The Introduction of Technological Innovation and Skills in Chinese Mold Manufacturing

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【Abstract】This paper analyzes the factors of rapid quality improvement in the Chinese mold industry.

After 2000, the introduction of technological innovations and the employment of Japanese technical experts enabled Chinese manufacturers to produce high-quality molds.

The author conducted field research on twenty Chinese mold manufacturers. Based on this field research and an analytical framework of "number of skill categories" and "an introduction to the standards of technological innovation," to conclude that two factors of rapid quality improvement, the introduction of technological innovation and Japanese experts' skills, can be adopted as an effective method of quality improvement in the Chinese mold industry.

1. Introduction

Molds(1) determine the quality of mass-produced product parts such as automotive and electrical goods and require sophisticated production skills. The Japanese mold industry, which excelled at such skills, had dominated the global market since the 1980s. It was also difficult to transfer mold production technology overseas (Asai, 1998).

Improved mold production technologies among Asian countries and the hollowing-out of the Japanese mold industry have become issues in the past several years. China, previously only assembled parts, but now is becoming capable of partially procuring molds locally, albeit not all types. According to the World Trade Atlas, the value of China's molds exported to Japan has increased by nine-fold between 1998 and 2005. In particular, the value of plastic molds have increased 15 times during this period(2).

Why did the quality of Chinese molds improve rapidly during such a short period? This paper intends to answer this question. The trend of mold improvement was not observed in an earlier study of ethnic Chinese companies in Taiwan and Singapore between 1995 and 2002. The majority of companies had the capitalist idea of producing molds with a level of precision that can be designed and fabricated with low skills. This allows companies to recover their investment as quickly as possible (Saito, Asai, et al., 2003).

However, several different cases were observed in a study conducted on ethnic Chinese mold manufacturers (Taiwan, Singapore, and Chinese-based) in China between 2003 and 2005. Although the number of companies studied is limited, this paper conducts a comparative analysis to further analyze the details that cannot be obtained through questionnaires. Specifically, it considers the perspectives of the level of implemented technological innovations, and the changes in skills because of this level.

This paper is organized as follows: Section 2 examines previous studies and defines "skill" and "technological innovation," which become key concepts in this paper. Section 3 analyzes the cases of leading plastic mold manufacturers, and discusses how skills in the Japanese mold industry have changed along with technological innovations. Section 4 describes the cases of ethnic Chinese plastic mold manufacturers studied in China. The study results are examined in Section 5, then a summary and discussion of remaining issues in Section 6.

2. Classification of Skill and Technological Innovation

Significant change among Chinese mold manufacturers in such a short period of time is explained by technological innovations in the mold production process(3). Specifically, skill-less manufacturing(4) is made possible by introducing state-of-the-art numerical control (NC) machine tools and software. Such tools include 3-D solid computer aided design (CAD)(5), computer aided manufacturing (CAM, which exports the NC data to the machine tool by using the CAD data), and computer aided engineering (CAE, which performs simulation).

Technological innovation for machine tools and software has advanced; however, is it possible to produce high-quality molds without skills in the mold industry, which is a skill-intensive industry? This section defines "skill" and "technological innovation" before conducting case analysis.

2-1. Skill

Based on the examination of previous studies, as well as field research conducted in 1993 on mold manufacturers in Japan and overseas, skills considered necessary in producing molds are classified under five categories including: (1) routine skill, (2) craft-type skill, (3) intellectual interference skill, (4) the skill to adapt to change, and (5) managerial integration skill. Later, these categories are used as a basis for analysis. The five skills are defined as follows:

(1) Routine skill

Nomura (1989) classified experts into two categories: routine experts and adaptive experts. He deemed that routine experts, who have mastered the patterns of typical skills, are able to demonstrate their skill only under certain area-specific conditions. The speed and precision of performing a task is mastered by repeating the same operation in a given work. Routine skill is the first skill required in general mold production.

On the other hand, adaptive experts are capable of adapting to changing conditions by using their intuition and knowledge. They also have skills to think of a new plan, and foresee the results when executed. While this adaptive skill includes another skill described later, this paper divides skills into five categories.

(2) Craft-type Skill

Koike (2001, 2004, and 2006) and Chuma (2001, 2006) discuss the craft-type skill, intellectual inference skill, and skill to adapt to change in their studies on mold production operators and machine tool operators, respectively.

The craft-type skill could be interpreted as manual techniques of skilled workers, and skills for tasks such as fabrication, achieved by pushing the limits on tools, machinery, equipment, and so on. Specifically, this refers to precise skills of achieving micron-level precision by using a machine tool that can only output a precision of 1/100 mm, or achieving micron-level precision by using a file rather than a grinding machine.

