The Journal of Gifu Keizai University, Vol. 31, No. 2/3 (1997)

Changing Strategy and Process *in* Product Development of Japanese Machine Tool Builders[1]

by

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1. INTRODUCTION

The Japanese machine tool industry has been the largest supplier of metal-cutting machine tools since 1982. It accounted for 27% of the world production of machine tools in 1994, making it the largest exporter of machine tools for that year.

Numerically controlled (hereafter NC) lathes accounted for about 25% of the total value of Japanese machine tool production in 1995, and machining centers (hereafter MCs) accounted for about 26%, together comprising more than half of total production. NC lathes and MCs are the two major products of Japanese machine tool industry.

The industry exported 68% of its production value in 1995. The export grew by 45% in 1995 as compared to the previous year. The

major export destinations for 1995 were the United States (32%), Korea (13%), and China (6%). EC countries accounted for 18% of the total export. Especially the exports to Germany, Belgium and the UK all grew from between 200% to 300% in 1995. The category of NC machine tools accounted for 78% of the total export in 1995.[2]

Based on the figures above, it can be said that NC machine tools are the major exports of Japanese machine tool industry. But the production value dropped continuously from 1992 to 1994. Over 1994 it dropped by more than 50% compared with the previous peak value in 1991, a point when the Japanese economy was in the last phase of its so-called "bubble economy." It increased in 1995, but to only 54% of the 1991 peak.[3] The combined ordinary profit of the eight major machine tool companies have been negative for three years running since 1992, although that trend is expected to reverse for 1996.[4]

Confronted with these hard circumstances, Japanese machine tool builders rearranged their managerial strategy, especially their product development strategy. They tried to develop faster and cheaper machines because their customers, especially small firms, had been forced to reduce the cost of their products such as auto parts, dies, and molds, and shorten the delivery time.

From 1994 to 1996 the orders for machine tools had continuously increased. But the projected profit for 1996 was less than half of the 1991 peak level.[5] This was the result of fierce price-cutting competition during the recent recession. Some of the major companies remained to be in the red for a while. Many of them were engaged in the business of making special-purpose machine tools. The companies with positive profit were those that were making general purpose machines (such as MCs and NC lathes), or exporting at a high rate.[6]

In a cooperative project, Japanese and German researchers surveyed the product development strategies of machine tool builders in Japan and compared them with other countries' builders. We selected two companies. One of them, code-named "Jama," used to specialize as a lathe manufacturer and now is one of the major manufacturers of NC lathes and MCs. While most Japanese builders purchase numerical controls (NCs) from outside companies, Jama is unique in that it has

developed its NCs in-house since 1963. Another company we selected, whose code-name is "Nima," used to be a milling machine manufacturer and now is one of the major manufacturers of MCs and NC milling machines. It was one of the two companies that developed MCs earliest in Japan in 1966, eight years after the first MC in the world was introduced in the US. On the basis of a few hearings at Jama and Nima, the strategies of the two companies can be characterized as follows.

2. JAMA's PRODUCT DEVELOPMENT STRATEGY

2.1. *Profile of Jama*

Number of employees: 2,000 in 1995

Product range: NC lathes account for 60% of all sales of machine tools; MCs: 25%; grinders: 5%.

Domestic market share (and ranking) of production units: NC lathes: 18.2% (1st); MCs: 12.0% (3rd); NC cylindrical grinders: 8.2% (3rd), in 1992.

Growth: Sales for 1994 were 37% of those in the last boom.

Percentage of sales exported: 34% in 1992.

Overseas affiliations: One affiliate and four subsidiary companies.

2.2. *Organization of Jama*

According to the organization chart shown in Figure 1, Jama has a Design Department in charge of mechanical design. It has five groups, two of which are support groups for the remaining three, which are in charge of NC lathes, MCs and grinders respectively.

Jama's Development Center is in charge of R&D. It is in charge of the development of new technology for spindles and guideways as well as the testing of prototypes of new machine tools. Seventy percent of the engineers are university graduates majoring in mechanical engineering.

