The Organizational Structure that Interpenetrates Knowledge inside the Company

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Abstract—**The purpose of this paper is to reveal the organizationl structure that interpenetrates knowledge among the different businesses through process innovation. The knowledge interpenetrated inside the company enhances the product efficiency of the business unit which plans to promote process innovation with previous equipment used in different businesses. To reveal the organizational structure, this paper used a case study of process innovation that observed the production process of the Temperature Compensated Crystal Oscillator (TCXO) within Kyocera. To interpenetrate knowledge as a whole company, an interface organization is needed. This interface organization accumulates and diffuses this knowledge to the company during the period of process innovation. However, interface organization is not a business unit that produces key components. This suggests that the interfacing organization which accumulates knowledge related with businesses and functions do not necessarily have the possibility to accumulate knowledge that is related with key component.**

Index Term — **Interfacing organization, interpenetration process, organizationl structure, process innovation.**

I. Introduction

It has been argued that the production process equipment for specific product is hard to apply to the other product's process innovation. This is because, during the utilization, the equipment within the special context is adjusted to fit that situation for efficient movement. In addition to that, during the business unit's experience with the special context with that equipment, that unit accumulated a special routine, and knowledge about the usage of the equipment (all- inclusive term is knowledge). The knowledge related with product process equipment accelerates, producing the same product on one hand, while its limited points of views accumulated within the special context make it hard to apply to the other product ([1]-[4], [8]-[10]).

However, the argument of previous research is limited because the research only focused on specific knowledge and equipment. Indeed, technology and equipment are rapidly changing and the pressure of the cost cutting is imposed on the company to combine special knowledge and equipment with general knowledge and equipment as they confront a process innovation. Therefore, up to date research should include both special and general knowledge and equipment as considering process innovation involving the diverse use of knowledge and equipment.

Experiencing the special context and general context, the company can understand and absorb several versatile theories (i.e., that is obtained from laboratory experiment) and know-how (which is the knowledge accumulated by experience with the trial and error experience at the factory) that are related with product process operation. This suggests that using this versatile theory and know-how the organization can apply previous product process equipment to the other product's process innovation.

For the *interpenetration* of both specific and general knowledge (both of them including versatile and ingenuity), that related with previous equipment, first, the organization has to accumulate interface knowledge that bridges these two kinds of knowledge. Then the company applies this knowledge that was utilized in the product process to the other product's process [5]-[7].

However, there are few arguments about the organizational structure to accumulate interface knowledge to interpenetrate the special knowledge and general knowledge to promote process innovation. There needs to be one place for the company to combine the knowledge that is absorbed through experiencing two different contexts and putting that knowledge to practical use. Therefore, this paper sheds light on the organization structure and the characteristic that brings out the knowledge interpenetrated that is needed to promote process innovation efficiently.

II. Previous Research

The process innovation needs the knowledge that is not just from the inside of the organization but also from the outside. About this perspective of absorbing knowledge, reference [12] argued that the process innovation needs four kinds of capacities to analyze and get external resources from the outside to the inside organization. One is the excessive capacity. This is defined as the ability to collect, sort, and analyze knowledge from both internal and external resources.

Three of the others are the adaptive, integrative, and innovative management capacity. Adaptive capacity is the ability to ensure that new pieces of equipment are suitable for the organization's own purpose even though they may have been originally developed for other uses. Furthermore, integrative capacity is the ability to make it possible for a new or modified piece of knowledge to be fitted into an existing production process with a minimum cost and adjustment elsewhere in the process.

Finally, innovative management capacity is the ability to control and coordinate all the capacity through process innovation.

Like this perspective, for mutual exploitation of resources and application of some product process equipment to the other products, a company needs to organize the structure to accumulate several capabilities and share the special knowledge and general knowledge that are related with other parallel businesses [11]. In addition to that it is important to manage the structure that informs the problems and know-how between each function's parts or businesses.

Although these researches perceive the demand of the

Manuscript received May 16, 2012; revised June 20, 2012.
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capacities and organizational structure to interpenetrate knowledge inside the organization to promote process innovation, there are few arguments about the characteristics of the businesses and the organizational structure as a whole. With analysis of the case study of the product process innovation with Temperature Compensated Crystal Oscillator (henceforth, TCXO) in Kyocera corporation (henceforth, Kyocera)[1], this paper reveals the organizational structure and characteristics that make the interpenetrative knowledge[2].