(3) Intellectual Inference Skill

Chuma (2001) defined the intellectual inference skill as a quick and accurate identification of the cause of failure in the production process. Koike (2001, 2006) lists an ability of skilled assembly and adjustment workers in the mold production process(6) as providing opinions to the concept designer to modify the mold structure from various perspectives such as ease of mold fabrication and avoidance of poor molding.

There is an additional skill involved in deducing the cause of poor quality. Sometimes, poor quality such as jagged edges can appear in the molded product once the mold is assembled and tested, even if the mold parts are within the required precision parameters during the assembly and adjustment process.

(4) The Skill to Adapt to Change

According to Koike (2005), this includes changes in the production method, production volume, product configuration, and personnel organization. Under mold production, this includes the skill to adapt to changes in mold structure, the number of guaranteed shots, or molding material, etc.

(5) Managerial Integration Skill

Hayashi (1999) defines managerial integration skill as certain contextual knowledge and experience that is not popularized or standardized. It states that members who share the contextual skill improve their ability to handle issues by cooperating and generating new wisdom, because the overlapping skills and qualifications of each employee lead to redundant structures at an organizational level. However, in the work of Hayashi (1999), this is limited to skills related to the scope of adjacent divisions.

This paper defines managerial integration skill as extensive knowledge of the mold production process and the skill to facilitate correction when there is a problem. Ultimately, it is a skill to coordinate the entire mold production process.

The ability to reach consensus, which is one of the competitive advantages of the Japanese manufacturing industry (Fujimoto, 2006) is defined as delicate mutual adjustment during parts design, cooperation between development and production, and in-depth communication in the field where the relationship between product function and parts becomes entangled. Under the categorization in this paper, the combination of intellectual inference skill and managerial integration skill would correspond to this definition.

In addition, molds that require nano-precision have been produced in recent years. Chuma (2006) notes that, unlike in the past, advanced technological innovation in digitization leads to the weakening of not only the craft-type skill of skilled workers in the field, but also intellectual inference skill and managerial integration skill(7).

2-2. Technological Innovation

Technological innovation in this paper refers to the technological advancements in machine tools and software that have had a significant impact on mold production skills. Referencing the field study conducted at the in-house mold plant of a major automobile manufacturer, literature from the Japan Society for the Promotion of Machine Industry, and the work of Baba (2005), this paper classifies technological innovations into five stages. The stages are: (1) the manual labor-oriented process, (2) introduction of the copy milling machine, (3) introduction of NC, (4) introduction of 2-D CAD and the machining center, to start data-based mold production, and (5) mold production by data-based design and direct NC molding utilizing 3-D solid CAD and ultra-high speed processing machine.

The approximate period up to the end of the 1950s, when the copy milling machine was introduced, is Stage (1). Stage (2) lasted approximately 15 years after the introduction of the copy milling machine, followed by Stage (3), from the early 1970s to the mid-1980s. The period between the mid-1980s and mid-1990s is Stage (4), and the period after Stage (4) to the present is Stage (5) [(8)].

In the case of Chinese companies discussed in this paper, they have entered the mold industry in the overlap between Stages (4) and (5).

3. Changes in Skills with Technological Innovations in the Japanese Mold Industry

This section will review previous studies, as well as case studies on mold manufacturers in Japan—an advanced country in terms of molds—and examine how the introduction of technological innovations affected mold production skills.

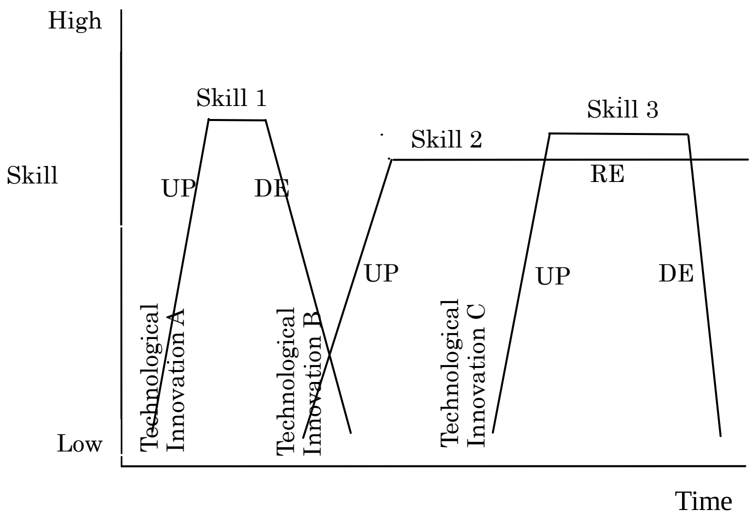
The field of labor sociology had debated from the 1980s to the early 1990s whether technological innovation would make skills unnecessary, newly necessary, or both.

