Division, would you like to respond?


Noda (GM)

Noda: Thank you for your extensive remarks and wide range of guidance.
For digital twin technology, when the so-called "real world" is created atop a digital world, that is, the world of computers, we believe that the key lies in the technology to bring the real world and the digital world as close together as possible. CNC GUIDE 2, which you commented on, reproduces CNC operations precisely. Technologies including Surface Estimation that faithfully reproduces machined surfaces, and the concept of servo models which reflects the machine's characteristics that you have just mentioned, will narrow the gap between the real world and the digital world, and digital world processes will become very useful for optimizing the real world. Of course, there are difficult issues to be handled such as tool simulation, but we believe that the value of digital technology will increase even more with the accumulation of such technologies.
Regarding technology for connecting robots, as FANUC is a company that offers both CNCs and robots, we shall strongly focus on their combined use.
The last point you mentioned is indeed about the entire machining process. That is, roughly speaking, the processes starting with programing and ending with machining.
At this Open House Show, we have presented a technology that enables verification in the digital world. Questions are posed such as "are the NC programs generated from CAD/CAM optimal for the machine tool to be used?" "Do they make sense from an NC perspective?" If any problems are found, we correct them in the digital world. We feel that FANUC can make a huge contribution to the entire machining process, and not just limited to machining alone.
Thank you for your comments today which covered a broad range. I look forward to your continued guidance.

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

Professor Takagi: Thank you so much for inviting me today. The first thing I saw at the Open House Show was a collaborative robot. I believe I mentioned last year that robots' movements were becoming more and more human-like. This year, it seemed that the robot was screwing parts more smoothly than a human, and its movements could be said to be even superior. I was also amazed by the CRX-25*i*A having a payload of 30 kg. In addition, in one exhibit, I was able to experience teaching a collaborative robot by holding its tip and writing a letter of the alphabet with it. The robot learned my motions and subsequently wrote the exact same letter. Though it was a bit stiff, and to be honest, rather difficult, I am sure it will be more effortless next year.


Professor Takagi

Another outstanding exhibit was the AI thermal displacement compensation function. It impressed me in being a very cost-effective, energy-saving technology. By using this function, a 50-minute warm-up is not required, machining precision doesn't decline, and there is no need of an adjustable temperature room. I am a complete amateur when it comes to robotics, so consider this to be a novice's opinion. Then there were also some key words such as being "predictable" and "preventive maintenance." I suspect sensing technology is used in some way, and in this context, I presume sensor circuits play a vital role. However, so far, the only sensors FANUC is using are for vision and touch. Is this correct? Since there are five senses, three others remain. To be specific, smell, taste, and hearing. Taste may be a bit difficult to use, but as for smell, I recently heard that it is possible to detect abnormalities in the smell of oil and to link this to failure diagnosis. I think such technology will become necessary from now on. I specialize in analog circuits, and such sensing technology is a strong area of analog circuits. "Digital" is a buzz word in today's world, and in the field of integrated circuits, digital circuits have become the mainstream. However, it was said in the past that anyone can make digital circuits. This was made possible by using a hardware description language, but making a digital circuit with this language resulted in the same circuit being produced regardless of who made it. In order to differentiate, the circuit had to be analog. These days, digital circuits are systems rather than circuits, so the matter is not that simple. Still, I believe that analog circuits will continue to be useful for the sake of differentiation.
Another interesting exhibit that I observed today was the downsizing of hardware housing. I was surprised by the extremely high density of the printed circuit boards. At the same time, I thought that there was no room for humans to make further progress as physical limits have been reached. This will become a major issue in the future. The same is true for sensor circuits. When we face physical limits, the mindset that everyone must have is to change our antennas that are pointed in a single direction, so that they cover a wider area completely. In education, there are two types of learning: self-directed learning for adults and teacher-directed learning for children. In self-directed learning, information which is required immediately is learned through tasks. This is said to motivate learning in adults and provide a direction to follow. In contrast, teacher-directed learning

which is mainly for children, focuses on subjects, and students learn information that they may use one day. Though you may already be putting this into practice, I think it will be difficult to overcome the physical limitations that we may face in the future if we are not attentive of information that we may use someday, or more importantly, information that we do not know when or whether we will use. In order to change, whether starting with the method or from the basics, it is important to have a willingness to study, no matter how vague the objective may be. That's all from me.

President Yamaguchi: Thank you, Professor Takagi. General Manager Hada, would you like to respond?


Hada (GM)

Hada: I am Hada from the CNC Hardware Research & Development Division. I appreciate your presence and the various suggestions you have offered. As they were somewhat diverse, please allow me to respond by summarizing the main points.
You are currently offering guidance on collaborative robots, keeping in mind the physical limitations that you mentioned. By consulting with you, there has been a change in perspective which has led to your offering new proposals. We are very grateful for this.
Regarding the hardware housing becoming smaller, which was discussed in the latter half, as indicated by you, I regret to admit that my perspective has become narrower. Despite being electricians, in the future I would like to absorb knowledge from various fields, and not just electricity, in order to look for solutions. Of course, analog expertise is necessary, and I hope you will continue to guide us in this area. Thank you for coming today.

President Yamaguchi: Thank you. Next, Professor Sasahara, what are your views?

Professor Sasahara: I am Sasahara from the Tokyo University of Agriculture and Technology. Thank you for giving me a one-day tour today. I really enjoyed it, and time passed very quickly.
I would like to talk about a number of topics. The first is the new CNC system, 500*i*-A. The speed being 2.7 times faster is a dramatic change. Also, the new system was innovative in being designed without being bound by conventional constraints. This has made difficult machining such as 5-axis machining, immensely easier. In the 5-axis machining exhibit, Jog operation rotated the C-axis when the tool was in contact with the workpiece, and the tool maintained contact with the machining point as it rotated. I think machining by visually referencing the machining point, such as in the

FANUC Series 500*i*-A

machining of a single unit, will still be requested. This would be a very welcome function for such users, as well as being easy to use.

Professor Sasahara

In terms of speed, the block processing time has also been shortened, and high-speed CPU seems to be playing an active role in contributing to high–speed simultaneously processing in a variety of processes. On the other hand, from the viewpoint of faster, more precise machining itself, the use of conventional programs without modification may hinder the new performance from being 100% utilized. This is in line with what Professor Hideki Aoyama just said. It would be wonderful if FANUC could communicate to users and machine tool manufacturers the best way to use the CNC to bring out the best in the new performance. Specifically, NC programs should be created by keeping in mind the minute line segment length determined by the block processing time and feed rate. Although the line segment length will be considerably shorter than before, it can be processed at high speed, leading to higher precision.