Figure 1. ***Organization chart of Jama, a machine tool builder***

Personnel Department

General Affairs Department

Information Networking Center

Sales Department

Service Department

Development Center: evaluation of new products /30

Design Department /100+
- Group 1: lathe
- Group 2: MC
- Group 3: grinder
- Unit Design Group: for Groups 1, 2, 3
- Parts Design Group: for Groups 1, 2, 3

Electrical Department /200+
- Section 1: electric products
  - production control of NC; contracting
  - production of components: control box, drive unit, servomotor
  - sales of NC
- Section 2: electrical engineering
  - basic software for all machines
  - application software for each machine
  - design of control box for all machines

Purchasing Department

Manufacturing Department /500+
- Production Engineering Section
- Machining Section
- Assembly Section
- Production Control Section

Note: The numbers after '/' show the round numbers of members.

The Electrical Department has two sections. One is in charge of the production of NCs, control boxes, motors, and so on. The other is in charge of the development of basic- and application-software for NCs and the design of control boxes.

2.3. *Product Development Strategy and Time*

Jama develops a new series of machine tools every five or six years when the technologies embodied in their products become obsolete. For example, concerning NC lathes, the A Series started in 1978 and six models were developed. The production of two of them was abandoned in 1988. Therefore their life-span was ten years. The next generation (B Series) started in 1982 and eight models were developed. Three of them were developed in 1984, but their production was abandoned in 1988. Therefore their life-span was five years. The C Series started in 1986 and seven models were developed.

Twenty years ago, the time-to-market (the time from market survey to delivery), used to be two years, and ten years ago it was one year. It is from eight to ten months these days.

During the so-called "bubble economy," many users bought advanced and multifunctional machines even if they were expensive. Since the recent recession, users have tended to require smaller and cheaper machines with limited functions because they have been forced to reduce the cost of products such as auto parts. Therefore Jama tries hard to use common parts among different models, buy parts and components from abroad, and develop new machines with limited functions.

2.4. *Product Development Process*

Figure 2 diagrams development procedures. The first stage of the product development process, Survey/Planning, starts with concept development. The process of drafting a plan for a new machine includes considering the performance of the spindle and the function of the NC.

In the case of NC lathes, a design engineer of the Group 1 in the Design Department drafts a plan and presents it at the Strategy

Committee meeting. The Strategy Committee is held monthly. It consists of the members from almost all the Departments: Sales, Design, Electrical, Manufacturing and Service. It examines the plan proposed by the mechanical engineers from the Design Department, discusses users' demands (information which salespeople usually pick up), makes comparisons with competitors' product specifications, and forecasts sales of the prospective model. The Committee decides on the specifications, the development time, and the production cost and pricing of the new machine.

In the case of the development of a new series of machine tools, known as a full model change, the Committee takes a few months to approve the plan. After approval, the basic design, the basic drawing, and the parts drawing, which is the making of all the drawings for the parts and components necessary for manufacturing, are done in about four months.

In the case of the design of NC lathes, a chief engineer, along with several subordinate leader engineers, is put in charge of one whole series of machine tools. Each leader engineer is in charge of one model in the series and directs a few engineers. They meet as necessary, working according to the decisions made by the Strategy Committee, and report to their bosses frequently on progress. Six guest engineers belong to Group 1 and are deployed to help those engineers who have too great a workload.

After the basic design is finished, the basic specifications for the NC are conveyed to the Electrical Department. The electrical engineers begin to work on their design for the NC, and construct a unit by the time the machine prototype is built.

Using the basic drawing as a guide, the Manufacturing Department starts to prepare for production.

After the parts drawing is done, they begin to build the prototype. It is completed in three months' time.

The prototype is tested in the Development Center. It takes about a month.