Attewell (1992) states that machines' replacement of skills due to technological changes and the emergence of new skills occurs simultaneously, rather than occurring separately. In other words, old skills are replaced (de-skilling) and new skills emerge (upgrading-skill) through technological innovations. However, there are skills that survive and evolve because they cannot be replaced by machines. This seems to coincide with the re-skilling concept noted by Zuboff (1988).

While the transformation of skills in these three directions is repeated for each technological innovation, it does not necessarily follow the same path. A basic conceptual diagram of this is illustrated in Figure 1. Under Technological Innovation A in Figure 1, Skill 1 becomes necessary after innovation and maintenance, but becomes unnecessary upon Technological Innovation B. Skill 2 simultaneously becomes necessary. New Skill 3 then becomes necessary upon Technological Innovation C, but Skill 2 continues to be necessary, as it cannot be replaced by machines and software.

Table 1 summarizes the stages of technological innovation and the changes in skills based on the field studies conducted between 1993 and 2005 with 20 major mold manufacturers, including in-house manufacturers, in Japan.

Figure 1　Technological Innovation and Changes in Skill



Source: Prepared by the author.

・UP: upgrading-skill (new skill that becomes necessary)

・RE: re-skilling (skill that continues to be necessary)

・DE: de-skilling (skill that becomes unnecessary)

Table 1　Technological Innovation and Changes in Skills at Large Japanese Mold Manufacturers

Stages of Technological Innovation Implementation	(1)	(2)	(3)	(4)	(5)
Routine skill	↑	↑	→	↓	↓
Craft-type skill	↑	↑	↑	→	↓
Intellectual inference skill	―	―	↑	↑	↑
Skill to adapt to change	↑	↑	↑	↑	↑
Managerial integration skill	―	↑	↑	↑	↑

Source: Prepared by the author.

・↑: upgrading-skill (new skill that becomes necessary)

・→: re-skilling (skill that continues to be necessary)

・↓: de-skilling (skill that becomes unnecessary)

・―: Skill that does not exist

4. Study Results

Field studies were conducted using 40 mold manufacturers in China (Shanghai, Kunshan, Qingdao, and Yongkang) during the period April 2003 to May 2005. This section sets aside Japanese companies and press die manufacturers, and examines the field studies conducted with 20 plastic mold Chinese-owned manufacturing companies. Specifically to analyze (1) the quality, cost, and delivery (QCD) of the manufactured molds, (2) the awareness among business operators and managers regarding the need for skills in mold production, (3) the method of human resource development, (4) Japanese technical advisors' role, the skills they possess, and their work experience, and (5) the level of implemented technological innovations.

According to the *China Die and Mold Industry Yearbook* by the China Die & Mould Industrial Association (2005), a survey conducted at approximately the same time as the field studies notes that there are more than 20,000 die and mold manufacturers throughout China as of 2003 (p. 51). The cases reviewed in this paper, and Companies X, Y, and Z in particular, can be considered progressive cases. According to the survey, the average precision of plastic molds is 2/100 to 5/100 mm (p. 7). However, these three companies all exceed the average, and the precision of Company Y is particularly exceptional. Based on the field studies with 20 companies, more than two-thirds employed the commercially capitalist idea, as did the ethnic Chinese companies that studied before 2003 (Asai, 2002).

However, in the more recent data there were more cases of industrially capitalist companies. This paper discusses three types that were particularly characteristic among them, in addition to Company W, a traditional type of commercial capitalist, making four types of companies. As a note, the overview of those four companies is illustrated in Table 2.

Table 2 Overview of Four Companies (April 2003 to May 2005)

	Company W	Company X (Kunshan)	Company X (Shenzen)	Company Y	Company Z
Year Founded	2002	2002	1994	2001	1993
# of Employees	100	2,000	4,000	400	400
Production Capacity	20 molds per month	120 molds per month	*1	15 molds per month	100 molds per month
# of Engineers	20	100	200	6	35
Molds' Main Purpose	Consumer electronics, covers for general goods	Connector	Covers for PCs, mobile phones, gaming consoles	Gears	Washing machine tubs Internal liner of refrigerators
Number of Japanese Technicians (Years/Experience)	0	10 (including those with 40+ years' experience)		1 (30+ years)	1 (20+ years)
Number of 3-D solid CADs	20	54	132	6	Several *2
Precision	5/100 mm	1/100 mm	1/100 mm	5/1000 mm	1/100 mm
Number of Machine Tools *3	50	350	1000	60	80

Source: Prepared by the author and based on interviews.