The second topic concerns digital twin related developments. There were various exhibits such as CNC GUIDE and servo tuning. What appealed to me the most was the ability to accurately input not only physical characteristics, such as the machine tool's friction and inertia, but also servo characteristics, for accurate simulation. For example, if a machined surface is simulated and slight streaks appear, the machine tool manufacturer can adjust the servo parameters. In contrast, users can only modify the NC program as a sole countermeasure. Although it is not an imminent issue, users would appreciate some kind of solution to be provided or developed on the CNC side to handle machining problems. As another example, the technology to change the spindle speed when chattering occurs already exists. Still, being able to change some setting value or parameter to avoid the problem when a defect occurs in machining would be welcome. In such cases, something like an in-process function for monitoring machining by a machine tool is needed as well. For example, not only information from temperature and acceleration sensors, but also information from servos can be used to identify chattering. I expect technologies that combine monitoring and adaptive control will emerge in the future.

Finally, there was one more feature that amazed me. It was a function that involves the conditions for setting oscillation cutting and vibration cutting in an NC. To be specific, the amount of the phase to be shifted for interrupting cutting so that chips can be shredded could be displayed on screen. The screen is very easy for the user to understand. "OK" is shown if chips can be shredded, and "NG" if chips cannot be shredded. This status is displayed along with the tool's

Servo Exhibit

trajectory. This is a wonderful technology and user interface which allow the user to intuitively understand whether the entered parameters will result in successful machining. That concludes what I wish to say. Thank you very much.

President Yamaguchi: Professor Sasahara, thank you. General Manager Iwashita, do you have any comments?


Iwashita (GM)

Iwashita: I am Iwashita from the CNC Software Research & Development Division. Thank you for offering many valuable comments and guidance today. We have been continuously improving real-world performance, but recently the real world has become considerably more sophisticated and complex, and we believe it is important to utilize digital technology in the form of "digital twin" in order to continue improving real-world performance.
Since elemental technologies have finally been defined, going forward, we would like to organize them by categorizing those for users and those for machine tool manufacturers. We are eager to receive your continued guidance. Thank you for participating in this discussion.

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

Professor Matsubara: Thank you for the various explanations. I apologize for always going into detail. In this year's Open House Show, you have greatly improved basic performance while making coordinate conversion very simple in multi-axis configurations. From our perspective, this is an important point. In terms of closing the gap between reality and what we think in our minds, the offset center point on an axis will certainly effect motion accuracy. Therefore, it is significant that you have established a means to identify the deviation. Of course, measurement technology for this objective will have to be developed.
Also, adding to the topic on servo, it is great that you have improved the motor and sensor interface to increase the speed and the servo loop's gain. The reason why the servo loop is unstable is because of detection or processing delays, even though the motor encoder provides feedback on speed.
Since the 1990s, delays have become progressively shorter, allowing for higher loop gain, and the natural frequencies of the concerned vibrations have become increasingly higher. It has gone up again this time, and problems have surfaced due to new mechanical vibrations, so the analysis of the mechanical configuration will be necessary. With digital twin, the frequency response is also acquired by the servo. Although the frequency response is a nonparametric model, it can identify the machine configuration parameters, so in the future, the center of focus will be the specific physical parameters which may become problematic on the machine side. Knowledge of the different characteristics of various positions and postures is presumed to create technologies for differentiating machine tool manufacturers. The manner in which to neatly organize this knowledge and reflect it in models will be key to digital twin technology. CNC knows the machine position accurately as well as the timeline, so steady progress can be expected.


Professor Matsubara

Concerning robotics, there was an exhibit of a robot operated by G-code. As we have been using G-code from the past, the capability to use G-code will play a major role in eliminating the barrier of programming languages.
With collaborative robots, there are two types of collaboration: human-robot collaboration and machine-robot collaboration. I believe the collaboration between these three – that is, humans, robots and machines - will be the way forward. In this sense, the ability to share coordinates is important. In other words, starting with having a common language and being able to understand, the next step is to consider how to share and collaborate in physical space. This is another point where the gap between reality and what we think in our minds is narrowing, and I am very excited to see how things will develop.
That is all from me. Thank you.

President Yamaguchi: Thank you, Professor Matsubara. General Manager Fukuda, any comments?


Fukuda (GM)

Fukuda: I am Fukuda from the Servo Research & Development Division. Professor Matsubara, thank you for presenting your views. This year, we exhibited the αi-D SERVO. This servo product has been completely redesigned from the inside out. From your comments, we are very pleased to find that you think highly of our efforts to steadily improve basic performance. Since servo products directly impact a machine's performance, we will continue to steadfastly improve basic performance.
In addition, Professor Matsubara remarked that the distance between robots and CNC has shrunk when talking about kinematics conversion, including CNC, and also when referring to the real and digital worlds. We are very happy and feel reassured that our development is recognized as heading in

the right direction.
We believe that there is more to be done, including efforts to conserve energy. We feel that our direction for the next ten years or so has been clarified, and we will continue to do our best. Thank you.

Robot

President Yamaguchi: At this time, let's shift the topic to robots. We would like to start with Professor Asama. Professor Asama, please state your views.

Professor Asama: I am Asama from the University of Tokyo. Thank you very much for inviting me to FANUC's Open House Show. I am currently the chairperson of IFAC, the International Federation of Automatic Control, and the World Congress of IFAC will be held at PACIFICO Yokohama from July 9 to 14. FANUC will be supporting us there as well, so thank you again.
Today, I viewed the Open House Show with great interest. As expected, the collaborative robots were what impressed me the most. The first time I saw a collaborative robot, it was displayed modestly in a remote area of the venue. But now they have become the stars of the Show, with many series lined up in the center of the hall. I was particularly impressed by the collaborative robots with long arms and high payloads.
Second, I had the impression that service activities using servers, such as the shift to Digital Transformation and AI, has progressed rapidly.
Third, I feel that the design has improved. As I slightly mentioned previously, I think design is very important. Even in factories, workers are more motivated to work if well-designed equipment is installed. In this sense, it is my impression that the design of robots has greatly improved compared to before, and this will result in users feeling good when using your robots. These are the three points that had the greatest impact.


