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A Discussion of The Transition of New Technologies from The Generation to The Diffusion based on The Thermodynamics Model

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Abstract

Although the process in which a new technology is researched, developed and spreads into the society as goods or service is complicated, it is thought possible to grasp the feature of the spreading technology. This research assumed the new technology diffusion process to the simple model using the concept of a thermodynamic dissipative structure, and it was considered the process which the new technology diffuses to the society as a field. It was found out that the turning point which divides the case where it spread widely and the case where it does not is influenced to the total of the scale of all industries which may spread. And the problem of such a complex system was simplified like the complexity of combination.

As a result, it was proposed the new handy evaluation index which may be able to grasp the possibility of the spread of the new technology.

Key words : **Self-organization, Dissipative structure, Phase transition, MANDARA, Complex system**

1. Introduction

When a new analysis technology is introduced into a site of research and development (R & D), there are not few cases where it is not fixed in a site oppositely to a plan.

And also, when a new elemental technology which is added a new function to goods of existence is applied, even if that has the high performance, there are a lot of examples which cannot go out to the society as a new product.

In this paper, it is shown that these new analysis technologies and/or new elemental technologies are generated with the new concepts, and after that, they are spread with 3 stages of expansion, that is, the use, the transfer and the diffuse, in the complicated relationship between "technology and society".

And a practical management technology on a highly complicated spread process from the generation to the diffusion of new technologies is considered, and the importance of the transfer stage is also discussed.

2. Overview of typical technology spread in past

There are mother knowledge and technologies to accomplish new technologies and products. Therefore, in this paper, it is determined the core of the new technology has been generated when it was knowledge-ized by a new concept or business model and so no. So we surveyed typical three cases on an introduction of a new technology restructuring the organization and a development of new product with reform of cost-consciousness.

2.1. Personal computer

A typical new technology which improved the efficiency of office work in the organization is so-called office

automation(OA) technology including a fax, a word processor, a microfilm and so on. We focus on a personal computer(PC) among these equipments, and consider the appearance of a word processor function. Of course, a PC is the new product which was formed on the stage of the enormous fundamental research on the electronic computer technology which continues from the vacuum tube age. But according to the definition, this stage is abstracted, it is supposed that we can specify the time when a concept of a new technology as a PC was formed.

In an early period, a Japanese word processor was introduced as a new technology of a Kana-kanji conversion function. It gave a heavy burden to a user who didn't have used a typewriter because it needs a proficiency of a keyboard operation.

However, a Japanese word processor introduced into a site of office to get a support because it was judged the benefit with improvement of the office work efficiency was bigger than the investment of the various charges even if it can be used only as a word processor. A little later, it developed into the word processor function setting in the PC.

2.2. Exhaust gas purge system of automotive

We will look back about an exhaust gas purge system of a vehicle as a next example. When the information on the US Muskie Act spread out in Japan, from the final stage in the 60 's to an early stage in the 70 's, the technologies of the exhaust gas purge system had developed rapidly in Japanese manufacturers and been completed as the fundamentals of lean burn and three-way catalyst technology.

In 1973, Honda had put a car powered by CVCC Engine(Fig.1) on the market loading prior to the world. Because Honda had got a new vision of ‘an environmental performance’ in the background where such high-cost new technology had been adopted as goods. Even if it had suggested by the Muskie Act as ‘the performance which should be shouldered before long’ in addition to a direct effect of the power and the mileage, this example had been superior to the conventional theory of the cost vs. the effect.

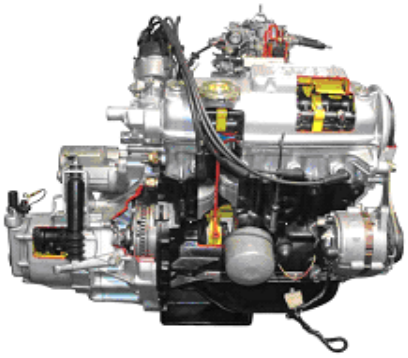

Fig.1 Honda CVCC Engine

2.3. Recycling technology

Finally, we consider about recycling technology of an aluminum can and a plastic bottle. In particular, recycling of a plastic bottle cannot always indicate the positive direct effect compared with the case of aluminum can. However, the use of plastic bottle recycling was fixed getting an incentive of administrative guidance. We can point out this case is the good example which can spread as a new technology, even if it isn't an innovative one.

In case of 2-1, the effect by the introduction of the new technology is estimated as an improvement of the performance of the system which consists of a former technology (i.e. direct effect) by a conventional relation between the cost and the effect (or benefit), and it is characteristic that the premise is looked through easily, that is, its effect corresponding with the cost. Therefore, its introduction is spontaneous, and expands inducing the appearance of the next goods improved more. It can be said to be a typical example where an innovative new technology spreads into the society.

However, even if little, the case of 2-2 or 2-3 can not be explained only by a conventional relation between the cost and effect. The case of 2-2 is a good example which Uzawa pointed out referring to Kapp[(1)], that is, the cost goods should shoulder is calculated relating to the social responsibility of an enterprise, or primarily, the goods with the actions which disturb the desirable environment for mankind shoulder a responsibility which bears the processing and the replenishment to cancel these side effects. After that, the enterprise will share the cost of the goods which is ignored before that. It is pointed out such time comes sooner or later.

