Roadmapping of Sustainable Manufacturing Technologies in Japan

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Abstract
To enhance the competitiveness of Japanese industries, continuous R&D efforts of elemental technologies are important. It is also helpful to know the overview of the area to enhance efficiency of the developments. In industrial technologies, since the practical needs in future are the strong driving force, it is necessary to determine appropriate targets of development. Thus, making roadmaps of technological area is useful to know the appropriate and efficient targets of development. Since Inverse Manufacturing Forum is a research association covering R&D area of sustainable manufacturing technologies, the mission to make the roadmap was outsourced to a committee based on Inverse Manufacturing Forum which was organized under Manufacturing Science and Technology Center. This paper briefly introduces about the history and overview of the roadmapping effort of sustainable manufacturing technologies.

Keywords: sustainable manufacturing, inverse manufacturing forum,

1 WHY ROADMAPPING?

Few one disagrees that sustainable manufacturing technologies are the keys to satisfy high quality of life and low carbon society. However, it is very difficult to determine which technologies should be put emphasis on and what kind of approach should be taken, since so many sustainable manufacturing technologies have been proposed and it is impossible to implement all the technologies now. To take a strategic approach towards implementation of sustainable technologies, strategic thinking and categorization of technologies are necessary. The strategy of technological development extracted from these strategic thinking is so-called technological roadmap.

A committee organized under Manufacturing Science and Technology Center has been working on the technological roadmapping from 2007. Some members from Inverse Manufacturing Forum have been working for the committee. Many technologies which were discussed in the Forum were also listed up to the technological roadmap. In 2007, individual technologies were listed. In addition, possible candidates of national R&D project were discussed and three groups of technologies were proposed. Those three were "Highly efficient diverse-types-and-small-quantity production system," "Sustainable society simulator," and "manufacturing and inverse manufacturing integrated production system." In 2008, top-down thinking to show categorization which may help to achieve sustainable society was tried. As the result of the discussion, logic tree of sustainable manufacturing technologies was proposed. In 2009, a new integrated project proposal in integrating above-mentioned three groups was proposed. Again in 2010, modification of technological roadmap was discussed.

In the paper, the approach of roadmapping is explained with the layered categorization strategy of technologies. Then, the three project candidates and its visual images are shown. Through these efforts, the paper tries to draw a big picture of Japanese trends on R&D of sustainable manufacturing technologies.

2 SCENARIO ORIENTED APPROACH

2.1 Typical approach of roadmapping

Effort of making a technological roadmap is recently common in many industries in Japan. If there is a good technological roadmap, it is helpful to know what kind of development should be focused on for efficient R&D effort. For example, if the target of the development is 5 years later, it is necessary to focus on a technology which is predicted to be developed at least later than 5 years. This type of technological roadmaps is typically seen in device technology such as semi-conductor devices, MEMS, and so on. In these roadmaps, level of technologies should be exactly estimated and step-by-step progress of the technologies should be taken into account. Since these roadmaps are based on an extrapolation of practical technologies, these are very useful in predicting technological trends in near or mid-term future.

However, once there is a big change in social situations such as legislations, global economies, reduction target of global warming gas, and so on, this type of approach is not so appropriate. That was the motivation of technological roadmapping of sustainable manufacturing technologies.

2.2 Necessity of back-casting

As it is briefly mentioned in the former section, target of the reduction of green house gas is still under discussion. Therefore, there is a big possibility that a drastic change in the technological trend. It is so-called "paradigm shift" or

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"quantum jump." In such a situation, the step-by-step approach of roadmapping is no more effective. Instead, the roadmap should list necessary set of technologies to reach the designated goals. And it should clarify which technologies in current world will contribute to enhance sustainability and which technologies should be promoted. This approach is called back-casting. The roadmap of sustainable manufacturing also takes back-casting approach.

2.3 Scenario-based approach

To take the back-casting approach, a scenario which will be the goal of technological development should be decided. The following description is the essence of the scenario which the team decided at the beginning of roadmapping effort. The scenario is targeting 2025.

General situations:

Although there have been many efforts of the reduction of fossil energy consumption, according to the economical growth of newly industrialized country such as China and India, the world consumption of primary energy has reached 1.4 times of that in 2000. Development of renewable energy technologies that are being expected to replace some of the energy supply have been carried out. And the ratio of renewable energy has been increasing steadily. However, a drastic increase has not come yet.

The reduction target of greenhouse gas in 2050 has been agreed by major emitting countries. Corresponding to the agreement, the goal of greenhouse gas reduction in Japan has also been decided. (It is minus 60 to 70% of the amount of 2000.)

Production technologies which can enhance eco-efficiency (value of the products/lifecycle environmental burden) to 4 times of that of 2000 have been developed. However, since technologies have not spread to every industry, the reduction of greenhouse gas emissions in Japan is carried out by the combination of the lean production in industries, reduce designs and energy efficient designs of products, emission trades, the carbon tax and CO2 storage technologies.