The results of the tests are evaluated by the mechanical engineers themselves. They examine not only machine performance, but also

Figure 2. ***Procedure for the development***

Stage	month	Design	Electric/Control (NC)
Survey/Planning	1 to 3 (2)	concept and planning R&D meeting <---------- monthly committee for approval	
Development Design	4 (2)	basic design --------> --------specification making basic drawing ----------> parts drawing ----------> technical documents	design
Prototype	3 (1)		ordering making----------
Evaluation	1	evaluation----------<----------|----------<----------<----------	
Commercial Design	1 (1)	redesign planning redesign drawing ----------> reevaluation ---------- redesignplanning/drawing --------≫ final design and drawing ----------> operation manual, parts book design of option units design of peripheral units	final design and drawing
Production			ordering for production production----------

Note: The numbers in ( ) under "month" mean the required terms in the case of small

of new machine tool at Jama, 1992

Development/Test (spindle)	Manufacturing/Inspection
strategic product: concept, spec, cost, schedule ---------->	
----------	preparation of manufacturing/equipment
----------	planning of production process=cost estimation
	ordering for making of prototype
	machining
------>----------	prototype assembling=cost accounting
	adjustment
basic testing ----------<----------	inspection
testing and development	
durability test	
----------	ordering for making of the 2nd prototype
re-testing ----------<----------	machining, assembling

----------> ----------	ordering for production
	machining
----------> ----------	assembling
	inspection=final evaluation to sell
	delivery

sized NC lathe.

manufacturability. They redesign the machine if necessary. In this case, the second prototype is built, tested and evaluated again. If necessary, the mechanical engineers redesign the machine again. In any case, usually a few prototypes are built, but when the machine is large, one prototype is built. This process of redesigning for commercial production, or Commercial Design, takes about a month.

At last, the final design and drawing is done. The result is transmitted to the Electrical Department to produce NCs and other electric units, and to the Manufacturing Department to start the production of the machines.

Then the mechanical engineers begin to design the optional units and peripheral units.

Jama has adopted a continuous development approach for their products. Every month, the Strategy Committee considers what new machines would be salable in the market. The representatives from the Sales Department suggest abstract concepts for such machines, and, based on those suggestions, the mechanical engineers create a concrete plan. Another committee named Review Committee considers the existing series of products and decides, for example, which model should be abandoned or which components such as NC or spindle should be changed to new ones. Namely, for the five the content of any of the series and its models is continuously improved. Every five years, the Strategy Committee develops a totally new series based on those improvements. In the case of one new machine developed in 1992, approximately 40% of its design was carried over from another machine in the former series, while the spindle, the turret-indexing mechanism, and the NC were renewed to meet the user's demands for higher speed and a lower price. This is why the development time of Jama is shorter than the average of Western machine tool builders.

2.4.1. Spindle development

The Development Center has several engineers who are specialists in spindles. Each engineer is in charge of a certain type of spindle as a whole. They are always engaged in developing new and advanced

spindles. They build the prototype spindles, evaluate them and redesign to improve them.

At the planning stage of a new machine, the mechanical engineers select from among the previously developed spindles the one best-suited to the new machine. Sometimes they modify a spindle to make it more suitable for a new machine.

2.4.2 NC development

The mechanical engineers in the Design Department decide about the specifications and/or functions of the NCs needed for new machines. According to the specifications, the engineers in the Electrical Department design the hardware and software for the NCs.

For the actual production of the control boxes, Jama farms out contracts to other companies. Jama also subcontracts the NC software to other software companies.

When a new generation of NCs is developed, the software changes to a large extent. But the software for models in the same series is basically the same. When a model has a special unit such as an automatic tool changer (ATC), special software for it needs to be developed and added to the basic software.

The allocation of tasks among software engineers changes every month as the workload changes.

2.5. *Suppliers and the Relationship with Other Companies*

Jama has more than 300 suppliers, some of which supply standard parts while others supply specific components designed by Jama. Some of the suppliers are bigger than Jama and supply many kinds of items such as cathode-ray tubes for NCs, integrated circuits and spindle parts (bearings, springs and large motors). Certain suppliers are engaged in making out detailed drawings of machines, assembling NCs, making NC software, machining and forming metal and so on.