And more, in the case of 2-3, it seems that the opinion by Althusser[(2)] is appropriate. Namely, he pointed out the society has a self-productivity and the social common sense can be fixed as the next one renewed by the appearance of the suitable ideologies, even if it was inconvenient before that.

3. A concept of dissipative structure

A case of the spread of the above-mentioned new technology suggests that it is a more important viewpoint what kind of influential territory spreads outside it than the direct effect by its use.

According to the social Darwinism by H. Spencer, social evolution is achieved in the direction of complication.

However, for partial process requires a cut to the whole concept, the evolution of the system as a certain partial process cannot exclude the influence of the environmental evolution that is its outside world.

Therefore you assume that it is only when a metagalaxy is treated when a law of evolution can be formulated according to N.Georgescu-Roegen[(3)].

On the other hand, a concept of the dissipation structure [(4)] has been accepted as a theory with a possibility that a social evolutionism can be explained rationally in recent years. The point is the understanding by the thermodynamics that the unstabilization is a herald to next order-ization, for example, the structure of Rayleigh-Benard cells where natural convection makes the atmosphere phenomenon is often learned about as a typical example.

Or the temperature difference between the upper and lower walls is small when liquid such as water is enclosed with parallel cylinder space like a laboratory dish, a base is heated uniformly and the top plane is cooled uniformly, and a cylinder face is insulated. When the temperature difference between the upper and lower walls is small, the convection which occurs to the innards can be ignored, and heat transfer is governed by conduction. fluid is almost stationary as a stable structure.

Next when a certain temperature difference is given, a little natural convection which is disorder and can carry a larger amount of heat is generated. And when a larger temperature difference is given, time/space averaged convective velocity increases, and soon it transfers into a turbulent flow.

However, depending on the increasing rate of the temperature and the viscosity of fluid, when the temperature difference becomes larger, sometimes a flow structure that looks like a tortoiseshell appears from the disorderly turbulent natural convection. In Fig.2, the stable structure is achieved, that is, an upward flow in the territory of the hexagonal shaped white stripe, and a weak downward flow formed in the wide territory inside it.

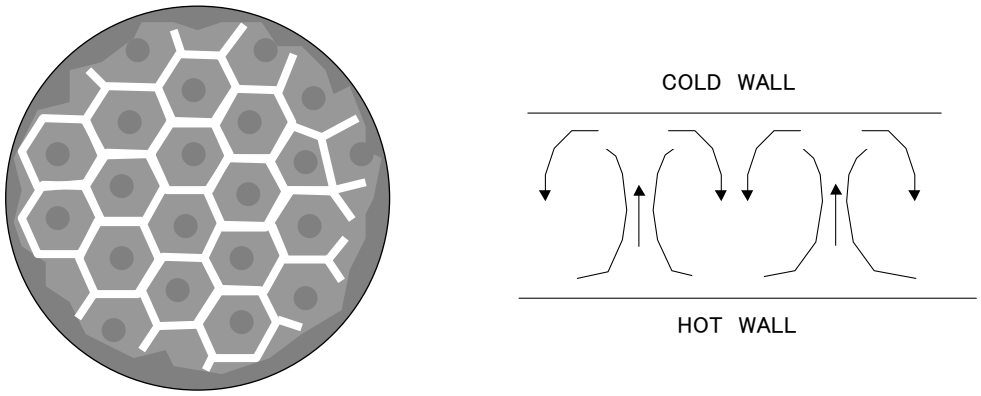

Fig. 2 Rayleigh-Benard cells

In this unstable system beyond the point of thermodynamic branch, the nonlinearity and nonequilibrium condition will become a driving force to support its structure, and sometimes new selforganizations appear.In this paper, the concept of dissipative structure is quoted as a theory with a possibility that can explain the social Darwinism.

For example, it can be understood a problem of biology as a development process of a complex system by this concept of the selforganization, and many studies [(5) - (7)] have been already reported.

The principle is indicated notionally in Fig.3. When the system is in a state with small fluctuation, its structure is stable, but the instability of a structure is increased by the feed back of disturbance and fluctuation. After that, an order shows again with the new macroscopic structure in the condition that is far from the stable state in an early stage.

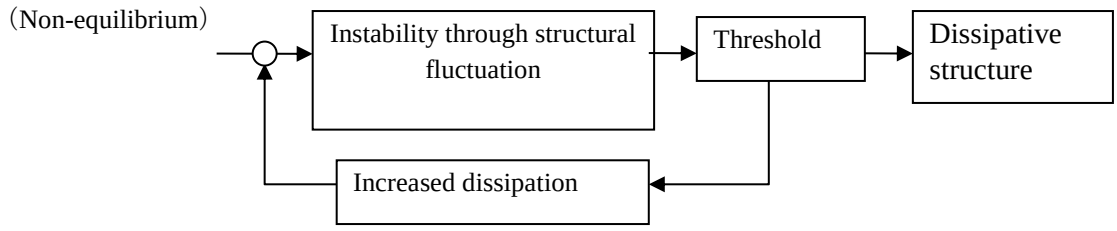

Fig.3 Feedback of evolution

It is possible to regard that generation of a new technology and its spread is phase transition of the structure when we think in the complex system as "technology and society", and, for example, it is possible to indicate as Fig.4.

We assume that a product and technology are used to remove the phenomenon which is not desirable (i.e. negative advantage) in society or organization. Even if society and the organization may act following the minimum entropy generation principle by ~~a~~ product and technological introduction, the new negative advantage begins to be recognized soon to increase the throughput with development of the activity.