However, in 2025, the problem of lack of natural resources is becoming more and more urgent. Thus, not only the linear development of current technologies but also a paradigm shift including the establishment of new lifestyles is being required, to establish the real low-carbon society in 2050.

In addition, more detailed scenarios was decided for all the lifecycle stages of products that are "design," "production," "usage" and "end-of life."

3 HISTORY OF DISCUSSION

3.1 First year; 2007

Through the first year's discussion in the committee, a categorization of element technologies has been carried out. As it is mentioned in the later section, the technologies were categorized to 4 roads and 9 approaches.

3.2 Second year; 2008

Based on the first year's discussion, the committee discussed the intermediate social situations to connect element technologies and the goal (societal scenario). The intermediate social situations have been named "meso-layer." Then, a logical procedure so-called logic tree to start from the meso-layer and reach to elemental technologies was drawn. In addition, 3 groups of elemental technologies that can be possible candidates of national R&D projects have been discussed and decided.

3.3 Third year; 2009

According to the change of the governmental policy, small modifications on the scenario were discussed. Plus, a general direction of R&D to integrate above-mentioned three subjects was considered and drawn on the introductory scenario.

3.4 Rolling of the roadmap; 2010

The roadmap was examined by some new committee members from private companies. Some claims, opinions and suggestions about whether the roadmap is helpful to show the direction of R&D to those private companies were extracted.

4 LISTING AND CATEGORIZATION OF TECHNOLOGIES

4.1 Four roads to sustainability

As it was mentioned in section 3.1, elemental technologies of sustainable manufacturing were categorized based on 4 directions to establish sustainability and 9 approaches to reach the goals.

These are the 4 roads.

1. Life cycle thinking
2. Minimization
3. Heightening of added value
4. Succession of skill

4.2 Nine approaches towards sustainabilitys

Elemental technologies are also categorized to 9 approaches to establish the sustainability. Not same as the usual technological roadmap, aforementioned 4 roads and 9 approaches are not large sections and intermediate sections, because the relations between 4 roads and 9

approaches are many-to-many correspondence. The next are the 9 approaches.

a. Servicizing
b. Visualization
c. Computerization
d. Ubiquitousizing
e. Reutilization
f. Substitution
g. Balancing
h. Standardization
i. Personal training

4.3 Element technologies towards sustinabilies

Each elemental technology for sustainable manufacturing was categorized using aforementioned 4 roads and 11 approaches as labels. Table 1 shown below is a part of the technological roadmap

Table 1 Technological roadmap of sustainable manufacturing technology (partial)

Life cycle thinking	Servicizing	Maintenance technologies	*Estimation technology of residual life * Risk-based preservation technology *Management technology of usage history * Maintenance business
		Design support technologies of environmental conscious business strategies	Software technology of supporting environmental conscious business strategies
	Systemi-zation	Lifecycle design technologies	* Design technology of LC strategies
			* Lifecycle simulation * Comparison technology of alternatives
			* Easy-to-recycle design technology
			* Easy-to reuse design technology
		Reduce design technologies	*Optimum design technology of structures
	Re-utilization	Management technologies of product circulation fro reuse	* Forecast of generation of reusable parts * Management of stock of reusable parts *Production planning utilizing reusable parts
			*Utilization technology of high-functional materials *Utilization technology of recovered material and parts
		Lifecycle management technologies	*Management technology of lifecycle information *Management technology of usage history *Fusion technology of products and information
		Management and design technologies of global circulation of products	*Design technology for global product circulation *Technology assure traceability
			*Social system establishment for global product circulation
		Product life management technologies	*Product life prediction technology *Product life diagnosis technology *Product life design technology
		Quality management technologies	*Residual life diagnosis technology * Degradation diagnosis technology *Non-destructive testing technology *Remote testing technology

5 SUBJECTS TO PUSH

5.1 13 groups of tecnologies

In the second year of discussion, since the first year's roadmap didn't show which technologies should be focused on strongly, the committee tried to extract group of key technologies that will be inevitable to develop to establish sustainable society. These are the 13 groups of technologies to be put emphasis on.

a. Lifecycle design technologies
b. Sustainability estimation technologies
c. Managment technologies for global product circulation
d. Modeling technologies of products
e. Fusion technologies with products
f. Technologies to ensure traceability
g. Technologies to design good balance of products and services
h. Fusion technologies of products and services
i. Technologies to minimize portotyping
j. High effeiciency various kind and vriant production technologies
k. Manufacturing system technologies to integrate mnufacturing and inverse manufacturing
l. Energy-efficient and resource-efficient technologies in manufacturing processes
m. Manufacturing process technologies with high yield of materials

5.2 Three candidates for national R&D project

In the second year of discussion, the committee also proposed three potential candidates of national R&D projects concerning sustainable manufacturing technologies. Fig.1 to 3 are the schematic images of the 3 subjects.

(1) Sustainability Scenario Simulater

Sustainability Scenario Simulater can express how development and spread of technologies, consciousness of citizens, societal lives and environmental impacts can change along the time, concretely and exactly, including the image of the society..