Jama has organized a supplier association of 100 members. A few of them are bigger than Jama, but the average number of employees in the members is 20 to 30.

Joint development activities by Jama and its suppliers have been carried out in some limited areas; for example, the covering of the ATC magazine for MC and the lubrication system of the NC lathe.

2.6. *Coordination of Engineering and Manufacturing in Product Development*

After the concept drawing is done, engineers and some manufacturing people have a few meetings to examine the new machine's manufacturability.

As the designers of machines are responsible for the final costs in the end, they are required to have a detailed knowledge about the capabilities of in-house manufacturing equipment, and any design they make must take these into full consideration. However, if manufacturing people find any mistakes in the drawings and report it to the designer, the designer must immediately correct them. But manufacturing people are not allowed to make corrections themselves. And in those cases when manufacturing people find that a certain key component can not be manufactured by in-house manufacturing equipment, they offer this opinion to the manager, who tries to find a subcontractor capable of doing it or begins to consider to purchase the needed equipment.

2.7. *CAD and CAM*[7]

In 1994 the old CAD system in the Design Department was totally replaced with new, less expensive one so that each engineer has his own CAD on PC. The engineers usually use 2-dimensional system and 90% of parts drawings is made on it.

Since the year the engineers inside and outside in design companies has used the common CAD system. That has eliminated the troublesome work of converting various kinds of CAD data from each other. But the time for designing itself is hardly shortened.

A few 3-dimensional systems are used for checking machine structure. They hardly contribute to improved efficiency while they are very expensive.

CAD data in a technical format of large machine-parts can be converted directly to CAM data at the Production Engineering Section in the Manufacturing Department.

It is then used as control programs for FMSs. But large parts account for only 4% of the total number of machine tool parts. Most of NC data is made in the Manufacturing Department, often on factory floor, referring to design sheets.

The specification of NC designated by the Design Department is sent to the Electrical Department in documents. They do not need to send it through digital network. In the Electrical Department they use CAD system for circuit designing, which is different from one in the Design Department.

2.8. *Personnel Development*

As on-the-job training (OJT) is the main form of training, job displacement is considered important. Personnel follows a plan that changes the workplaces of 80 people every year. Job displacement inside a given department occurs every month. There are some examples of re-deployment of personnel from one department to another: from Manufacturing to Design, from Manufacturing to Service, from Sales Engineering to Electrical. But it seems that some people in important positions do not get re-deployed: for example, some experts in NC lathes in Group 1 have never been re-deployed. Moreover, there has never been a re-deployment between the NC lathe Group and the MC Group.

Experience in manufacturing is considered important. When employees start to work with Jama, for the first six months they receive basic training in machining, assembly and design at the training plant. And for one year after that, they get experience in various sections of the Manufacturing Department.

3. NIMA's PRODUCT DEVELOPMENT STRATEGY

3.1. Profile of Nima

Number of employees: 1,250 in 1992.

Product range: In 1993 MCs accounted for 40%, NC milling machines 15% and NC electric discharge machines (EDM) 25% of all sales of machine tools.

Domestic market share (and ranking) of production units: MCs: 8.2% (6); NC milling machines: 28.5% (1); NC profile milling machines: 56.0% (1); NC EDMs: 9.8% (3), in 1992.

Growth: Orders in 1994 were a third of those in the last boom.

Percentage of sales exported: 20% on average.

Overseas affiliations: Four affiliated companies.

3.2. Organization of Nima

Nima established its R&D center in 1990, and now it plays a critical roll for their development of new machine tools.