When reaching a threshold with the new negative advantage which cannot be conquered by the former technology, several new technologies are generated to clear it out and or to reduce them substantially.

According to this concept, it is possible to guess that the organization of the enterprise grows up involving generation of the new business form as Fig.5. An enterprise invests various funds and expanses the share in the market to improve the profitability of the business. It is soon recognized that the profitability cannot be secured any more by the extension. A new product with a new technology appears as the one which changes this situation and reorganizes the structure of the organization and/or the market. It will be a typical example that PC is developed as office automation with an appearance of the Internet.

From above, it is shown that the feedback of the evolution acts like a nesting structure(i.e. Fractale), that is, the generation of a new technology is in the generation of the new business form.

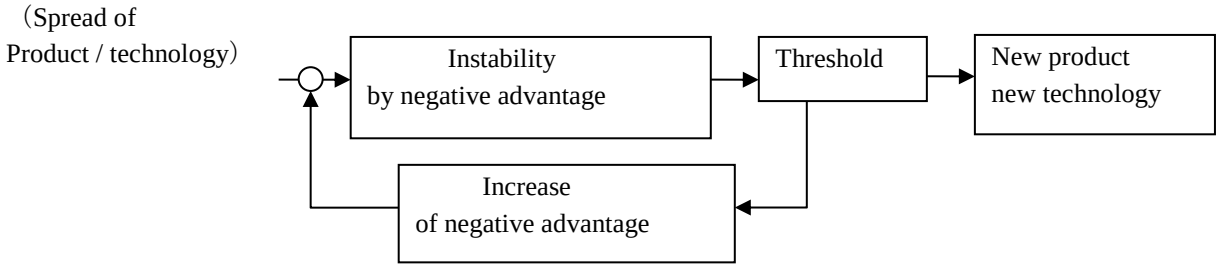

Fig.4 Generation of new technology

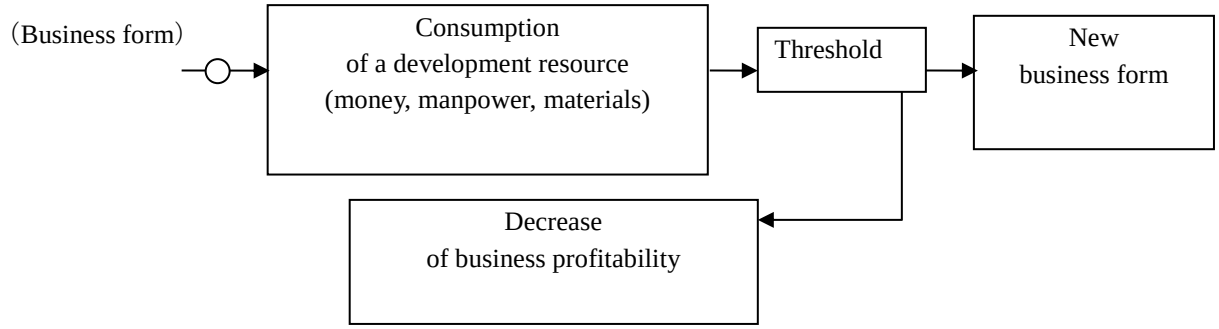

Fig.5 Growth of enterprise

4. A modeling of the diffuse process of a new technology

We focus on a feature that generation of a new enterprise and a new technology like the nesting structure and model the spread of a new technology as follows.

When negative advantage in some systems reached the standard which should be conquered, several new technologies generated in this system shift into the process of use setting in the environment organization which is in dominance. From the inside of the new technology in the stage of use, more innovative new technologies appear moving toward the market which is the environment organization of the dominance, and they come to the stage of spread. There are some cases to arrive in the stage of spread through the stage of transfer.

It is possible to consider the spread of a new technology as the process of selforganization for the new dissipative structure. It is classified into 3 stages for a convenience(Fig.6).

Use : The stage in which the generated new technology is used spontaneously inside of a professional group in an organization

Transfer : The stage in which use is expanded by a professional group. It is expected that a generated new technology spread into the society and/or the organizations.

Spread : The stage in which a generated new technology is accepted widely in the society

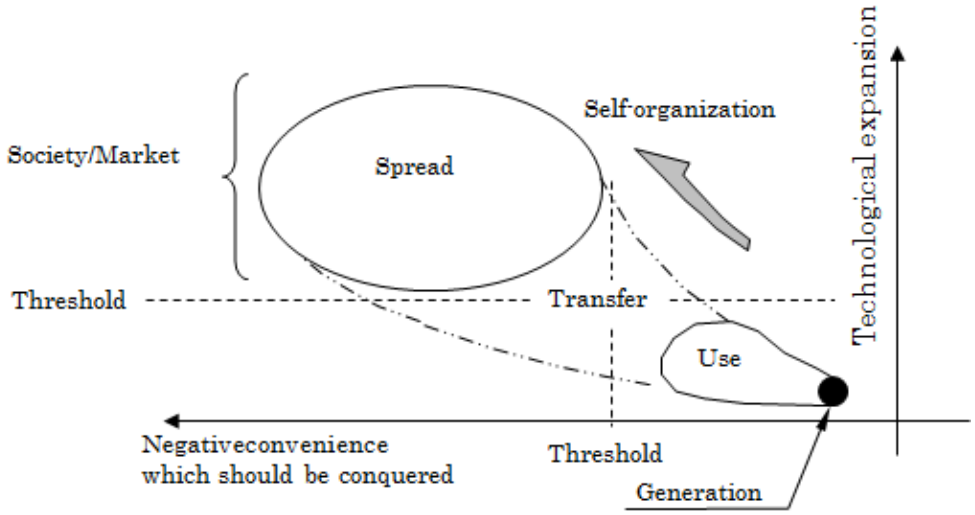

Fig.6 Diffuse process of new technology

Birth of a new technology (generation) is a result to a request from instability of the society (the system). At first, a generated new technology will be used by the limited environmental society. Next, it shifts to the stage of transfer when the side of the wider external society is expected to sweep away or reduce the instability of business and/or products. And finally, it reaches the stage of spread in which it appears in a market.