Professor Asama

To elaborate a bit more, the collaborative robots have a much wider range of applications due to their high payload capacities and longer arms. Although the main applications are assembly, material handling, welding, painting, and transport, I was excited to find that robots have expanded into service areas such as making cakes.
One major point is that each joint is fitted with a force sensor. This enables estimation of the force being applied to the hand along with what is actually happening at the point of


Collaborative Robot CRX Exhibit

contact with the workpiece. I think this positively influences the expansion of these applications.
Next, regarding teaching, I heard that this function is able to adapt to various skills. While teaching a robot, the robot gradually learns the skills of the professional expert and becomes capable of replicating these skills. This is quite useful in extracting various skills and passing them on to the next generation. It seems as if the collaborative robot is cultivating new applications.
Moreover, once skills can be extracted, FANUC will not only be able to sell robots that have been taught, but can also expand into customizing robots so that users can find new usages and values to create their own unique robot.
So, for example, if the robot used by Rokusaburo Michiba (a renowned Japanese chef) masters Rokusaburo Michiba's skills, this will probably make the robot itself more valuable than FANUC regards it to be. I thought that this collaborative robot could become a medium for accumulating and passing on such skills.
Second, the use of collaborative robots may have a positive mental impact on people, such as gaining a sense of satisfaction or accomplishment in their jobs in factories and other workplaces. There are hopes that the use of collaborative robots will benefit workers, such as increasing their motivation.
Third, a display which was discreet, but had high significance to me, was the energy conservation and carbon neutrality exhibit. In the manufacturing industry of the future, environmental impact is an inevitable issue that must be addressed, and new business opportunities should be explored in this area.
I hope FANUC will continue to promote these activities and contribute to sustainability. I have said many things, but in a word, I found the Open House Show to be very impressive. Thank you very much for today.

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

Inaba: Thank you, Professor Asama. As you said, this year's Open House Show focused on collaborative robots. We exhibited a 50 kg payload collaborative robot for the first time. It was possible to use the mechanical unit of CR-35*i*B without change and use software to make enhancements. In addition to our tradition of reliability and conventional functions, we made ease of use appealing, with focus on the CRX series.

Inaba (GM)

Allow me to narrow down my comments to the ease of use.
One of the highlights was having a robot learn and replicate the skills of experts, as you noted. As we discussed a bit at last year's roundtable discussion, this technology is the gateway to the transferring of skills... though this expression may be an exaggeration. Just as a parent teaches a child, a person teaches a robot step by step. This allows people's skills to be digitized via the robot and converted into data for programs.
We think that the ability to pass on skills through data may be a clue to solving the social issue of labor shortages. This makes the data itself valuable, and this value depends on the skill of the person who is teaching. Certainly, the data on the motion of arranging food on a plate taught by Rokusaburo Michiba and the data taught by me will be quite different in value (laughter). As these technologies develop, I believe collecting data to trains skills and reproducing the skill with robots will become a new role for robots.
We will also pay attention to learning generative systems as a subsequent technology. The ability to use existing training data to generate new patterns could be applied to achieve more autonomous motion. I would like to keep in mind that the type of questions to be input, that Professor Asama referred to, is also an important technology. It was interesting to find that in robot education (creation of training data), not only teaching but also coaching elements are included.
We will strive to make most of our abilities, to contribute to the realization of a sustainable society, including addressing labor shortage problems and environmental issues. The range of automation and applications is expanding. We would like to work with our customers not only in supplying robots, but also in facilitating their usage. As society is changing even faster, it is becoming more important to adopt an approach with which we can capture customers' requests and quickly reflect feedback in the manufacturing site. As part of this endeavor, we have begun employing a rolling release model, that is, a concept with which updates of software are delivered frequently. This is applied to only a few models. However, customers are assured that the latest functions are always available, by downloading the latest updates via the Internet. Also by analyzing data, Zero Down Time is also able to provide maintenance services to customers in a timely manner. By utilizing IoT technology, we will keep on striving to shorten the distance between ourselves and our customers, and provide prompt service. We would appreciate if you would keep on offering assistance and guidance.

President Yamaguchi: Next, Professor Sugano, can we hear from you?

Professor Sugano: I am Sugano from Waseda University. Thank you for inviting me to participate in this discussion. Seeing so many robots actually in front of me makes me realize the importance of the real thing, in other words, how strongly physical existence has an impact.
We have been talking too much about cyberspace lately and in my opinion, there should be more proper discussions

Palletizing with CRX

CRX Screwing Function

about the physical world. I believe that in particular, Japan's legacy of "making things," that is generally represented by the manufacturing industry, is manifested as actual objects. In that sense, I was overwhelmed today.


Professor Sugano

Excuse me for speaking mostly about robots, but I was able to reconfirm the importance of basic robot performance. Torque control and force control are the most fundamental, but at the same time, I thought that the white robot which performs much like humans in a certain sense, could be used in a variety of applications. Today, I have seen a great number of applications, and I think it is clear that new applications are being created by users besides within FANUC, thanks to the white robot's high basic performance. Of course, for cost reduction, yellow robots are used more and more, which is natural, but I strongly feel that the white robots will take center stage in new fields.

Also, regarding teaching mentioned earlier, we can of course instill skills into white robots by using them, but I think the key point is how AI will be involved. There is talk of Google and other companies lining up many robots and conducting reinforcement learning and deep learning. However, I would like to promote using AI in the form of people teaching robots in a leader-follower fashion, and after a few dozen times of repetition, the skill being learned almost completely. Imitation control is one example, but I believe that robots with high basic performance, especially with respect to force and torque, are the ones that can be used in such a manner. AI is becoming prevalent and is being applied in various situations. I hope you will focus on that part of the business as well.

The key point will be the handling of data. The topic of logs was also discussed today. Needless to say, FANUC collects a wide variety of logs to predict and diagnose machine tool failures, but it is extremely important to also record robot motion data. I believe it is necessary for robots to keep on learning based on collected data.

Data is extremely crucial, but I have heard that it remains difficult to apply AI to data in the state of logs and complete the decision making process. However, I would very much like you to overcome this challenge. Especially the United States is quite advanced in processing with AI, such as can be seen with GPT. To be frank, Japan lags far behind and can no longer catch up. You might be offended to hear this, but this is a reality that we must face. On the other hand, Japan is undeniably strong in the field of robots - to be specific, the physical aspects. It is essential to make good use of AI to enhance the skills of robots, and I would like to request that FANUC work on this.