As Figure 3 shows, the R&D Center has two smaller centers in it. One is the Technical Development Center, which is divided into two groups. The Technical Development Center and its two Groups are respectively supervised by directors. The first group in the organization chart is the Technical Development Group, in charge of mechanical design, and it in turn is divided into five sections. One of those is in charge of research, and the others (M1, M2, M3 and M4) are each in charge of one or several types of machine tools, such as the vertical MC, horizontal MC and so on. The other group in the Technical Development Center is the Control & System Group, in charge of electric control & system development, which in turn is divided into three sections. The eight sections of the Technical Development Center each have from 7 to 25 engineers.

Nima has assigned the EDM Development Center in the R&D Center to develop new electric discharge machines. In addition, the Die

Figure 3. ***Organization chart of Nima, a machine tool builder***

Planning, Finance and Administration Division

Sales Division
- Sales Planning Department
- Sales Departments: for each type of machine
- Regional Sales Departments
- Sales Engineering Department

R&D Center (since 1990)
- Technical Development Center=director
  - Technical Development Group: mechanical design=director
    - Research
    - M1: vertical MC
    - M2: horizontal MC
    - M3: middle-sized, 5-axis
    - M4: large
  - Control & System Development Group: electric control & system=director
    - S1: basic/advanced technology
    - S2: controller hardware
    - S3: software, FMS
- EDM* Development Center
  - Group1: E.D.M.
  - Group2: wire E.D.M.
  - Group3: machining condition technology
- Technical Administration Office

DMS** Engineering Center

Manufacturing Division
- Factory 1 /200
  - Machining Plant
  - Assembly Department
    - each Section to each model
- Factory 2 /150
  - Machining Plant
  - Assembly Department
    - each Section to each model

Notes: * electric discharge machine
** die and mold system: automatic manufacturing system of die and mold

and Mold System (DMS) Engineering Center has been established to develop a new automatic manufacturing system for dies and molds.

80% of the engineers at the R&D Center majored in mechanical engineering and 20% majored in electronics. There are only a few employees with graduate-level education.

The Manufacturing Division includes two factories. Each of them has a machining plant and an assembly department.

3.3. Product Development Strategy and Time

70% of Nima's customers in Japan are die and mold manufacturers, and 30% are machine parts manufacturers, more than 60% of which are auto parts manufacturers.

Nima usually spends from three months to a year for market survey. As it is a builder of general purpose machine tools, it has tried to produce machines with functions that meet the demand of the majority of users.

In the case of their milling machines, the development time used to be two years: one year for design and another for completion as a commercial product. They are trying to reduce the time to one year because the life-span of the product is only two years these days.

Many users need more efficient machines that enable them to reduce cost and shorten delivery time. To meet such demands, Nima has developed high-speed spindles and a special control system to enable high-speed feed for the cutters while maintaining a fine finish. These help to eliminate some of the manufacturing processes for dies and molds needed before, which results in shortened delivery time.

Originally, Nima had mainly developed machine tools for making dies and molds. Five years ago they developed an MC used for machining of metal parts. But the quantity of sales was small. Then, in order to develop another machine, Nima selected from the engineers in the R&D Center some young ones who seemed to be less affected by conventional concepts. Within two years, Nima made a market survey and developed a new machine with a high speed spindle three years ago. The main characteristic of this high speed spindle is that it can reach its highest

speed in only 1.6 seconds. Nima says the new MC reduces a large part of the 20 to 30% of the total running time that conventional high-speed spindle machines ordinarily need for their initial start and stop. More than 700 units of the new machines have already been sold.

Not only does Nima try to shorten the development time for their products, but they try to develop machines which help to reduce production time and cost to the users.

3.4. Product Development Process

Nima has no standard time schedule for product development. They decide on a time limit and development schedule whenever they begin

Figure 4. ***Outline of procedure for development of new machine tool at Nima, 1995***

Stage	*[Time needed]*
Survey/Concept	*[three months to a year, sometimes two years]*
market survey on the demands of the wide range of users	
concept of a new machine	
Design	*[a year/now half a year]*
start of development team (selection of members)	
detail specification	
design of each unit	
use of CAD system	
Prototype	
making of units and assembly	
testing	
Manufacturing	*[a year/now half a year]*
machining and subassembling of units	*[a few months]*
final assembly	
design and manufacture of option units	*[a few months to a year]*

Note: This Figure is diagrammed being based on our hearing at Nima.

to develop a new machine. Figure 4 gives a rough outline of the development procedure, based on our hearing at Nima.