In particular, there is often an appearance of new social structure with complete 'phase transition' at the process from transfer to spread. When it is clear the influential territory is wide, spread progresses first. Such a new technology can conquer a larger negative advantage, and it can be seen its spread is the paradigm shift type. PCs and the Internet described above will be a good example.

When it is not clear enough that the influential territory a generated new technology exerts has a big expanse, or when the preparations to accept advantage of a new technology in society and a market are not enough, it can reache the stage of spread if the stage of transfer progresses first. And even when the spread progressed first, there exists a case that additional transfer occurs in the stage to more magnification.

5. Operation

Technology is intentional. New future technology is being planned in the complicated system, in the expanse of society and in wider scope of a market. Therefore, a structure of knowledge which shows the relation of technology and society has to generate. And it seems that a mathematical model which expresses the process from generation to diffuse is the effective method in future's R&D of a new technology and planning of a new product.

From the previous section, a new technology is generated to clean up or to reduce substantially the negative advantage which can't be conquered by the former technology. And it suggested the criticality to be used actually or to come to the stage of spread is the width of the influential territory.

When a new technology was generated, it is difficult to see how wide the range of its influential territory is.
As far as we know, there is not a method to analyze it quantitatively up to now.

However, we can refer to MINAKATA-MANDARA(Fig.7) introduced by Tsurumi [8] as a qualitative argument for example.
From Fig.7, MINAKATA had enough understood that an structure of slime mold was influenced deeply by fortuity

factor around organization the environment, and could not be predicted only by causality.

MANDARA is often learned about as KONGOKAI MANDARA in Japan, it expresses a metagalaxy as a system by SHINGON Esoteric Buddhism. While the concept of KONGOKAI MANDARA is magnificence, the occurrence tendency of phenomenon is understood as a phase in MINAKATA MANDARA, that is the way to make it easy to understand by simplifying fortuity and probability as a phase. And it is expressed as an open system with many inletflows and outletflows of each element.

On the other hand, Fig. 8 is based on the diagram of the technological relation showed by Konishi [(9)].The complicated and various intellectual stimuli are linked around a large feedback system generating a new technology which creates the next new technology in this diagram. Particularly, it is pointed out that the synergistic effect and compound effect of system engineering connect with the next new technology through the boundary of science territories (the path A in Fig.8). It is the system considered with the influence of the outside of it, and is common to MINAKATA MANDARA and the dissipative structure.

And recently the text mining techniques to analyze Big Data is becoming so practical that it will be an effective method to make a diagram of the technological relation as shown in the Fig.8.

From the above consideration, it seems that there are 3 points for modeling. Namely, the 1st one is expression of negative advantage, the 2nd one is expression of fortuity, and, the 3rd one is a setting method in a boundary of a system (the territory to analyze).

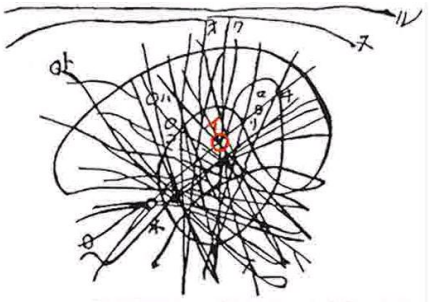

Fig.7 MINAKATA MANDARA

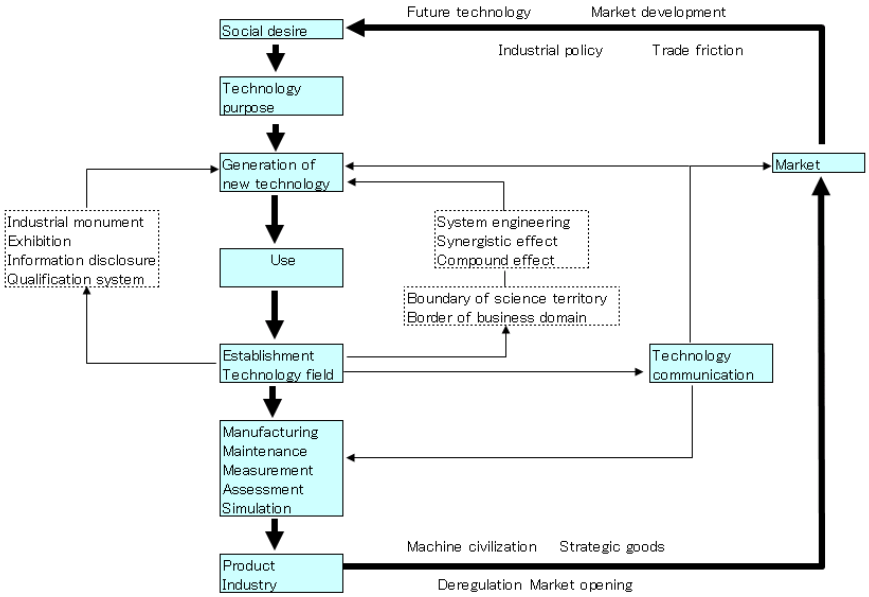

Fig.8 Diagram of the technological relation

It is generally very difficult to model such complication and the widespread system strictly. Even if modeling has been successful, it requires enormous calculation resources to get a solution. Modeling needs to simplify and replace boldly.