On a personal note, in March I assumed the position of Chairman of the Robotics Society of Japan. As I mentioned earlier, I have a sense of crisis that Japan will be extremely weak in the global market unless progress is made focusing on the physical aspects of robots to make Japan the most advanced, such as by connecting AI to robots rather than concentrating on information science.

This is no longer just a matter limited to the academic world. We would like to strengthen the cooperation between academia and actual manufacturers, and also the Japan Robot Association. We would very much appreciate your cooperation in such collaboration. That concludes my remarks. Thank you.

President Yamaguchi: Thank you, Professor Sugano, for your valuable input. General Manager Abe, do you have any comments?


Abe (GM)

Abe: Thank you, Professor Sugano. The key point is the importance of basic performance, and I believe that the thorough work done in the mechanical unit, sensors, motors and servos within the mechanical unit of robots has led to the development of the CRX's current functions. It is very motivating to hear your comments on our achievements.
We will continue to concentrate on developing basic performance and handling data, including exploring progress in data using AI, as you have advised. FANUC would also like to actively participate in the Robotics Society of Japan, and we look forward to your continued support.

President Yamaguchi: Thank you. Next, Professor Okatani, can we hear from you?

Professor Okatani: I am Okatani from Tohoku University. I too received a detailed explanation of collaborative robots and vision applications. I was impressed by the steady progress that has been made in just one year.
Every year, I take this opportunity to discuss the progress of AI and its implications, including its applications to robotics. Last year, as I recall, I talked about the great progress in AI that manipulates language, and as you know, ChatGPT became a very hot topic in the latter half of the year in a way that found public acceptance. The use of AI in language is truly a revolutionary, though disruptive technology.
Perhaps the original creator was also surprised – what I mean to say is that it was not created intentionally. This makes it even more astonishing.
I would like to say two things about this technology.
One direction is to apply this kind of language AI to be used in robots. In general, it is believed that we are entering an era in which human-machine communication will be done with words using language models such as ChatGPT.
First, regarding computers, we are no longer in an age in which Excel users need to use the mouse to click on cells and write macros. Users should be able to tell the computer verbally what functions they want and have the computer create the Excel table as requested. Also, the era of creating computer programs from scratch has already come to an end. We are now in an era in which language models can be used to write codes. For instance, we can use a language model to make a specific program. Though the result may not work as is without modification, we can use this as a template. Also, language models can be utilized for other usages such as testing and debugging. Therefore, if we consider teaching as being a kind of program, I think there is much room for such intervention.


Professor Okatani

Another is that AI used for language has made dramatic strides forward in this manner, and it also must be noted that voice recognition and some aspects of image recognition have also made great progress since the emergence of deep learning.
However, not everything can be done, and there are still many things that cannot be accomplished. What separates what can and cannot be done still depends on whether the subject is in the digital world or the real world. It ultimately comes down to how much data is available for learning, as was already discussed.
AI for language processing has been successful because a method has been found to learn from the vast amount of text data on the Internet. However, such data was not originally prepared with the intention of being used with AI. The same is true for the application of images and speech recognition, and one of the reasons for their success is that there was originally an environment in which abundant data was available.
As is evident from the struggles with autonomous driving, applying AI to the real world has yet to be successful. One of the main reasons is that if we start by collecting data, a sufficient amount would not be collected to the level of being capable of practical use. The situation can be explained in this way.
In terms of applying AI to robots, many problems remain to be solved. As Professor Sugano already mentioned, Japan is no match for the U.S. However, in terms of applying AI to the real world, I believe there is still room for Japan to do more, as it cannot be said that other countries in the world have been successful. Then there is the importance of data, which was discussed previously.
Storing a large amount of random data could turn out to be very important in the future, even if we don't yet know how it will be useful. I think that it is good to value such a perspective. That's all from me. Thank you.

President Yamaguchi: Thank you, Professor Okatani. General Manager Kato, let us hear from you.

Kato: I am Kato from the Robot Software Research & Development Division. I would like to thank you for always providing us with advice. The new functions exhibited at this year's Open House Show included direct teaching of a collaborative robot to replicate manual work, high-speed bin picking, which has been continuously enhanced, and AI-based box detection, all of which were developed under the guidance of

the Professors here today. We will continue to improve robots based on your feedback, including approaches to manual work which you experienced today, and the feel of the robot's operation.

Kato (GM)

What is common in these exhibits is that robots learn from human know-how, such as the work itself and box detection. In the future, rather than having robots simply imitate people, as Professor Okatani commented, we would like to make progress in the mechanism for collecting data and extracting the essence of the data, as well as lowering the communication hurdle between people and machines. We will continue to develop robots that can automate manufacturing facilities more easily, and we look forward to your guiding us further.

President Yamaguchi: Thank you. We still have some time left. Would anyone like to say anything else about robots?

Abe: I would like to make a comment on data. Related to data, we have a robot IoT product called "Zero Down Time," which at present, collects data from more than 35,000 robots. As I said during my explanation, data is a treasure, and we are actually in the midst of working to create various functions from the gathered data.
There are still doubts as to whether we have reached the point where this can be called "AI," but all of our R&D staff are working together to come up with a variety of ideas, and we would be very grateful if you would continue to offer advice.

President Yamaguchi: Thank you. Now, going back to FA, are there any additional comments?

Hada: I would like to make a comment. I am Hada from the CNC Hardware Research & Development Division. To be honest, we hardware engineers are in rather a tight spot, but I think there is still much that can be done with analog technology, and I am very happy to hear that we can differentiate ourselves with this technology. We would very much appreciate your cooperation in improving basic performance, although these will not be evident from outside.

President Yamaguchi: General Manager Iwashita, what are your views?

Iwashita: Professor Sasahara spoke about the use of sensors at the end of his comments. We have been using motors as sensors for torque and vibration in addition to position and speed in a variety of applications within the scope of motor control, but we are seeing limitations in observing the state of the tip of the machine. In the future, I would like to expand the scope of application by utilizing external sensors. We welcome your guidance regarding this matter.

President Yamaguchi: General Manager Fukuda, would you care to say a few words?

Fukuda: I would now like to talk about our energy saving initiatives. For the αi-D SERVO that we just announced, we did not want to merely make improvements to the motor and the amplifier. Instead, we wanted to do everything possible, so we reexamined the design from the beginning. Of course, materials and devices are getting better and better, but we also reviewed the basic designs of both motors and amplifiers and were able to reduce losses by about 10%. Since it is offered as a system, it was vital to conduct a complete review. We hope to continue our development with a focus on reducing energy consumption. Thank you.

President Yamaguchi: Thank you very much.