The initial concept of a new machine comes from the Sales Division. Then the mechanical engineers in the Technical Development Group of the R&D Center begin to design.

In order to develop a new machine, a development project is started by mechanical engineers from one of the four sections (M1 to M4) in the Technical Development Group and engineers from S2 and S3 in the Control & System Group. One of them is appointed project leader. They have a regular meeting weekly and have informal communications as necessary. Other engineers of the Control & System Group sometimes join the meeting if necessary. Occasionally guest engineers who have a general ability to design also participate.

The mechanical engineers, if necessary, consult with people in the Sales Division and the engineers in the Control & System Group about the machine's specifications. But the mechanical engineers are ultimately responsible for completing the design. Neither people in the Manufacturing Division nor those in production engineering participate in the design process.

Two prototypes are built on average. They are tested against the planned specifications, and evaluated for manufacturability and cost. Unless machine performance is given special priority, the emphasis is on manufacturability. The machines are sometimes used in Nima's factories to test their durability.

There are no specialists in testing. The design engineers themselves test the prototypes.

3.4.1. Development of spindles and ATCs

Under a project leader, mechanical engineers are each in charge of one or more of the machine tool units, such as the spindles, tables, beds, and ATCs. No engineer is a specialist in any specific unit. The engineers change assignments among the various units. They are trained to be capable of designing any unit. But these days, in order to reduce the development time some engineers are assigned to the same unit they were previously in charge of.

The development time of a new spindle can be as long as two years because of the necessity for experimental testing of its prototype. It takes three months to redesign a spindle. Nima develops spindles without any help from other companies. Some guest engineers from some design companies participate, but they work only as assistants. Nima, however, develops spindle bearings in cooperation with some bearing manufacturers as it has insufficient ability to develop them by itself.

New ATCs are developed in-house, but for their redesign, Nima sometimes subcontracts to other companies.

3.4.2. NC Development

Nima buys NCs and some electric components such as motors from other manufacturers. The selection of an NC supplier depends on the customer's order. In order to make their machines more original and keep their position at the most advanced level of technology, Nima adds some original technology to the NCs, as was the case in the development of the control system for high-speed spindles mentioned in 3.3, as well as to the motors.

3.5. Suppliers and the Relationship with Other Companies

Nima contracts with thirty smaller companies for part of the manufacturing process, mainly machining. Each of the companies has less than twenty employees.

Nima, as mentioned above, develops some spindle bearings in cooperation with outside manufacturers and purchases NCs and motors from other companies.

3.6. Coordination of Engineering and Manufacturing in Product Development

Before the prototypes are built, the mechanical engineers coordinate with the people in the Manufacturing Division, reviewing the drawings together. But the manufacturing people do not participate in the design itself.

3.7. *CAD*

CAD is mainly used for the drawing. Nima uses some kinds of CAD software on personal computers, a part of which are connected to the communication network. A three-dimensional CAD system on work-stations is used for analyzing and checking the machine structure.

3.8. *Personnel Development*

The engineers do not undergo a special training, but develop their skill through OJT. Each mechanical engineer, as mentioned above, is trained to be capable of designing any unit for any machine tool. However, rare is the displacement of engineers between the Technical Development Group and the Control & System Group.

The engineers used to get experience in manufacturing for two years on starting to work with Nima. But this custom has been abolished for the last few years because such experience might inhibit young engineers from creating new ideas and concepts.

3.9. *Production*

Most of the units are machined and sub-assembled in a few months. Then the assembly begins. At the same time the option parts and units are designed and manufactured. It usually takes a few months, but it may take up to a year if they are special ones.