Firstly, expression of negative advantage is assumed something like a chain reaction as shown in Fig.9. A complex systems is changed for complication of the combination, and the self-organization ability is regarded as a threshold equivalent to criticality of chain reaction. The relative evaluation index is applied to each element, the distance until the phase transition(criticality) is presumed by a comparison the total of evaluation with the threshold assumed beforehand.

Idea of MINAKATA MANDARA is effective to express fortuity and the territory of analysis. When a new product or technology is developing, the diagram like Fig.8 is necessary to consider where the present state is, it is estimated a possibility coming to the phase transition is high if many key factors appear in it and its possibility is low if no key factor appears in it. And they appear as key factor, that is, technical material, a person or a concept by which was assumed beforehand.

A relation between Fig.8 and Fig.9 is similar to a relation between FTA and FMEA. It is a handy evaluation technique to grasp an expansion of new technology. It has a potential that a practical management technology can be built about the process from its generation to its diffuse. Therefore, it seems to contribute to efficient practical use of many development resources if the formulated method to give a guideline on the management can be built.

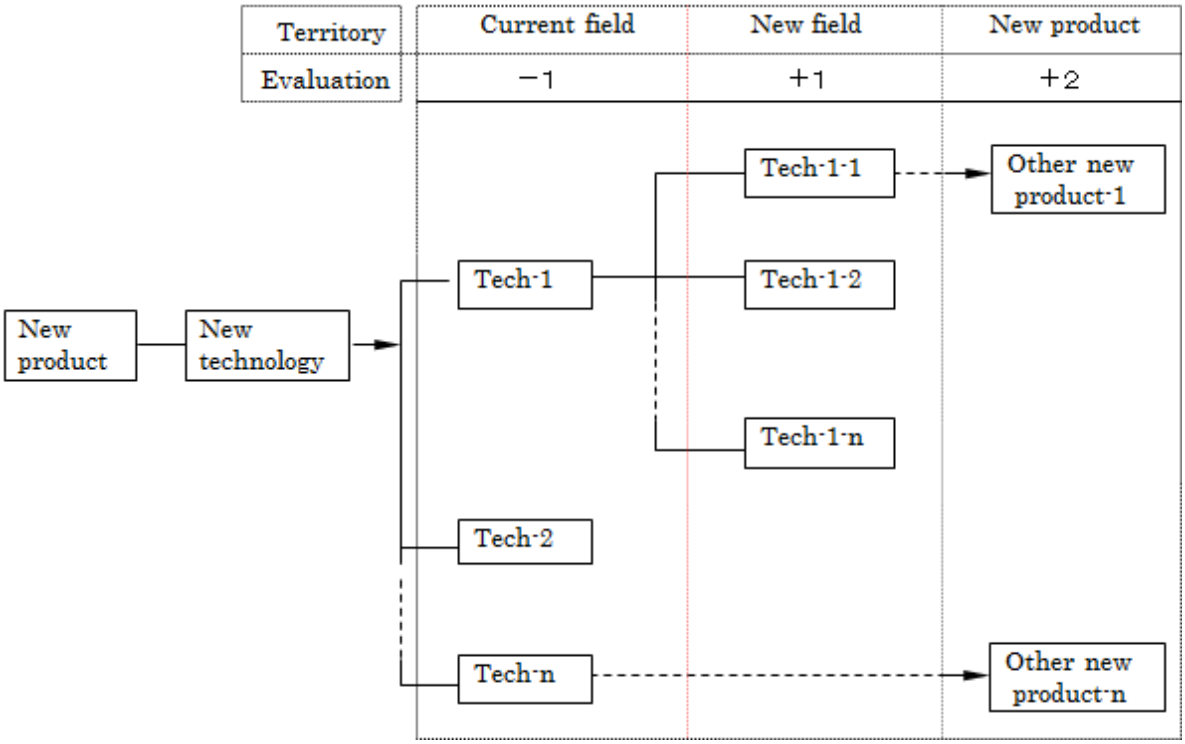

Fig.9 Chain of the technological spread

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6. Case study

In this chapter, the two cases of the actual development were analyzed by using the new handy evaluation index as shown in Fig.9. One is a new hardware system and another is a new software system. Hereinafter, the example is described.

6.1. On-board heat waste recovery system

The energy to be exhausted is released from vehicles to the outside environment. The system using Rankine cycle can salvage it. Fig.10 is an example applied to the vehicle. This system is combined with two subsystems. One is recovering the brake energy (Hybrid system) and the other is recovering waste heat (Rankine system). Honda has already finished the fundamental research of this system[(10)]. Now hybrid system that is a part of this system is expanding into the mass production, and it has been in the stage of the spread. But heat waste recovery system has not been even in the stage of use.

Then what kind of technical difference separated these 2 subsystems? Generally, people say that it cannot be accepted in a market when a system is complicated and expensive. Is it really true ?
Even though, according to social Darwinism, the evolution progresses into the direction of complication.