ROBOMACHINE

President Yamaguchi: Next, we will move on to ROBOMACHINE. Professor Shamoto, can we start with you?

Professor Shamoto: I am Shamoto from Nagoya University. Thank you for inviting me again this year. I have gained much knowledge. First, regarding ROBOMACHINE in general, I continue to be impressed by the steady improvements in performance. In addition to basic performance, you have made consistent progress in terms of ease of use.
For example, ROBOCUT has been reviewed from the basics, and its robustness and precision have improved dramatically. I presume that although precision has improved multifold, the cost increase has not been substantial, meaning that the original excellence in cost performance has become even better. I consider this to be remarkable.
Second, regarding ROBOCUT, I was very interested in the automatic wire feeding function, with which the wire is fed automatically into a hole. I once worked on a project that automatically guided shredded chips into a pipe, where 100% of the chips had to be placed in the pipe. It was explained to me that the automatic wire feeding function has a success rate that is very close to 100%. What is great about automatic wire feeding is that in case of failure, it can be redone automatically.
As for ROBODRILL, Z-axis acceleration has risen from 1.5G to 2.2G, resulting in the improvement in cycle time. This also represents steady progress.
There were many other improvements, such as increasing the DDR speed to achieve vertical lathe-like turning and lengthening the stroke. Energy-saving features have also become more sophisticated, and by detailed control of pe-

ripheral devices, energy was additionally saved by several percent. I am amazed that you are able to consistently progress step by step every year.

There are two points worth noting with respect to functionality. The first is a function called "Machining Mode Setting Function 2." With this, you seem to be heading in an excellent direction.

Professor Shamoto

Requirements such as improving machining efficiency, decreasing inner drill rotational direction errors, and vibration suppression have long existed. To satisfy such requirements, the machine tool's acceleration/deceleration parameters must be re-set. Prioritizing any one of the three will inevitably impair the others, and only a user with deep knowledge will be able to set the parameters properly. Making this visible in a radar chart and simplifying the settings is a superb step in the right direction. I hope you will continue to move forward in this direction and improve functionality based on users' feedback. Moreover, in the future, apart from the qualitative radar chart, I would advise gradually making efforts to quantify. For example, investigate the number of microns of the inner drill rotational error, the level of vibrations, or the machining time reduction percentage.

The dedicated G-code is another feature that caught my attention. You explained that these functions were created from machining technology that was used on-site, and have developed very useful functions such as Z-axis vibration suppression and deburring cycles. In my opinion, it would be a waste to limit their use to ROBODRILL. It would be a good idea to make these functions generic and expand their implementation to the CNCs of other companies.

It is also my impression that, while various improvements have been made in functions, measures to enhance machine tool movements, decrease energy consumption among others, have pretty much been exhausted. Of course, it is important to continue making steady progress, but I feel that there is less room for improvement in basic performance. I may have mentioned this last year, and it may be similar to what Professor Sasahara said earlier about monitoring, but I feel that at the end of the day, the process will be what matters. In terms of functions, examples are the SSV (Spindle Speed Variation) chatter vibration suppression function and shredding chips with low-frequency vibration. If such features can be used more easily or automatically, processes can be improved. For example, chatter suppression may double machining efficiency, and cut machining time by half. Such a reduction in machining time is difficult to achieve with NC acceleration/deceleration settings, and if machining

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time is reduced to that extent, energy consumption will also be reduced in two-digit percentages. This could have a tremendous impact. Of course, improving the process is quite demanding, but I encourage you to consider this in parallel.
One last comment. A topic I have long been researching is mirror cutting. This is the process of machining a surface to be as beautiful as a mirror. High-precision machine tools are inevitably connected to increases in costs. However, suppressing the fine vibrations will be sufficient to simply improve the surface quality, or reduce only the roughness of the finished surface, or just make the appearance better. This is a small cost increase compared to the cost of improving precision. I believe this is an area that even a cost-effective machine such as ROBODRILL can adequately target. Meanwhile, I think that the peripheral technologies to achieve such mirror finishing are gradually being developed and becoming abundant. For example, the same is true of FANUC NC functions such as Fine Surface Technology. As for tool technology, research has resulted in being able to sharpen low-cost diamond-coated tools with high efficiency using lasers. I expect that tools capable of mirror-finishing and micromachining at a low cost will become available in the future. Since such potential is becoming apparent along with progress in peripheral technologies, I hope you will consider the feasibility of developing such machines. That's all from me. Thank you.

President Yamaguchi: Thank you, Professor Shamoto. General Manager Takatsugi, can you respond?

Takatsugi: Thank you for your varied and valuable guidance, Professor Shamoto. I would like to talk about what you said, though my wording may not be well organized.


Takatsugi (GM)

First, it was a relief to hear that you think the current direction of our approach to ROBOMACHINE is correct. This is an encouragement to all of us. It is true that some issues remain, but we will work on them one after another for next year's New Products Open House Show.
One of your advices that left a deep impression is that if we delved a little more deeply into the machining process and made the process clearer, we might be able to find some new hints.
For example, in the case of ROBODRILL, our knowledge of tools is still limited, so there is much to be done regarding the relationship between the workpiece and the machine.
ROBOSHOT has used mold flow analysis software to integrate simulation results, but there is room for further research on how to link the results to actual phenomena and how to enable ease of use.
The target for ROBOCUT is to reduce machining time and to make it have sufficient machining capabilities at the level of being able to machine parts. To do so, we have been made aware once more that we need to fully clarify the phenomena of the machining process and make breakthroughs. I would like to go back to the basics and deepen our understanding.
Second, I have come to notice the perspective of proposing ROBOSHOT to customers not just as a single unit, but including its surroundings, such as in the form of a cell. I am very grateful for your providing me this insight. We look forward to your continued support.

President Yamaguchi: Thank you. Next, Professor Matsumura, please state your views.