Nima disassembled its flexible manufacturing system (FMS) in 1994. Five 5-face double column MCs, which need a complicated program, have been replaced by three Nima-made horizontal MCs.

4. CONCLUSION

The major characteristics of the two companies' strategies comparing with each other are summarized as follows, the abstract of which is presented in the Table 1.

4.1. Company Profile

The main product of Jama is the NC lathe. Jama produces the largest share of units in NC lathes and the third largest share of MCs in Japan.

Nima used to specialize as a milling machine builder and now its main products are MCs. In Japan it produces the largest share of units in NC milling machines and the sixth largest share of units in MCs.

Both companies suffered from the sharp drop of orders after the last boom during 1988–91. They are trying hard to develop, in a shorter period, those machine tools which meet better the users' demands for shortened delivery time and reduced manufacturing cost.

4.2. Organization and Process for the Product Development

The product development process stages can be briefly described as planning/survey/concept—development design—prototype construction and testing—commercial design—manufacturing/production.

In Jama, based on the abstract concept from the Sales Department, the mechanical engineers present the initial plan of a new series of machine tools to a special committee every five or six years. The committee, in which representatives from almost all the departments participate, has a meeting monthly and examines such plans. In the case of Nima, the initial concept for new machines is produced in the Sales Division.

In recent years Jama is spending 8 to 10 months to develop new NC lathes which are partly carried-over models. Jama improves some units of their existing machines constantly over a five-year period.

Table 1. ***Comparison of Two Machine Tool Builders in Japan, Jama and Nima***

	Common	Jama	Nima
◆ Main product		NC lathe, 1st share MC, 3rd share	MC, 6th share NC milling machine, 1st share
◆ Development process	*concept—development design—prototype and testing—commercial design—manufacturing*		
Initial concept		Strategy Committee, monthly sales people and mechanical engineers every 5 or 6 years for new series Review Committee continuous development	Sales Planning Department sales people
Development time		8–10 months for a carried-over model	market survey: 1 year development: 1–2 years
◆ Organization for development	*a mechanical design department and an electrical/software development department*		
Project team system		mechanical engineers	mechanical and electrical engineers
	Mechanical engineers are finally responsible for the design.		
Project leader	*simultaneous engineering*		
		chief engineer—one series leader engineer—one model	project leader—one model an engineer—one or more units exchange of unit = OJT
◆ Suppliers or subcontractors		300 firms	30 small firms for manufacturing

NC	original	(past) cooperation with NC supplier (now) purchase
Spindle	specialists in-house continuous development	job rotation spindle bearing—cooperation
◆ Cooperation with manufacturing for manufacturability	review of basic drawings	communication before prototype
	not so large *Mechanical engineers themselves consider manufacturability as important.*	
◆ CAD/CAM	*CAD on PC is mainly used for drawing.* *3 dimensional system is for checking machine structure.* 2 dimensional CAD system for each engineer	
◆ Personnel Development	*job displacement and OJT*	
Engineers' experience in manufacturing	initial training	less considered than before
◆ Users	auto parts, metal parts, dies and molds	dies and molds, auto parts
Users' demand	*reducing costs and shortening delivery time*	

Note: The described in italics mean the common characteristics to the two companies.

Whereas Nima usually spends 1 year for market survey and 1 to 2 years for the development of new MCs.

Both companies have separate mechanical design departments and electrical/software departments. The mechanical design department in each company is divided into several sections. Each section is in charge of one or more types of machine tool. A project team for new product development is organized mainly from the engineers in one of the sections.

In the case of Nima, some electrical engineers join the project team. But in Nima as well as in Jama, the mechanical engineers are finally responsible for the design and decide on the specifications of NCs. From this point in the process, the NCs at Jama start to be developed in the electrical/software development department according to those specifications.

Project leaders play an important role in both companies. In Jama, there is a chief engineer responsible for each series of new machine tools who supervises several leader engineers. They in turn are each responsible for one or more of the models in the series. At Nima, there is a project leader for each new model, who supervises several engineers who are each in charge of one or more of its units. Engineers change which units they are in charge of. Such displacement is one part of the OJT program.