Actually, the cost of hybrid vehicles was very pessimistic when it is in the prototype stage, although it is in the price we can reach now. For the mass production, storage of a manufacturing technique by the motor and battery industry was needed, and it led to the success.

It is the feature that these industries (motor and battery) are very large scale and are the fundamental technologies related to various technical fields. Or the battery technology requested for hybrid cars can be applied to other products and it is a very wide technology in influential territory.

On the other hand, relatively, main device technologies required by the on-board heat waste recovery system are special and the industrial scale of expander, evaporator and the condenser is small. Therefore the influential territory becomes more limiting compared with battery and/or motor. This means that it is difficult to become the target of aggressive technological accumulation of a manufacturing and material technology in market principle.

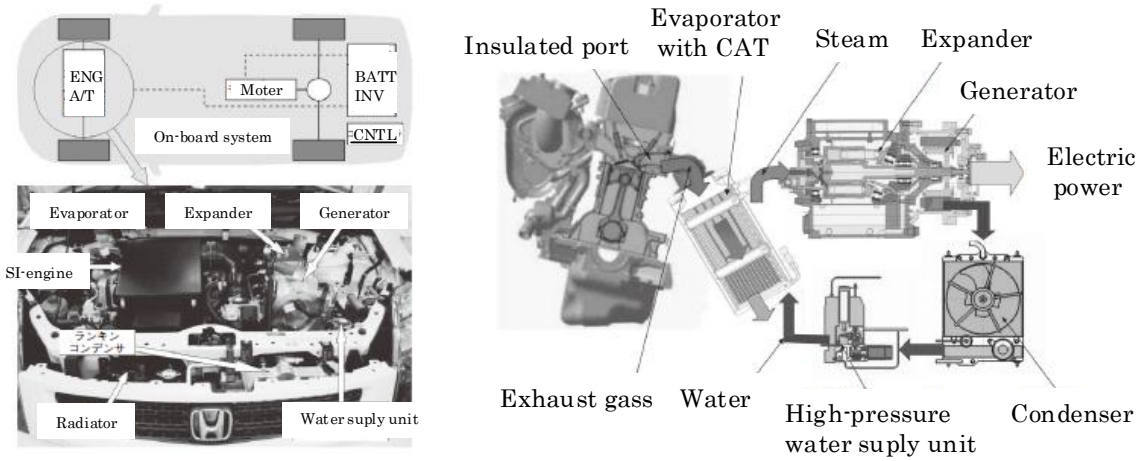

Fig.10 On-board heat recovery system

For example, the evaluation of the hybrid system is 7 points, but the Rankine system is 0 points when the spread effect of the elemental technology is estimated by Fig.11. This is the present evaluation point, but it seems that there is not large difference even if the evaluation was estimated at the early time of the development.

It can be seen that the main factor which disturbs the spread of a new technology is not a technical characteristic as a subsystem but an influence territory of a new technology or the total of the scale of all industry which can spread. It is possible to consider complication of a chain of the spread does not sufficiently become criticality of self-organization when the composed technology stays in the industry which is relatively small even if it is a new technology for the vehicle. Conversely the aggressive technological accumulation occurs automatically when it reaches criticality even if the large-scale operation of transfer is not taken.

Such criticality explained by the selforganization of the dissipative structure occurs in far-from-equilibrium system. That is so-called a problem of complex systems, but there is a possibility that the characteristics of the new technology can be surveyed by applying such a handy evaluation.

On the other hand, technological accumulation can be led when a kind of technological opinion~~'s~~ is formed through public administration and mass communication, for example, even if it does not reach this threshold.

When the influential territory of the new technology is small and it does not reach this threshold, it can reach into transfer or spread under the market principle of course if the practicality of a new technology and a new product can be judged by a relation of cost vs. effect. Or if the cost of the elemental technology and the composition device is reduced sufficiently and it is clear the increase of cost is smaller than the cost corresponding to the advantage of it, or it is inspected sufficiently the cost will be saved theoretically in the future, the influence of the new technology is equivalent to a fluctuation around the stable equilibrium state. Then its spread is argued by the usual cost vs. effect.