Professor Matsumura: Thank you very much for your invitation. I learn a great deal by participating in your Open House Show every year.
What impressed me was that this year, FANUC has become much more user-oriented in development. It is very important to master the use of machine tools, so I think it is wonderful that you are working on developing diversely from the user's point of view.
For FANUC, user-oriented means both development for machine tool manufacturers and development for end users. First, in the development of the 500*i*-A that you introduced to machine tool manufacturers, everything from the software to the peripheral devices was reviewed in order to make full use of the hardware. This should make it easier for machine tool manufacturers to develop applications.
Also, your approach to 5-axis machining is excellent, and I think this will lead to the further development of digital twin. In this context, the user interface for development and web application in particular, as well as remote monitoring and pre-confirmation of alarms, will contribute to further practical use. Another interesting feature of 5-axis machining is the ability to use both automatic mode and manual operation together. This concept was an eye-opener.
At the same time, I felt much consideration was given to end users regarding ROBODRILL parameter settings. Many of today's small-and-medium-sized enterprises find it difficult to change parameter settings on their own. Therefore, I think the attempt to apply a template for parameters according to the application is extremely good from the perspective of mastering the use of machine tools. Also, last year, you introduced a function for changing parameters according to the weight of the load on the table. This year, the resolution has been further increased to allow for detailed parameter setting, and the fact that this is linked to the machining mode setting function makes it a technology that reduces the user's burden.
The ability to set such parameters may lead to being applied and developed in machining in which cutting conditions may

incur damage to the finished surface - for example, it may become possible for brittle material to be cut without cracking it. It was also explained that using the machining mode setting function will have a positive effect on the finished surface. I believe that in addition to improvements in the finished surface, there may be a difference in tool wear as well. Tool life is very important to users, and if it can be extended by parameter settings, that would be a very attractive feature indeed.


Professor Matsumura

It is interesting to note that ROBODRILL's functions for adapting to the environment are varied, and include functions such as control of peripheral devices and mist collectors, as well as a sleep mode, which are selectable by the user. The fact that the user can select functions rather than simply having functions exist is a user-oriented technology.

Though the machining mode setting function is wonderful, differentiating between various manufacturers may become difficult. The ability to fine-tune parameters is attractive, but I think the challenge will be the manner in which fine-tuning is executed. Since the optimal parameters are dependent on the tool fitted to the machine and the workpiece material, further advancements can be expected by making the machine capable of sensing the tool model and workpiece material model.

Finally, in terms of upgrading machining capacity, you have extended the maximum travel of the Y-axis, increased the number of tools that can be mounted in order to centralize the process, and raised acceleration to 2.2G in order to reduce machining time. Furthermore, regarding diversification in machining, there was a turning exhibit with the spindle attached to the table. I sensed that an evolution was occurring in these efforts to improve ROBODRILL's machining capabilities.

As a technology for mastering the use of machine tools, I hope that you will consider not only the hardware, but also how to make machine models that take the characteristics of the tools used and the workpiece material into account.

Once again, I would like to thank you for introducing very valuable development technologies.

That's all from me.

President Yamaguchi: Professor Matsumura, thank you for your valuable guidance. General Manager Tong, anything from your side?

Tong: Professor Matsumura, thank you. The market we are now dealing with is changing dramatically. Therefore, we understand that in order to survive, it is important to be aware of market trends and to provide what customers need as quickly as possible.

Also, the addition of a tool model and a work material model to the machining mode setting function that you described is certainly something that is necessary from the customer's perspective. Please continue to guide us.


Tong (GM)

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

Professor Emeritus Kunieda: Thank you very much for inviting me here today. I was able to deepen my knowledge. Please allow me to express my thoughts on ROBOCUT.

First, I would like to speak about machining accuracy. In wire EDMs (electric discharge machines), the wire vibrates and there is a gap between the tool and workpiece. It is a fantastic accomplishment that you have achieved an accuracy of ± 1 micron under such circumstances, especially given that there is a space between the wire guides in the upper / lower machine heads and the workpiece.

Such accuracy cannot be achieved without considerable ingenuity. When there is no discharge, the electrostatic force acting on the wire will cause the wire to be attracted to the workpiece, while during discharge, bubbles created around the wire will expand and burst, creating a force in the opposite direction.

Therefore, unless the attracting and repelling electrostatic forces are balanced, it will not be possible to cut straight. In spite of this tough situation, you have successfully optimized this process from rough machining to finishing, ultimately achieving the proper accuracy. The process of setting the machining conditions correctly is quite a challenge, especially the quantification.

There will likely be attempts to use AI and create physical models to quantify, but using AI alone has limitations. Therefore, I would like to convince you to use physical models for quantification.

It is also very important to visualize the movement of the wire, which vibrates like a caterpillar. For example, direct observation of the wire movement itself is important, but how the discharge points are distributed also has high significance. The distribution being random is an indication of the most stable state.

The technology of detecting the discharge location is of essential importance. It was already being studied in Japan 30 years ago. Recently, this technology has finally been put to practical use abroad by a Swiss manufacturer. It is unfortunate that Japan is lagging behind. As this is a very important matter, I hope you will work on it.

If we know the location of the discharge point at the moment of discharge, we can instantly determine whether this location is good or bad. If the location is bad, the power will

instantly be stopped. The discharge point can be controlled in this way. I would like you to give it a try.
However, since this requires a judgment to be made and the power supply to be cut off in a single moment, which may be less than one microsecond, it will certainly be extremely back-breaking. Still, I encourage you to take on the challenge.
As I mention every year, only a small percentage of the melted debris is released as machining scrap. This debris re-solidifies, resulting in extremely low efficiency.
We know that removing just 10% of the debris would increase machining speed by several times, but it is tremendously difficult to come up with a means for doing so. It will not be easy to control discharge waveforms and voltage waveforms with a pulse width of 1 microsecond.
Since power electronics has progressed considerably, I encourage you to attempt removing debris more efficiently. For example, by slightly changing the waveform. Thank you.


Professor Emeritus Kunieda

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


Fujimoto (GM)

Fujimoto: I am Fujimoto from the ROBOCUT Research & Development Division. I would like to thank Professor Emeritus Kunieda for always offering guidance based on academic research of discharge phenomena to improve the performance of EDMs.
As Professor Emeritus Kunieda mentioned, understanding the attracting and repelling forces between the workpiece and wire, detecting the discharge location, and improving machining efficiency by removing more amounts of melted debris after discharge are important development topics that will directly improve machining accuracy and productivity, as General Manager Takatsugi mentioned. By understanding the discharge phenomenon, we will continue our efforts to improve performance, producing results one by one. Thank you for your continued guidance and cooperation. We appreciate your coming today.

President Yamaguchi: Thank you. Next, Professor Kajihara,

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please tell us your views.

Professor Kajihara: I am Kajihara from the University of Tokyo. Last year, I participated in the roundtable discussion for the first time, and I am grateful to be invited again this year.

I would like to speak mainly about ROBOSHOT. When I saw the Open House Show last year, it was my impression that the focus was on networking. However, this year, you have shown many advancements in terms of environmental issues, recycling, reducing electricity consumption, and other contents that are exactly in line with global trends. Thank you very much.