III. Data[3]

A. The Attribution of TCXO

TCXO is a component that is used in cell phones for keeping the frequency oscillation even under the temperature fluctuation. The cell phone makes the telephone call and data communication with TCXO[4] under the several temperature environments. TCXO is composed by a crystal oscillator that is composed by a crystal unit and three integrated circuit chips– amplification, oscillation, and temperature compensation. The crystal unit is composed by a crystal blank cutting from the synthetic quartz and an electric pole. TCXO is evaluated by a standing frequency oscillation[5].

This comes from the crystal blank’s characteristics and the originated cutting an angular degree from the synthetic quartz. Hence, each blank’s cutting an angular degree is important and it is adjusted to make standing frequency oscillation with the standing electronic voltage. Furthermore, the adjustment with the temperature compensated circuit chip affects the stability of frequency oscillation.

The standardization of each crystal blank’s subtle angular degree and its stable frequency is evaluated in the industry. Thus, it is important to understand each crystal blank’s characteristic and the way to adjust for the standing frequency oscillation to get a competitive advantage in the worldwide market.

B. The Product process Innovation with TCXO in Kyocera

TCXO has shrunk in size during the last 20 years as the cell phone has miniaturized in size but grown in functions despite limited space. In 1998, the smallest TCXO was 5mm(wide)×3.2mm(long) compared with 1.6mm×1.2mm in 2011 in Kyocera. As the demand for shrinking the size of the TCXO increased, several suppliers, including Kyocera, decided to switch the production process equipment from the mechanical equipment to semiconductor equipment. In contrast to the former, called AT[6] system, a metal edged technology[7] was utilized to produce the crystal blanks, while the latter semiconductor equipment utilized the photolithographic system’s laser beam, producing the crystal blank[8]. The movement to photolithographic TCXO originated from the TCXO shrinkage. It is hard to line up the shrunken crystal blank in a tray and while attaching the integrated circuit with mechanical equipment. As a result of the change from 1.0mm×1.2mm size TCXO, Kyocera decided to produce crystal blanks with semiconductor equipment in 2012.

Though, using the semiconductor equipment with photolithographic system’s laser beam is new for the crystal business unit in Kyocera, it has already been utilized in other businesses. For example, a tuning fork quartz crystal business has produced a quartz crystal blank for watches. The context in which both companies are utilizing the crystal blank from the crystal wafer with photolithographic system’s laser beam is the same.

However, the characteristics of frequency oscillation of the crystal blank are different between the tuning fork quartz crystal and TCXO (AT TCXO and photolithography TCXO). In addition to that, the way to cut the crystal blank used for AT TCXO and for the photolithographic TCXO is different. For producing the crystal blank for AT TCXO, a mechanical equipment cuts off the lumbered crystal. Hence, for producing photolithographic TCXO, semiconductor equipment shapes the crystal wafer with a laser beam and snaps off the crystal blank from it. Kyocera implemented product process innovation with two stages for producing photolithographic TCXO with semiconductor equipment.

C. The Organization Structure that Interpenetrates Knowledge

1) First Stage: Communication Structure among Three Businesses

First, Kyocera constructed communications structure among three different business units’ engineers who have produced AT TCXO, the tuning fork quartz crystal, and work for producing photolithographic TCXO. Each of them works for different business units, though they work for the same function that is production, especially for producing the crystal blank and crystal unit. Through the communication among the three business units, engineers have known each other’s position and the responsibility for specific process and the necessary information they can get from the other business units. These communications among colleagues are extremely important for the successful interpenetration of knowledge inside the company. For producing the photolithographic TCXO, first, engineers of the AT TCXO who work in production function, especially, crystal blank and crystal unit of AT TCXO (TABLE1 (1)), need to inform and communicate with the photolithographic

[1] Although Kyocera Crystal Device Corporation is the subsidiary company of the Kyocera Corporation who produces the crystal unit for photolithographic TCXO, this paper calls the Kyocera Crystal Device Corporation as Kyocera. This is because Kyocera Corporation developed new equipment for photolithographic TCXO used in Kyocera Crystal Device Corporation. Without Kyocera corporation’s help, the Kyocera Crystal Device Corporation could not plan to make photolithographic TCXO.

[2] In terms of revealing the organizational structure that interpenetrates the knowledge, this paper conducted three interviews with Kyocera, the leading organization of the TCXO industry.

[3] The data is from interviews with Kyocera from Mar.2011 to Jun. 2012.

[4] The frequency used for cell phone has a margin of error of ±2ppm~5ppm. For example, if the 10MHz (10,000,000Hz) are required, 10,000,020Hz~10,000,050Hz error can be avoidable. But if the frequency is over this range, the cell phone would not make a phone call.

[5] This is from the interviews with Kyocera.