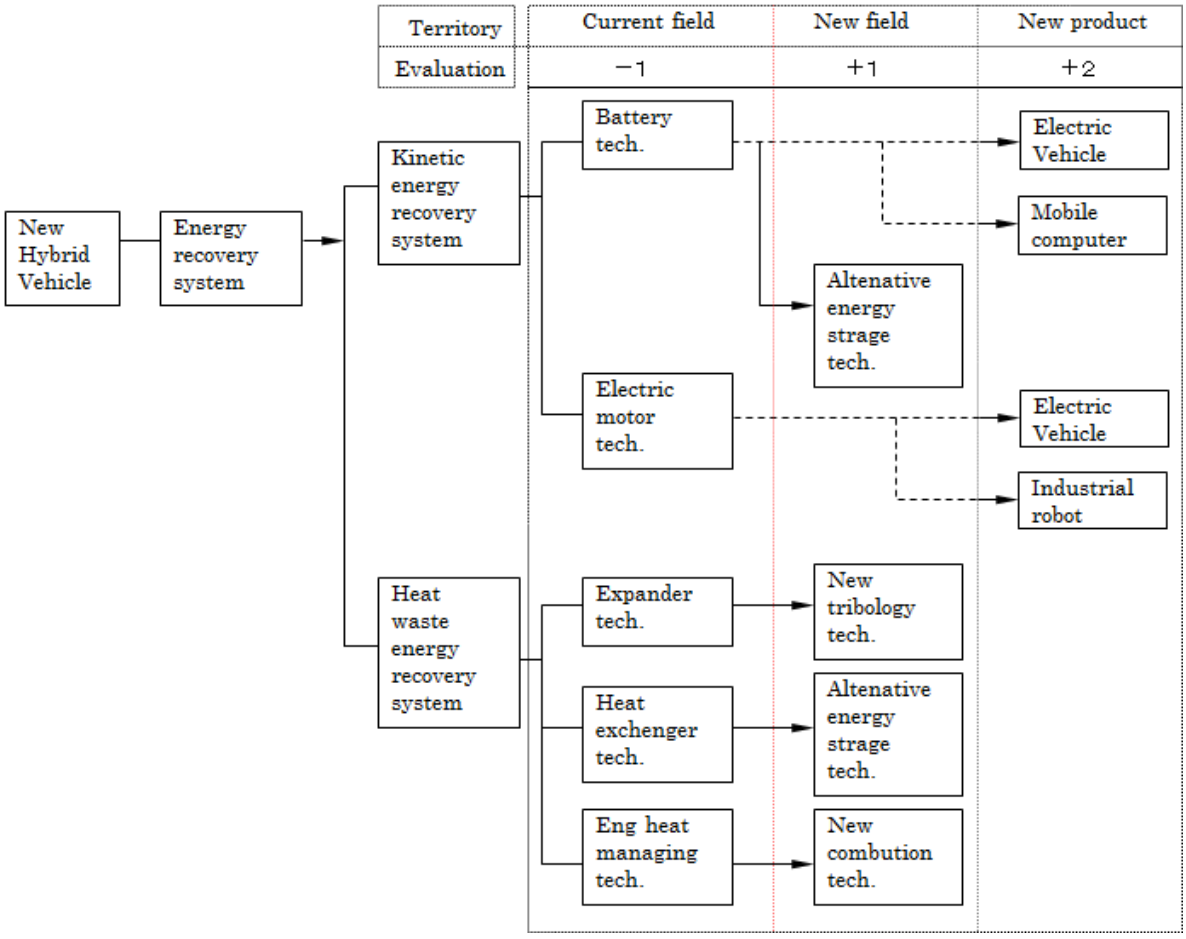

Fig.11 Evaluation of the system spread (On-board heat waste recovery system)

6.2. Innovational CFD system support to design work

Various design support tools are contrived and is tried to use in a site of development of motorcycle for an improvement of the business efficiency. For example, there is a try building up a consistent process from the design stage to the drawing stage by using a 3D-model, and a part of them has been performed in the site already.

Various heat and fluid analysis were become to be able to examine in a early design stage by using CFD (Computational Fluid Dynamics), and it becomes the result of them can be reflected into the design specification. Now, as for CFD, use progresses in several development scenes. By the way, there is a problem that needs much time and high skills for generating calculation mesh as well as technical knowledge when engineers of the design scene used CFD by themselves. We propose a Partial Cells in Cartesian coordinate method[11], in which flow field with any complicated shapes can be handled by Cartesian coordinate, as shown in Fig. 12, to settle the problem, then we promote also CFD use in actual motorcycle development scenes.

A first aim to reduce operation man-hour greatly, which is a negative advantage conquered, was achieved. However, since a large influence was given, problems were still left for the spread. One is a problem of the employment opportunity loss with high promotion of efficiency of the duties. That is similar to the phenomenon which has happened to the office jobs with an expanse in OA (Office Automation) formerly.