Note: As a note, these data are all as of the field study.

*1: The number of molds was not specified due to undertaking processes, such as modeling, to increase the rate of operation.

*2: The exact number was unclear because they were in a transition period from 2-D to 3-D.

*3: The total number of NC machine tools, such as advanced machining center and electric discharge machines.

<Company W: Visited on August 26, 2004>

Skill-less manufacturing is promoted by introducing state-of-the-art machine tools and software. These companies do not internally train personnel; they produce molds at a precision that is producible within the range of training provided by the equipment manufacturers. They generate a profit and recover their investment by manufacturing molds at the minimum level of precision required to avoid molding defects. Approximately 70% of the surveyed companies were similar to Company W, and they were all Taiwan- or Singapore-based companies. However, this type of method works only under the condition that molding materials and mold structures stay within similar ranges. In fact, the structure of molds does not change often, as the molds manufactured by Company W are for water purifier covers, general goods, etc., with simple shapes and less sculptured surfaces that rarely change the model. In addition, the molding materials rarely change.

However, because the margins of the molds manufactured by these companies are low and it is not possible to turn a large profit when specializing in molds, they are often contracted to perform the molding process and, in some cases, are a part of the assembly. Additionally, this type of corporate strategy for mold manufacturers was a pattern frequently observed among Taiwanese and Singaporean companies that are capital intensive, as also noted in the overseas studies conducted since 1995. This paper refers to them as traditional ethnic Chinese companies.

<Company X: Visited on May 19, 2005>

This is a Taiwan-based mold manufacturer, and the Kunshan plant was visited. Although the Shenzhen plant was not visited, it is included in this study as data about it was gathered at the Kunshan plant (See Table 2). The Shenzhen plant has a bigger factory than the Kunshan plant, as well as an integrated factory for molding and assembly. Nakagawa (2003) states that the company is probably the largest mold manufacturer in the world in terms of the number of employees. It can be noted that there are currently about two million employees(9).

A skill-less mold design is further promoted by both plants' introducing state-of-the-art 3-D solid CAD, recruiting system engineers from CAD vendors, and customizing 3-D solid CAD software for mold design. They are additionally turning a considerable portion of the mold production process into skill-less operation by assigning specialists for design, fabrication, and database creation, and by using state-of-the-art ultra-high-speed processing machines(10).

The company also operates three mold schools in China, teaching mold design and production technology over the course of one year to those who have graduated vocational school or high school, and hiring those who pass the graduation exam. Meanwhile, they also recruited approximately ten individuals, including skilled mold technicians with over 40 years of experience who were considered top of their class in Japan. They also recruited researchers who specialize in mold machining at Japanese universities as technical advisors. These Japanese technicians bring an ability to reach a consensus with the users, demonstrating the skill to adapt to changes when the product changes, the managerial integration skill using their experience, and the intellectual inference skill when a problem arises. As described, while promoting the skill-less mold production process, the management executives at Company X are keenly aware of the importance of skilled human resources.

<Company Y: Visited on August 27, 2004>

Company Y was referred to the study by a Japanese machine tool manufacturer as a company that manufactures gear molds with the highest precision among all their Shanghai clients.

Their technical advisor has more than 30 years of experience, and used to be the manager of a small- to medium-sized mold manufacturer in Japan. The company has installed manual lathes without the NC unit based on this technician's policy, and deliberately keeps the NC machining rate for mold parts at 60–70%. This is to create a more sophisticated NC program by making the operator comprehend the feeling of cutting the steel, maintaining the shape of the blade edge, the most efficient cutter movement, and so on. The company also allows engineers to try out the processing by using a manual lathe. This type of practice can be considered Japanese-style human resource development, in terms of allowing employees to gain a wider range of experience.

Company Y, which manufactures gear molds, is also required to guarantee several times more shots (1.5 million shots) compared to that of regular molds exported to Japan (300,000 to 500,000 shots) because their main users are Western companies with a longer cycle for model change. Therefore, they have to use hard-quenched steel, which is more difficult to process. Under such conditions, they produce molds at the precision of a five-micron tolerance, the same level as Japanese mold manufacturers.

However, various processes that require sophisticated skills, such as checking the product design data provided by the user and creating a conceptual design of the mold, are handled by the Japanese technical advisor as the five-year employee retention rate is 0%. The company was forced to make manufacturing partially skill-less due to the division of labor.

<Company Z: Visited on October 13, 2003>

A subsidiary of the largest consumer electronics manufacturer in China, Company Z specializes in molds. The study was conducted at the plant that manufactures large-sized plastic molds for washing machine tubs and refrigerators' internal liners.