[6] The crystal blank for AT TCXO cut from crystal synthetic quartz with the angular degree of 35°15´ called AT cutting.

[7] Because of this, the TCXO produced by AT system is called AT TCXO; henceforth, AT TCXO is used.

[8] The TCXO produced by photolithographic system is henceforth called photolithographic TCXO.

TCXO unit (TABLE1 (3)). This is because the characteristics of the AT TCXO are the same as the photolithographic TCXO (only the producing equipment is different). Then, the fork quartz crystal unit's engineers (TABLE1 (2)) have to communicate with photolithographic TCXO engineers because the basic principle to move photolithographic equipment for producing the tuning fork quartz crystal and photolithographic TCXO is the same.

Additionally, for enhancing the efficiency between this corporation and the other functions as a whole, the development headquarters of the AT TCXO business at Komae city in Tokyo (they have information about the customer needs) moved the manager to Hachiouji city (henceforth, Hachiouji) in Tokyo, which is producing the tuning fork quartz crystal blank and crystal unit, and plans to produce the crystal blank and crystal unit for the photolithographic TCXO. This is to inform the company of the customer needs and producing the photolithographic TCXO with semiconductor equipment while keeping the stable frequency oscillation.

Through that process, engineers from the development function and crystal blank and crystal unit of AT TCXO (in production function), photolithographic TCXO, and the tuning fork quartz crystal blank gathered at Hachiouji and discussed the analysis and adjustment of the prototype of the photolithographic TCXO. After this first stage, Kyocera went ahead for a second stage for setting up a new unit in the previous equipment that is used for AT TCXO and the tuning fork quartz crystal production.

The process of producing the photolithographic TCXO is separated into three steps: 1) producing synthetic quartz and crystal wafer (produced at Yamagata prefecture) is used commonly for the AT TCXO, photolithographic TCXO, and the tuning fork quartz crystal, 2) producing crystal blank and crystal unit that is composed of crystal blank and attaching integrated chips (at Hachiouji city in Tokyo and Yamagata prefecture), and 3) assembling the crystal unit into the package and sealing it in the metal case (Shiga and Yamagata prefecture) (TABLE I).

The crystal blank's cutting an angular degree and the quality of the synthesized quartz affects the crystal blank's characteristics and the stable frequency oscillation. Yamagata is the factory that produces the core component.

TABLE I: THE PRODUCTION STEPS AND THE PLACE EACH STEPS OF PRODUCT PROCESS HUB ARE PLACED[9]

	AT TCXO	Tuning fork quartz crystal	Photolitho-graphic TCXO
Synthetic quartz &Crystal Wafer	Y	Y	Y
Crystal blank &Crystal unit	S&Y(1)	H&Y(2)	H&Y(3)
Assembling &Packaging	S&Y	S	S&Y

Yamagata Prefecture = Y
Shiga Prefecture =S
Hachiouji city in Tokyo = H
The first places within the boxes are the main factory

[9] Though the Kyocera plant produced a prototype of the photolithographic TCXO in 2012, the date for mass production is not clear. This research refers to the previous process of the mass production.

2) *Second Stage: Communication Structure among Three Steps within the Production Function*

For producing photolithographic TCXO by utilizing the photolithographic system's laser beam, Kyocera tries to apply previous knowledge that was accumulated through the producing process of the AT TCXO (including the knowledge of the characteristic of the TCXO and ingenuity to produce AT TCXO). However, the versatile theory and ingenuity to operate equipment is different between mechanical equipment and semiconductor equipment. Kyocera has to construct an additional organizational structure including the (1), (2), (3) step in TABLE1 for making a photolithographic TCXO.

For producing the photolithographic TCXO, each step under the production function must combine the second (crystal blank and unit) and third steps' (assembling and packaging) knowledge with the first stage that is related to AT TCXO, tuning fork quartz crystal, and photolithographic TCXO (TABLE II).

TABLE II: THE WAY TO KNOWLEDGE INTERPENETRATION

	AT TCXO	Tuning fork quartz crystal	Photolitho-graphic TCXO
Synthetic quartz &Crystal wafer	Y	Y	Y
Crystal blank &Crystal unit	S&Y(1)	H&Y(2)	H&Y(3)
Assembling & Packaging	S&Y(4)	S (6)	(5)S&Y(7)

The communication arrows already explained are shown by the perforated line

The engineers who work for assembling and packaging of AT TCXO at Shiga prefecture have communicated with the crystal blank and unit's engineers of AT TCXO (TABLE II (1), (4)). This experience is important for the assembling and packaging in AT TCXO at Shiga prefecture.