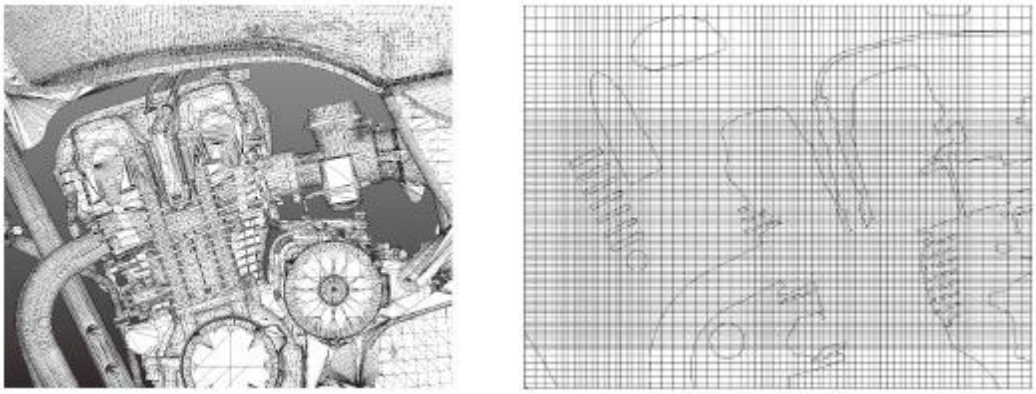

Fig.11 Partial Cells in Cartesian coordinate method

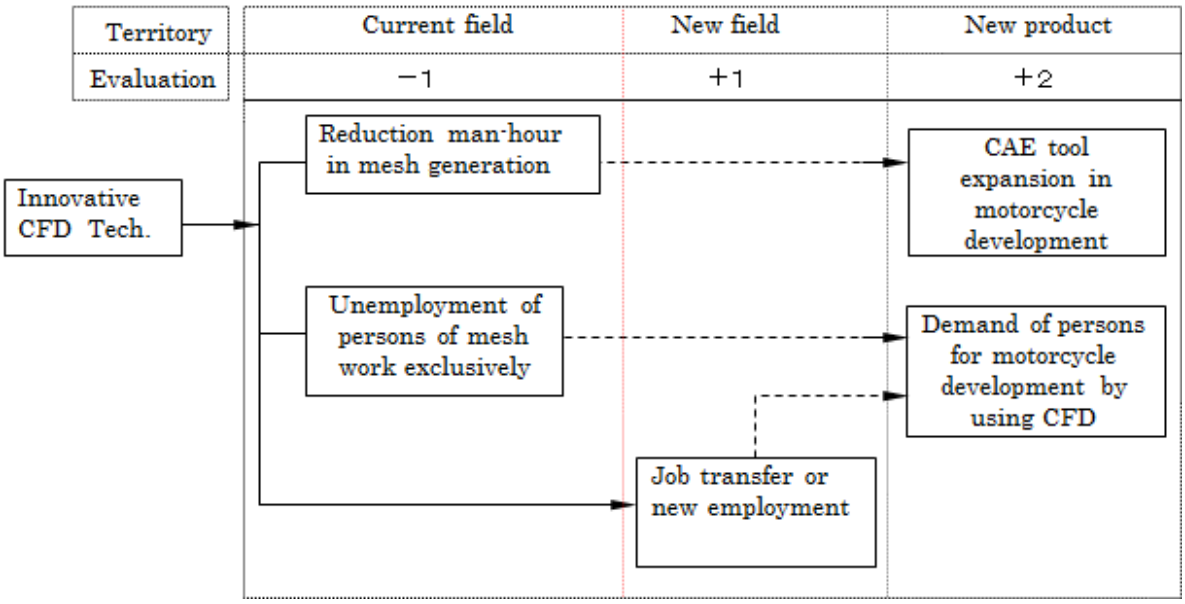

Fig.12 Evaluation of the system spread (Partial Cells in Cartesian coordinate method)

An unsolved issue concerning employment management exists outside the field of technical developments. When effects of the spread are estimated, 2 points of new product and 1 point of new product give total 3 points as an example shown in Fig. 13. Therefore, to spread this technology into a design site from the stage of use, in which stage success or failure is judged by the cost vs. effect, it is necessary to consider the employment management technology.

However, a typical problem of the process of transfer such as an employment management does not belong in the technology development territory. Therefore, to pick up such problems beforehand and to perform a necessary measure in parallel, it is expected to build a handy management tool for the R&D.

7. Conclusion

Even if a new technology of which technical characteristics are sufficiently met is generated, there are a case spreading widely and a case which is not so when it is used. We pointed out that a result is influenced by the size of the influential territory of the new technology,.

When the influential territory of the new technology was large, it can become the target of technological accumulation under market principle even if it is complicated and high degree of difficulty. Conversely, when the influential territory of the new technology was small, it can be seen like a fluctuation around the stable equilibrium state. In this case, its use/transfer/spread can be treated by the argument of the cost vs. the effect.

On these problems of complex systems, it is effective changing the complex systems to the complication of the combination to simplify it substantially. Specifically, a diagram of the technological relation about the technology is made first. Next, it is found the total of the evaluation by the chain of the technological spread which resolved a target of R&D into the elements. There is a possibility that the management of R&D can become efficient by a method similar to such FTA and FMEA. Because new future technology and new product tend to be considered in the complicated system with an expanse of society and market, it is necessary to hurry accumulation of the knowledge handling the opinion of technology and society and intellectual structuralization.

The engineers in a site look forward to an handy tool for the management of R&D, so detailed inspection about this method will be executed by increasing a case study from now on.

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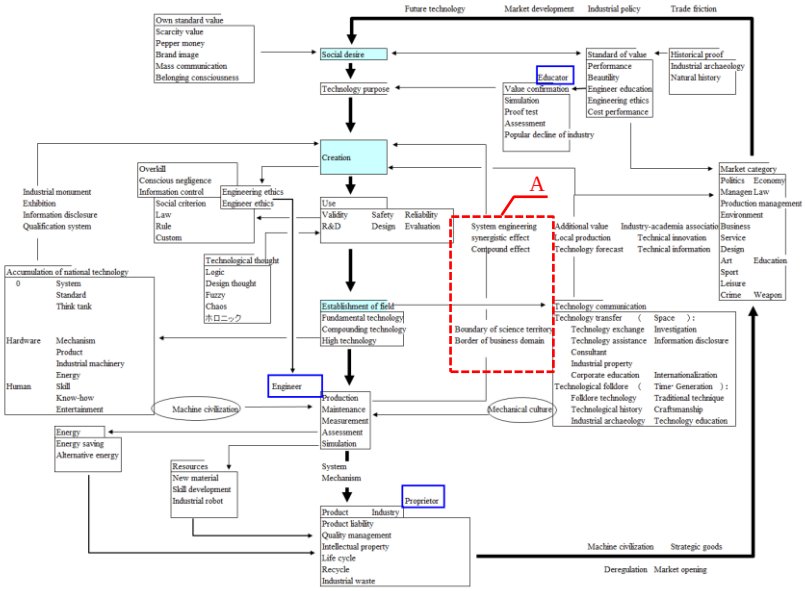
Appendix



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