The company's mold production method is based on a single-skilled worker system, and no job rotation occurs. The company stated that the operator of a given process has no knowledge about what occurs before and after their process.

They listed three steps, including conceptual design, CAM data preparation, and assembly and adjustment as processes that especially require skilled workers. The final assembly and adjustment step has approximately 100 workers, which is one-fourth of all employees. The Chinese administrator said this high proportion of workers was to correct the prior step.

Molds cannot really be produced without skills, as observed from these realities. Ten skilled Chinese workers, who oversee all employees assigned to assembly and adjustment, are referred to as "engineers" and are paid nearly ten times the salary that regular workers receive. However, "engineers" are not trained internally; those who gained work experience in Japanese companies in South China were recruited.

Additionally, Japanese engineers with more than 20 years of experience are hired to direct the overall mold production. However, it is difficult for them to use the managerial integration skill, as there is no communication between processes. The intellectual inference skill cannot be used either, as the company has a system that fines the individual who causes a problem. Furthermore, because the cycle for model change is long and the shape does not change often, workers were not able to demonstrate the skill to adapt to change(11).

5. Discussion

Table 3 lists Companies W, X, Y, and Z, the small Chinese mold manufacturer examined in the previous section, and Japanese mold manufacturers (large companies and small and medium-sized companies) that were interviewed separately, and summarizes the viewpoints of their stages of implemented technological innovations, and how many categories of skill they currently possess.

Table 3 The Stage of Implemented Technological Innovations and Organizational Skills

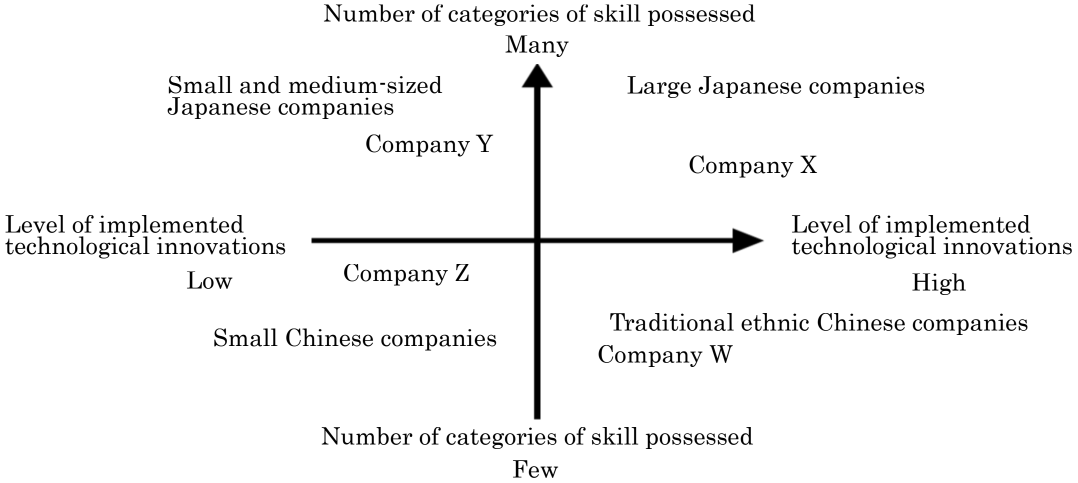
By Company and Skill Types	Large Japanese Company	Small-and Medium-Sized Japanese Company	Company W	Company X	Company Y	Company Z	Small Chinese Company
Stage of Technology Innovation Implementation	(5)	(4), (5)	(5)	(5)	(4), (5)	(4), (5)	(4), (5)
Routine skill	○	○	○	○	○	○	○
Craft-type Skill	○	○	×	×	○	○	×
Intellectual Inference Skill	○	○	×	○J	○J	×	×
Skill to Adapt to Change	○	○	×	○J	○J	×	×
Managerial Integration Skill	○	○	×	○J	○J	×	×

Source: Prepared by the author and based on interviews.

Note: ○J denotes skills possessed only by Japanese individuals.

Figure 2 categorizes the companies mentioned in the previous section by two axes, namely, the number of skill categories that the organization has on the vertical axis, and the level of implemented technological innovations on the horizontal axis, based on Table 3. The vertical axis illustrates how many skills out of the five categories they possess, while the horizontal axis illustrates the relative comparison of technological innovation at the mixed Stages (4) and (5), as described in 2-2. The following section analyzes four categories of companies.

Figure 2 Classification by Number of Skill Categories and Level of Implemented Technological Innovations



Source: Prepared by the author and based on field studies.

First, under the category of traditional ethnic Chinese companies represented by Company W, the number of categories of skills the organizations have is limited to one (routine skill) although the level of implemented technological innovation is high because they neither train personnel nor hire skilled individuals. Therefore, these companies tend to recover their investments and turn a profit by making molds that are producible within this scope.