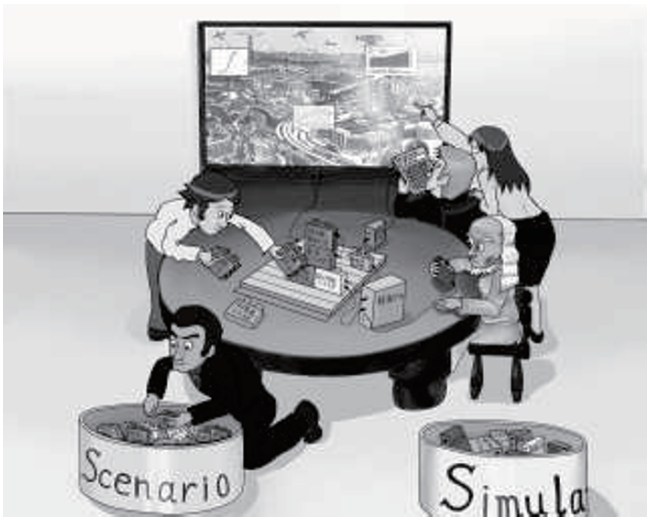

Fig. 1 Sustainability Scenario Simulater

(2) Efficient various-quantity-large-variety production

On-demand manufacturing can be a key to reduce waste, and enhance energy efficiency and resource efficiency of the production. Thus, the new manufacturing system should satisfy "on-demandness" of the production, from upstream to downstream. At the same time, functionalities of the products should be satisfied at a high level. Not only manufacturing process technologies but also diagnosis and prediction technologies of product performances are necessary. This kind of manufacturing system is also helpful to maintain knowhow of manufacturing and personal training.

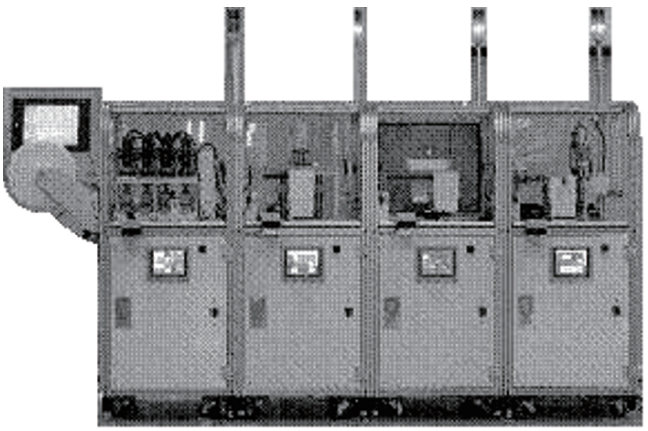

Fig.2 Prototype of the on-demand manufacturing system

(3) Manufacturing system combined with inverse manufacturing system

As it is recently seen in some of electronic products or automobile parts, reuse and remanufacturing of parts are becoming common. These remanufacturing especially combined with manufacturing will be a key technology

nowadays to enhance competitiveness of manufacturing. Thus, to carry out R&D of the integrated system will be a good strategy to promote Japanese manufacturing industries.

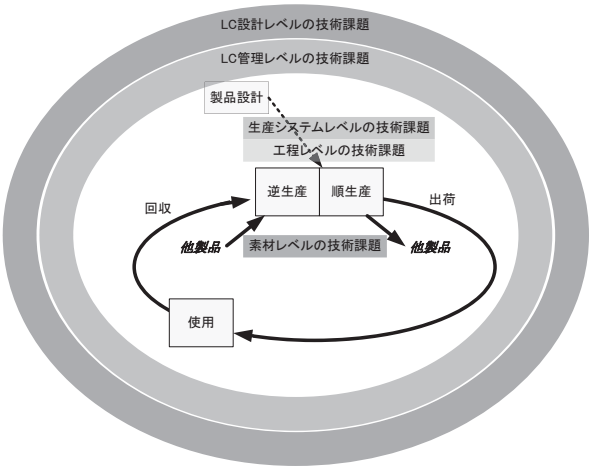

Fig.3 Concept of manufacturing system combined with inverse manufacturing system

6 ROADMAP FOR EFFICIENT R&D

Inverse manufacturing forum is a research consortium to discuss how the sustainable society can be achieved. Members have their own research topics. Concerning the research activities, R&D of actual manufacturing technologies, material technologies, design technologies, etc. have been carried out. Those efforts are the core of technological progress and very important. But, at the same time, for efficient developments and for enhancement of competitiveness of industries, having the overview of the area is helpful. In that aspect, roadmapping of the technologies is also necessary. And of course, for sustainable manufacturing technologies, Inverse Manufacturing Forum is the suitable organization to be in charge of the roadmapping.

Through 4 years effort of the committee, the technological roadmap of sustainable manufacturing technologies has been drawn. In addition, some promising groups of technologies which can be candidates of national R&D project have been extracted. The next step is to utilize the roadmap for efficient and strategic R&D, in private companies and public organizations.

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