Foreword

Future of High Value Manufacturing

(Evolution from Ultimate Form Generation to Function Generation)

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1. Introduction

In Japan, it is important to discuss a vision for Monozukuri (creative design and manufacturing), which is the country's industrial base.

However, Monozukuri that has long contributed to the prosperity of Japan with mass production and volume consumption is almost coming to an end. We will face circumstances that require us to develop another type of Monozukuri responding to various senses of values in the future.

For example, we need to take measures for achieving carbon neutral or supporting super-aging of society. It is being internationally discussed to develop novel technologies to accomplish these goals as an urgent challenge.

Besides technological innovation, economic and societal innovations are also indispensable. For these ends, we should have a broad range of knowledge and insight covering areas from human and social sciences to natural science. In recent years, some attempts have been actively made to establish a cross-sectional innovation and eco systems in which industry, academia and government can talk together through coalition. Then, what the Monozukuri field can do to help them achieve the ends. One is to develop even higher-accuracy, even higher-value-added products that cannot be achieved with foreign technologies. What is significant to achieve this is not only the existing simple Form Generation, but also Function Generation that creates a structure for expressing functions on the surface or internally. The author named this "Function Generation Machining" and has promoted its research and development to be one of the technologies for "High Value Manufacturing".

2. What Is Function Generation Machining?

Machined parts are normally evaluated for their machining accuracy with two criteria: form accuracy and surface roughness. Requirements for machining accuracy have recently become more intense with some of them exceeding nano order to reach pico order. To achieve such ultimate machining accuracy, comprehensive research and development has already been started covering machining principles, tooling, machine tools, evaluation and measurement methodologies, materials, assembly methods, and design theory. Function Generation Machining produces microscopic structures on an ultra-precision machined surface achieved with these techniques or controls crystal structures in the proximity of the machined surface, thereby expressing new functions.

In this way, a combination of form generation and function generation is used to try to achieve high-value-added generation. This type of Monozukuri is called Function Generation Machining. In other words, the conventional simple form generation should be merged with function generation into a new style of Monozukuri.

To achieve this, it is indispensable to scientifically make clear how the machining works in the molecular or atomic level and to establish a new machining process for realizing pico-precision machining. Specifically, this comprehensive technology to be established must leverage pico/nano/micro/macro or so-called multi-scale mechanical system design theory that supports pico-precision machining to complete a device or even a system, and tool design engineering, pico-level in-situ measurement and evaluation techniques, cooperation of machining simulators and systems, pico-level implementation for precision assembly of microscopic structures, and material generation and strength reliability evaluation for ensuring safety and security.

3. The Keyword Is “Hybrid”

Many function generation products have a hybrid structure. For example, μm-order diffraction grating is formed on an aspherical lens surface, and furthermore a several hundred nm-pitch moth-eye structure is superimposed to be a high-function hybrid refraction-diffraction optical device with nonreflective function. Such a hybrid structure can often be fabricated by combining different machining methods, not using them independently, to express significantly higher efficiency and/or special functions. These examples include ultrasonic-assisted grinding that combines ultrasonic machining and grinding, laser-assisted micro machining that combines laser cutting and grinding, and ultrasonic vibration assisted

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electrochemical grinding that combines three techniques: ultrasonic machining, grinding and electrolysis. In addition, one of the technologies recently developed is one that uses ultrafine bubble (UFB) machining fluid to simultaneously achieve improved machinability and surface modification. In this type of machining, the chip removal mechanism will be greatly affected by chemical factors because chips are as fine as nano order. Particularly where electrolysis, discharge, laser and UFB-assisted process are combined, nano-order physico-chemical phenomena must be understood not only from the mechanical engineering aspect, but also from the chemical and quantum aspects.

4. In Closing

This paper has introduced Function Generation Machining for achieving high-value-added Monozukuri that may be significant in discussing future Monozukuri. To implement a machining technique for future Monozukuri, scientific and rational Monozukuri based on understanding of what's really happening in the nano-order world is indispensable.

It is also important not to heavily depend on development of innovative mechanical solutions, namely, advanced hardware. Of course, hardware development is important, but software development is also essential in that hardware items cannot be combined and used efficiently without quality software. Furthermore, Monozukuri must essentially take into account production, disposal and recycling (including reuse) to be a recycling-based technology. In the life stream of "materials" (the syllable "mono" of Mono-zukuri literally means "material" in Japanese), greenhouse gases including CO2 are generated. Therefore, it is also needed to design and accomplish life cycle assessment to minimize the greenhouse gases.

Finally, needless to say, it is important to develop human resources with capability and spirit to overcome various difficulties in societally implementing novel technologies, the so-called Devil River, Valley of Death, and Darwinian Sea. It is strongly desired to establish a corporate environment for such human resources development to be realized in house as well. Simultaneously, I expect young engineers to develop and deliver entrepreneurship themselves for jumping into a world they have never seen before. I am really looking forward to seeing how Monozukuri (creative design and manufacturing) will evolve in future.