Next, Company X promotes skill-less manufacturing through the division of labor and database, in addition to the introduction of state-of-the-art technological innovations through large-scale capital investments. Their mold production is data-driven, made possible by elaborating upon the data in the previous process. The parts that cannot be created without skills are supplemented by the skills of Japanese technicians. It is difficult in actuality to produce micron-level molds at their level, and the individual skill levels are far from that of major Japanese companies; however, the number of skill categories the organizations possess is one category short compared to large Japanese companies because the latter have Japanese technical advisors.

On the other hand, large Japanese companies have a high level of implemented technological innovation, as well as skills within the organizations. Furthermore, with their extensive past experience in producing various molds, they have a high level of skill to adapt to change and to produce molds with high precision. However, at the major assembly company A, the in-house mold manufacturing division had become an issue. The management could not overlook the entire mold production process, and loss of the managerial integration skill, because the processes had already been highly developed with the advancement of the labor division by the time the managers were hired at the company. It is possible that Company X will face issues related to the managerial integration skill due to the advancement of the labor division as well as equipment, as they produce molds that are more sophisticated in the future. It may be necessary going forward to continue observation of this point.

The third type is Company Y, which has many similarities with small- and medium-sized Japanese companies. These similarities include choosing a focus, given investment funds and the implementation of technological innovations. In addition, having craft-type skill, created by installing manual machines allows employees to gain a wide range of experience to increase the division of labor. Having a sophisticated managerial integration skill, including the ability to conduct design reviews with the user is another similarity, although Company Y depends on one Japanese technician to do so.

Lastly, the small Chinese mold manufacturer and Company Z are classified as companies having a low level of technological innovation implementation and possessing only routine skills. While Company Z is a mold specialist subsidiary of a leading consumer electronics manufacturer in China, its current level of implemented technological innovations is low as they make molds for highly competitive products with low profit margins(12). Moreover, even if the Japanese technician had the managerial integration skill, he cannot use it in an environment where there is no communication between processes. These companies also do not have many opportunities to demonstrate the skill to adapt to change because Company Z's parent company owns several mold specialist subsidiaries to handle each product. With a small number of skill categories, they take an approach to mold production by focusing on routine skill as well as craft-type skill during the final assembly and adjustment step. Based on these results, Company Z is classified in the same category as the small Chinese company.

6. Summary

The examination of the field study results clarified the following in terms of this paper's question, "Why has the quality of Chinese molds improved in a short period of time in the past several years?"

First, Company X has highly advanced equipment and promotes skill-less manufacturing. They simultaneously have skills in many categories, and have similar tendencies as large Japanese companies at the organizational level, as demonstrated by the Japanese technical advisor they hired.

There are also companies similar to Company Y, which have many skill categories at the organizational level, and produce high-quality molds by hiring Japanese mold technicians with sophisticated mold production skills, even though their level of equipment is relatively lower compared to Company X. This is similar to the tendencies of small- and medium-sized mold manufacturers in Japan.

The results of the analysis, focusing on the number of skill categories and the level of implemented technological innovations, revealed that while there are many traditional ethnic Chinese companies similar to Company W, a new type of ethnic Chinese mold manufacturer exists. This type produces high-quality molds not only through implementing technological innovations, but also by hiring experienced Japanese mold technicians and utilizing their sophisticated mold production skill.

These companies, based on the level of implemented technological innovations, have entered the industry at the most advanced Stage (5), or the overlap between Stages (4) and (5). They successfully produce molds by having the same facilities as Japanese companies and several technicians or, in some cases, one technician with skills in multiple categories. Implementing such approaches seems to be one of the factors contributing to the improved quality of molds made in China.

The traditional Japanese mold industry has maintained its global competitive edge through the means of building skills among many employees, and adapting to technological innovations. However, Chinese companies have improved molds' quality by implementing technological innovations and having Japanese technicians with multiple skill categories handle work. Could such a trend be a threat to the Japanese mold industry? Is it applicable for another country? These are questions for future studies.

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(1) Molds are used when mass-producing parts of the same shape from raw materials, such as metal, plastic, glass, and rubber. There is a wide range of parts that are produced using molds, from automobiles, home electronics, various machineries, glass products, building materials, toys, and general goods. It is not an exaggeration to assert that the quality of the mold determines the quality, precision, and cost of the product.