Communication is important because the experience of the engineers who work for assembling and packaging of AT TCXO have the information related with the crystal blank and crystal unit of AT TCXO that the characteristics are the same as photolithographic TCXO. Therefore, the same knowledge is accumulated in both of the business units and it becomes the foundation of the communication (TABLE II (4), (5)).

In addition to this, since Shiga Prefecture already has experienced assembling and packaging in the process of producing the tuning fork quartz crystal, engineers who work for assembling and packaging have experienced communication with the crystal blank and crystal unit's engineers who work for the tuning fork quartz crystal unit.

Through this process, the engineers have information about the problems and the merits to produce with the crystal blank and crystal unit with semiconductor equipment (TABLE II (2), (6)). The knowledge about the crystal blank and crystal unit that are accumulated in the assembling and packaging step of tuning fork quartz crystal at Shiga prefecture is the basis to communicate the assembling and packaging step with the crystal blank and crystal unit for photolithographic TCXO (TABLE II (6), (7).(7) indicate the Shiga Prefecture).

For example, in producing a tuning fork quartz crystal, Kyocera uses the machine that snaps off the crystal blank from the crystal wafer and puts the crystal blank on the tray first. Then, they organize a line to clean and attach to the integrated chip (TABLE II (2), (6)). However, the way for producing the tuning fork quartz crystal takes lots of time and needs the engineers' hands to make the line and apply this way of production to photolithographic TCXO (TABLE2 (6), (7)). For improving the efficiency with the semiconductor equipment, Kyocera decided to set up a new unit which makes it possible to clean the crystal units without putting crystal units on the tray. Kyocera developed a new unit that vacuums the crystal blank into a chamber for efficient cleaning before producing the final product. This way used for assembling and attaching the photolithographic TCXO (TABLE II (3), (7)).

Setting up a new unit in the previous equipment and enhancing the production efficiency is important for the production at Hachiouji and Shiga prefecture. This is because every step has to make the profit by itself in Kyocera (called Ameba business). Kyocera has to think about the way to cut the price without reducing the production numbers. For increasing the number of the photolithographic TCXO while also lowering the price, Hachiouji and Shiga prefecture must discuss first. Then, Shiga prefecture must support Hachiouji's new volume of production with a new unit that was set up in the previous equipment. This new unit is made by a mechanical business unit at Shiga prefecture which develops almost all the machines that are used in the Kyocera group.

This development suggests that the mechanical business unit at Shiga prefecture accumulated important information related to the equipment and combines the knowledge from several business units and steps.

This development is related to improving the number of Kyocera's TCXO production. Because even if the Hachiouji produce the number decided through the discussion with Shiga prefecture, assembling and packaging step (Shiga prefecture) could not produce the number, both of steps could not make the profit from increasing the number of productions. For keeping up the profit with the production numbers, Shiga prefecture has to have the capability to correspond with the required production process while first accumulating special and general knowledge and cooperate with Hachiouji.

IV. Conclusion and Discussion

The purpose of this paper is to bring out the organizational structure that interpenetrates the knowledge through the production process during the process innovation.

With the case of the process innovation that observed the production process of TCXO in Kyocera, this paper reveals the organizational structure that communicates among the business units and the three steps within production function. Moreover, this case shows the information flows not just from the first step to last step (top down), but also from the last step to first step (bottom up) in production. Without the information from the last step about the product's capacity and possibility of affordable change, the utilization of the previous equipment and process innovation would not be a success.

However, the knowledge would not be interpenetrated among the business units or the steps within the function without a structure that interfaces with the knowledge ([6]-[7]). In Kyocera's case, this paper presumes that Shiga prefecture is the center of knowledge accumulation and plays an important role as the interfacing organization. This presumption is based on Shiga prefecture's role in producing the crystal blank and crystal unit, assembling and packaging for AT TCXO. The function and the characteristic is the same as AT TCXO and photolithographic TCXO. The difference is only the equipment.

Therefore, Shiga prefecture can transfer their knowledge related to AT TCXO to photolithographic TCXO. In addition to that, as Shiga prefecture is assembling and packaging the tuning fork quartz crystal, they have accumulated the knowledge about how to treat the crystal blank and crystal unit that is produced with semiconductor equipment. This suggests that the organizational structure needs the interface organization that is related to both of the businesses which utilizes equipment before and after process innovation to interpenetrate the knowledge inside the company. In addition to that, it is not mandatory that the interfacing organization be the organization that produces the key factor. In the case of Kyocera, the interface organization (at Shiga prefecture) and the key component producing unit (at Yamagata prefecture) are different.

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