My chief comments concern your approach to environmental issues. First, regarding recycling, I saw a demonstration of making a lens barrel for a very high-precision component of a smartphone out of recycled pellets.

Although you humbly stated that "errors occur to a certain extent," and "finished products are slightly more prone to error than general materials," I had the impression that the number of errors was at a level comparable to that of general materials. I have high expectations for major developments, and hope that I will see even more in the years to come.

You are also working on regrind. The parts of a joint of the car you showed this time had a hollow structure. You mentioned that regrind is somewhat less stable than recycled pellets, but I think there will be further developments with regrind.

In this context, I was told last year, with regard to recycled material, that the depth of the groove in the screw was increased to stabilize measurement. This year, in addition to enhancing this method, you have poured various efforts in the area of mixing regrind to attain greater stability. It was very interesting to see further progress in this area.

In one such demonstration of recycled material, a detailed sample of a smartphone lens barrel was made. The mold was made by a ROBOCUT, and I could see the good synergy of such technologies within the company.

As for the molding of regrind, there are molds with a hollow structure where cores are inserted into the mold, and after injection molding, the core is removed to produce a hollow item. I heard that the cycle time could be shortened by taking advantage of FANUC servo control to control such cores. That is, controlling the movement of cores, such as insertion for molding, and removal, before closing the mold.

In addition, last year's servo had two axes, but this year the number has increased to four. This allows more complex movements, so much more can be expected. These servos drive a ROBOSHOT, the molds inside are controlled by your servos, and items are removed by your collaborative robots, after which inspection of the finished item is done with your image processing technology. As this in an all-FANUC system, my impression is that users will find it very easy to use.

Also, regarding energy saving, last year you introduced covers for barrels and announced an 11% reduction in the heater's electricity consumption. This year, you added another jacket for heat retention and saved a further 10% of energy.


Professor Kajihara

Professor Emeritus Higuchi already mentioned that 10% is a mammoth value, and it is a great feat to have achieved this two years in a row. You have not simply considered placing a jacket. You have properly designed it in detail to increase the retention of heat. I saw this as being a most suitable way to conserve energy.

In addition to such environmental friendliness, it is very convenient for users to be able to check the results of simulations on the injection molding machine's panel and compare with the results of experiments.

This will not be possible unless the workstation's machine power is increased. But if it becomes possible to analyze the results of actual molding in their original state using simulation, and to feed back the data to be useful in the next molding, this will be the future of digital twin. We may have to wait for machine power to increase, but I hope to see something like that in the years to come.

Also, a function that I presume was added this year was the newly adopted interlock notification function in the panel. This function manages the machine's processes in sequences, detects when an event has not occurred due to an error in the user's operation or other causes, guesses the cause, and provides notification. This is a feature that users will greatly appreciate.

However, from what I have heard, this function has only been implemented in ROBOSHOT among ROBOMACHINE products. Please introduce this function to other machines as well.

That wraps up my comments, but I would now like to ask a couple of questions. I would appreciate your answering to the extent that you can.

First, regarding servo control of molds, last year there were two axes and this year it has become four, making complex movements possible. I would like to ask what kind of future developments you have in mind with respect to mold control by this servo.

Also, regarding reducing electricity consumption, there has been considerable progress in the past two years. Do you feel there is still room for improvement? Electricity costs are rising worldwide, and I think this is considered to be a critical problem everywhere, so even a 1% change would make a big difference.

Lastly, my attention was centered on recycled material this year. EU has laws and regulations that, for example, require the use of at least 10% recycled material in packaging. This means that demands exist and the technology is easily ac-

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cepted. However, since there are no such laws and regulations in Japan, it would be difficult to use recycled material unless there were some advantages, such as decrease in cost. I would appreciate your comments on your company's motivation for promoting the use of recycled material in Japan. That is all.

President Yamaguchi: Professor Kajihara, thank you for your questions. General Manager Uchiyama, would you like to reply?

Uchiyama: I am Uchiyama from the ROBOSHOT Research & Development Division. Professor Kajihara, we are grateful that you have devoted a full day for us. First, regarding recycled material, we used to think that recycled material was mostly used to make containers and other daily commodities, that is, so-called "general-purpose molded products." However, by talking with connector manufacturers at this year's Open House Show, we learned that this industry has already begun to apply such recycled material to some of their precision connectors. Since the precision molding field is our strongest area of expertise, we felt it necessary to strengthen our activities regarding recycled material in precision molding. In order to do so, we will focus on two areas, that is, function and molding technology.


Uchiyama (GM)

Second, regarding energy conservation, we have saved a substantial amount of energy with the heater's heat insulation jacket. Still there are many more areas in which heat insulation performance must be enhanced, and we would like to expand the range of our developments. For electric injection molding machines, energy saving has progressed by using electricity in the servo drive, and heaters now account for about 50% to 60% of total power consumption. Of course, reducing the energy consumption of servos is important, but for injection molding machines, making heaters use less energy is increasingly gaining importance. In that respect, we would like to make good use of the guidance you have given us in our future improvement activities.

Finally, regarding using servo-actuated molds, our objectives are to explore new shapes for molded products using electric servos. In addition, as electric servo systems consume less energy, we hope to collaborate with mold makers so that

molds take advantage of the benefits of electric servos. We will continue to try to make progress steadily in pursuing environmental friendliness and energy conservation, and hope you will continue to guide us along the way.

President Yamaguchi: Thank you. This concludes our discussion on FA, Robot, and ROBOMACHINE.