(2) Created by Global Trade Information Services, Inc., an American company, World Trade Atlas is a database of trade statistics covering 53 countries and regions around the world. Their data is sourced from each country's agency responsible for preparing statistics, and is based on the Harmonized Commodity Description and Coding System (HS), the product categorization system for trade statistics in the United States. Exported molds include those used for general goods, and "dress-up" parts sold at automobile parts stores, e.g., bumpers. Manufacturers are also emerging that specialize in molds exported to Japan. However, statistics as well as the interviews conducted with the Ministry of Economy, Trade, and Industry and industry associations did not clarify as to which molds, for what industries and usage, and what level of precision and quality of molds are increasing out of all molds exported to Japan from China. Additionally, while the value of molds exported from China to Hong Kong has increased the most, the majority are mostly exported to other countries via Hong Kong, and it is impossible to track which countries and regions import these molds.

Value of Exported Chinese Molds (All types, unit: $ million)

	1998	1999	2000	2001	2002	2003	2004	2005
All countries	96	134	174	190	252	337	494	741
Japan	9	9	15	21	32	42	60	81
Hong Kong	45	69	73	85	101	120	163	221
United States	5	6	12	13	15	27	35	70
Taiwan	14	20	26	9	13	13	27	45

Value of Exported Chinese Plastic Molds (unit: $ million)

	1998	1999	2000	2001	2002	2003	2004	2005
All countries	48	72	88	119	172	226	340	535
Japan	3	4	7	11	17	23	31	47
Hong Kong	29	47	51	58	78	97	137	193
United States	3	2	4	6	9	14	21	43
Taiwan	2	2	3	5	9	8	18	25

(3) As highlighted by the Japan Die & Mold Industry Association (2002), there is a view that mold manufacturing rapidly grew overseas, especially in China, because users had a Japanese mold manufacturer make the first mold and submit the mold design/fabrication data, then had an overseas company produce the mold using that data.

(4) Skill-less manufacturing means that the skills that used to be necessary have become unnecessary, or more people have become capable of easily achieving the target with a lower skill level through the introduction of engineering technology.

(5) "State-of-the-art NC machine tool" refers to numerical control machine tools with the revolution of the main spindle exceeding 30,000, with a micron-level machining precision, or with functions such as five-axis control processing, for example, capable of processing from two diagonal directions in addition to three straight X, Y, and Z directions.

"3-D solid CAD" is software that enables various design information to be digitalized, including internal structure in addition to the product's surface. Among high-end 3-D solid CADs, CATIA and Unigraphics each have a high market share. The former was developed by Dassault Systèmes in France and the latter by McDonnell Douglas in the United States. Both CADs were developed for designing aircraft rather than molds.

(6) The mold production process is as follows: first, the user provides the product design data to the mold manufacturer who, in turn, undertakes concept design based on the design data to determine the structure of the mold, the method of division, etc. After the concept design, a detailed design of the mold's parts occurs, followed by the CAM data preparation, machining, grinding, assembly and adjustment, testing, and fixing, to produce the mold.

(7) This phenomenon is also observed in the production of molds, such as non-spherical lenses, that require nano-precision. While the precision in plastic molds, up to about 5/100 mm, can be handled by machinery and programming, skills become essential over 5/100 mm, and up to 5/10,000 mm. Further, at the nano-level, the mold's precision is achieved by setting up a machine tool in a room with a seismic isolator and constant temperature, and using software.

(8) Baba (2005) uses five categories, based on an indicator called "automation rate of fabrication time" per literature by the Japan Small and Medium Enterprise Corporation.

(9) For additional information on this corporate group, please refer to "Hon Hai wa Teki ka Mikata ka (Is Hon Hai an Ally or Enemy?)" in *Nikkei Electronics'* July 31, 2006 issue, pages 87 to 116.

(10) This database becomes useful because the difference in shape of the molds that the company manufactures for connectors, mobile phones, and PC covers are relatively small; they only need to make slight changes to the

mold design data. However, producing mobile phone covers for the Japanese market is difficult because they require a three-micron precision.

(11) For more details, please refer to the work of Asai (2005).

(12) According to pages 144 to 145 in the November 2002 issue of *Nikkei Venture*, Iue, then president of SANYO Electric, recalls that Company Y in 2000 had an advanced mold plant even in comparison to those in Japan.

[References]

Asai, Keiichiro. (1998). Technological Transfer in Skill Intensive Industry: Establishment of Skill Succession Method for Overseas Production Bases [in Japanese]. *The Economic Science*, 45 (4), 41-58.

——— (2002). Taiwan Purasuchikku Mēkā no Kankyō Henka e no Taiō (The Way Plastic Manufacturers in Taiwan Respond to Environmental Changes). *Business Economy*, 38, 25-41.

——— (2005). Kōgaku Gijutsu no Shinten to Sukiru Manejimento: Qingdao Haier Mould Co., Ltd. no Kēsu o Chūshin ni (Engineering Technology Advancement and Skill Management: Based Mainly on the Case of Qingdao Haier Mould Co., Ltd. *Bulletin of Aichi Shukutoku University Faculty of Business*, 1, 1-13.

Attewell, P. (1992). Skill and Occupational Changes in US Manufacturing. *Technology and the Future of Work*, Oxford University Press, 46-88.

Baba, Toshiyuki. (2005). *Ajia no Susono Sangyō (Asia's Supporting Industries)*. Hakuto-Shobo Publishing Company.

China Die & Mould Industrial Association, ed. (2005). *China Die and Mold Industry Yearbook 2004*, China Machine Press.

Zhang Wei Xuan, et al. (2005). Terry Gou's Hon Hai emperor country. World magazine.

Chuma, Hiroyuki. (2001). Chapter 9 Inobēshon to Jukuren (Innovation and Skill). In *Inobēshon Manejimento Nyūmon (Introduction to Innovation Management)*. (pp.245-283). Nikkei, Inc.

——— (2006). Inobēshon to Jukuren (Innovation and Skill). *Nihon no Kigyō Shisutemu (Japan's Corporate System)*. Vol. 4 (pp.133-158). Yuhikaku Publishing.

Fujimoto, Takahiro. (2006). Soshiki Nōryoku to Seihin Ākitekucha (Organizational Capabilities and Product Architecture). *Nihon no Kigyō Shisutemu (Japan's Corporate System)*. Vol. 3 (pp.303-331). Yuhikaku Publishing.

——— & Shintaku, Junjiro. (2005). Architecture-based Analysis of Chinese Manufacturing industries [in Japanese]. Toyo Keizai, Inc.

Hayashi, Takashi. (1999). Nihon-gata Jinzai Ikusei Shisutemu no Yūkōsei to Kadai (The Effectiveness and Issues with the Japanese-style Human Resource Development System). *The Nanzan Journal of Economic Studies.* 14 (1 & 2), 345-375.

Japan Die & Mold Industry Association. (2002). *Sōgō Kaihatsu Keikaku Chōsa Jigyō: Chūgoku Kanagata Sangyō no Jittai Chōsa (Comprehensive Development Plan Investigation Study Project (Survey on the Chinese Mold Industry).*

Japan Society for the Promotion of Machine Industry, ed. (1983). *Engineering Industries of Japan.* Japan Society for the Promotion of Machine Industry.

Kishimoto, Yoshio. (2002). Zoku Chūgoku purasuchikku kanagata jijō (Cont'd. The Situation with the Plastic Molds in China). *Kikai to Kōgu (Machinery and Tools).* Supplementary April Issue, pp.20-25, Kogyo Chosakai Publishing.

Koike, Kazuo. (2001). Workers' Skills and Competitiveness in Manufacturing Industry [in Japanese]. *Hitotsubashi Business Review,* 49 (1), 16-27. Toyo Keizai, Inc.

——— (2004). Workers Skills to Contribute Competitive Advantage: Die-Making Workshop [in Japanese]. *The Hosei Journal of Business,* 40 (4), 31-42.

——— (2005). *Shigoto no Keizai-gaku: Dai 3-han (The Economics of Work: Third Edition).* Toyo Keizai, Inc.

——— (2006). Mono-dzukuri no Ginō (Skills for Creating Products). *Nihon no Kigyō Shisutemu (Japan's Corporate System)*. Vol. 4 (pp.110-132). Yuhikaku Publishing.

Nomura, Yukimasa. (1989). *Chi no Taitoku (Mastery of Knowledge).* Fukumura Suppan, Inc.

Nakagawa, Takeo. (2003). Chūgoku Seizō-gyō no Kyōi to Kyōi (Wonders and Threats of the Chinese Manufacturing Industry). *Gijutsu to Keizai (Technology and Economy).* August 2003, pp.26-43.

Kōkai wa Teki ka Mikata ka (Is Hon Hai an Ally or Enemy?). *Nikkei Electronics,* July 31, 2006 Issue. pp.87-116.

Saito, Eiji & Asai, Keiichiro, et al. (2003). *Ajia ni okeru Purasuchikku Kanagata Sangyō no Kokusai Hikaku Kenkyū: Nihon, Kankoku, Taiwan ni okeru Ankēto Chōsa to Sono Bunseki (International Comparative Study*

on the Plastic Mold Industry in Asia: Survey and Analysis of Japan, South Korea, and Taiwan). The Die and Mould Technology Promotion Foundation.
Zuboff, Shoshana. (1988). *In the Age of the Smart Machine: The Future of Work and Power.* Basic Books.