Summary

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

Professor Shinno: Thank you for inviting me to participate in this year's New Products Open House Show and roundtable discussion. It has been a while since I saw your latest products and leading technology in the field of FA, and I also enjoyed the free exchange of ideas and opinions. I sincerely appreciate this valuable opportunity that you have offered.
Today, I had the privilege of touring the Open House Show and gained a general understanding of the latest developments in FA and robot technology. As this was a special privilege, I reflected on how we should approach the social issue of "the creation of a smart factory" and the challenges we should solve. This Open House Show can be considered to be a presentation of "FANUC's concept of a smart factory and the advanced system modules that comprise it."
The smart factory as proposed by FANUC can be interpreted as being "a series of ROBOMACHINEs combined with organically integrated various software, including those related to IoT and AI, in the form of a factory system, to be used to optimize production processes, improve productivity and quality, as well as save energy."
Servo technology and advanced system modules represented by each ROBOMACHINE, which took center stage of the Show, have already been established as products and technologies with a high degree of perfection, as was explained with specific examples by the professors in this roundtable discussion. All of these products constitute a range of product series that have been refined over many years of R&D at FANUC. Therefore, it will not be easy to find new material for R&D.
Apart from this, there have been various discussions in Japan and abroad regarding the basic functions that smart factories should be equipped with. At this time, I would like to take up this topic by introducing the following five basic functions that I consider as having high priority as well as being relevant to the content of the Open House Show.
The first basic function is "Cyber Physical System (CPS)." CPS is a system technology that links physical space (the real world) with cyberspace (the virtual computer world) to create new values in manufacturing processes. The synchronization of physical space and cyberspace through IoT and other means is absolutely necessary for CPS. With CPS, an entire smart factory can be simulated in real time, and information can be shared efficiently. As a result, system status monitoring, thermal displacement suppression and compensation, self-diagnostics, and self- repair become possible. System modules for this basic function include the "FANUC Series 500*i*-A" and "Smart Digital Twin Manager," which applies digital twin technology to improve the machining process and inspection of machining results.


Professor Shinno

The second basic function is "good use of IoT and AI." The use of IoT and AI will elevate the efficient use of devices, sensors, and control systems in smart factories, so that manufacturing processes will become highly automated. At the same time, data can be collected and analyzed in real-time. This will in turn facilitate status monitoring and optimization of manufacturing processes, as well as making predictive maintenance, maintenance, quality control, and other processes possible. System modules for this basic function include "FIELD system" and "AI Servo Monitor in conjunction with MT-LINK*i*" for real-time data collection and analysis. This basic function is expected to be deployed across all system modules in the future.
The third basic function is "human-robot collaborative work." By focusing on the characteristics of humans and collaborative robots, the abilities of humans and collaborative robots can be mutually complemented to bring about an ideal form of collaborative work. This will result in making manufacturing processes more advanced, flexible, and optimizable. System modules for this basic function include the "CRX series" of collaborative robots, which reproduce the skills of experts through direct teaching.
The fourth basic function is the "digital ecosystem." By sharing all digital data related to production among systems, it becomes possible to improve production management, inventory management, and product traceability as well as to reduce energy consumption. System modules for this basic function include the "energy-saving new-generation servo system αi-D series SERVO."
The fifth basic function is "centralization of items and information." Such centralization allows production data and applications to be efficiently processed, stored, and referenced. In such a manner, remote access and scalability will improve. There are also high hopes that the entire production system, including the designing of processes and work, can be significantly transformed. System modules for this basic function include "FIELD system," which contributes to making manufacturing sites smarter through the use of digital data," and the "CNC Series 500*i*-A, which features sophisticated edge functions."
I have heard that all components and system modules of

a smart factory are either already released or soon to be released to the market as hardware and software products with a high degree of completeness. I hope that the "proliferation of smart factories" will accelerate. In order to speed up awareness and the spread of smart factories among customers, it would be useful to construct a compact smart factory, and conduct validation tests. The smart factory should combine and integrate the newly announced products and technologies with ROBOMACHINEs. The image will be of a comprehensive production line that includes raw materials, parts machining, surface treatment by laser systems, assembly by collaborative robots, painting, and final product inspection. As a result, customers' understanding and awareness of smart factories will increase, which in turn will greatly contribute to the desired goal of strengthening the international competitiveness of Japan's manufacturing industry.
Finally, on behalf of the professors participating in today's roundtable discussion, I would like to express my deep gratitude to FANUC for your efforts in preparing the Open House Show and this roundtable discussion. As a FANUC fan, I wish you continued growth and success. Thank you very much for today.

President Yamaguchi: Professor Shinno, thank you for bringing the discussion to a close. Finally, Chairman Inaba would like to express his gratitude.

Chairman Inaba: Thank you, Professor Shinno. I would also like to thank all the professors who attended today. I truly appreciate the wide range of guidance and advice we have received starting with Professor Shinno and all other participants.


Chairman Inaba

First, regarding CNC which is our basic product, the 500*i*-A CNC system was displayed. The hardware and software were completely renewed. Such a total renewal of a CNC was the first time in 20 years.
Combining it with the α*i*-D Servo, which was developed to be paired with the 500*i*-A, can bring out even better performance. We expect that a CNC system that connects machine tools in machining factories via a network will actually be developed, which will have the capability of optimizing the whole and not just partial optimization of individual standalone machines or devices.
One major theme of this year's Open House Show is "ease of use," a feature praised highly by the professors in attendance today. We have developed functions that make it easy to digitally adjust, set, simulate, and perform other operations on an NC. A major advantage of this system is that machine tool manufacturers and end users can easily make full use of the machine's performance.
Thank you also for complimenting the CRX design. As CRX works in collaboration with humans, if people feel discomfort or fear, it will not be possible for them to work together. First and foremost, we prioritized user-friendliness in the design. As for NC, Robot, and ROBOMACHINE, we questioned whether having good performance only, and ignoring making the design stylish was acceptable. The answer was that this wouldn't be feasible as a product. Therefore, we were very focused and careful in designing, and are grateful for your compliments.
We are naturally doing our best to reduce energy consumption by engaging in what we are capable of doing, but there is a long road ahead. We will continue to make steady efforts to improve energy-saving performance.

Lastly, our approach to smart factories and cloud computing that Professor Shinno mentioned was right on target. We will keep on making advancements in both areas. However, there are many customers who do not want to use cloud, so the reality is that on-premise systems are also in demand. In addition, we are not capable of building a cloud computing infrastructure on our own. That is why we are cooperating with partners such as Fujitsu Limited and NTT (Nippon Telegraph and Telephone Corporation). As for on-premise systems, we are pursuing two strategies. One is loading information collected onsite to the cloud, and the other is completing the process within the factory.
Unfortunately, we have not reached the stage in which we are able to disclose these results to you at present. Still, we are working hard to develop behind the scenes, and we are thinking of releasing products to the market one by one as they are completed.
Currently, the entire company is making every effort to use digital technology to make the dream of a smart factory come true. We hope to present our new technologies and new products at next year's Open House Show that are even more advanced compared to this year, and would like you to come back to see our progress. We look forward to your continued guidance.

President Yamaguchi: I would like to express my gratitude to the professors who visited our Open House Show and joined us today to offer many hours of guidance. We intend to develop new products and technologies based on the advice and direction you have provided. Thank you very much.

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