In either company, simultaneous engineering in product development seems to be carried out mainly in each project team. In Jama, the preparation of manufacturing equipment starts before the parts-drawing stage, in order to reduce the manufacturing period. That helps to reduce the time-to-market.

At Nima, before the prototypes are built, the mechanical engineers and the manufacturing people review the drawings together.

4.3. Suppliers' Involvement in the Product Development Process

4.3.1. Spindles

Both companies are almost entirely independent of other companies for the design of their spindles.

There are specialists in spindles at Jama, who are engaged in the development of new and advanced spindles apart from that of new machines. Some of the new spindles are adopted for new models in the concept stage. This has enabled Jama's continuous product-improvement.

In the case of Nima, the spindle designers are trained through job rotation.

4.3.2. NCs

Jama has developed its own NC. Many electrical engineers are engaged in the development of NC software. The NCs are assembled and their software is coded by other subcontractors.

Nima used to develop NCs in cooperation with a major NC manufacturer. Now it purchases NCs and motors from several electric component manufacturers. But it strives to add its original software to the NC.

Jama's strategy for NCs is very unique in Japan. Most of the Japanese machine tool builders buy NCs from a few suppliers, among which one has maintained the top share in the world, although some of the major builders require from these suppliers those NCs which can be revised to be more suitable for their machine tools.

4.4. Coordination of Engineering and Manufacturing in Product Development

In Jama, the manufacturing people participate in the Strategy Committee, but the Sales Department people are more influential because they know the demands of users better. The mechanical engineers together with manufacturing people examine the manufacturability of a design after the basic drawings are finished. If any mistakes are found, they correct them immediately so as not to delay the development time. The manufacturing people's opinions about manufacturability are also taken into account at the redesigning stage.

In the case of Nima, manufacturing people do not directly participate in design.

In both companies, the involvement of manufacturing people in the design process is not so extensive. The mechanical engineers themselves

consider manufacturability to be important. They daily make it a point to get sufficient knowledge about capabilities of the in-house manufacturing equipment. They constantly try to and are trained to avoid designing products that are too complicated to machine or assemble with the existing manufacturing capabilities.

4.5. CAD/CAM Strategy

CAD system on PC is mainly used for drawing process. In Jama all the mechanical engineers use a common 2-dimensional CAD system, which has eliminated some troublesome work since 1994. Only a part of the CAD data produced by this system is converted to CAM data.

Both in Nama and in Jama, expensive 3-dimensional systems are used for checking machine structure.

4.6. Personnel Development

Job displacement and OJT are the main forms of personnel development in both companies. But the key persons seem to stay in the same section for a longer time than other employees.

In Jama, the experience of manufacturing is included in the initial training for engineers. However, in the case of Nima, it is considered to be a factor that may possibly disturb engineers from creating new design concepts.

Appendix A:
The concluding remark for the presentation

It is critical to take notice of the attitude of Japanese machine tool builders to the users' demands or the market.

"Salable machines" is the phrase we often heard during the hearings at Japanese builders. Developing and manufacturing salable machines is usually the common goal of all the employees in a machine tool company in Japan. They make efforts to produce salable machines cooperating

with each other in the company to increase the sales or to contribute to the company's growth.

"Salable machines" are those machines which contribute to the sales increase or the growth of customers or users. In the hard situations of recession, the customers are forced to struggle with reducing costs and shortening delivery time, and require those machine tools which can meet those needs. This is the actual market of them in Japan, and those Japanese machine tool builders who can not respond it as aptly and quickly as possible may easily lose their market share.

So, Japanese machine tool builders are forced to carry out continuous development of products, to do full model change of machine tools, to replace the spindles with the faster ones and to create more efficient NC software. And in order to deliver quickly their products, the major Japanese machine tool builders do not customize their products after receiving orders, but develop standard machine tools on the basis of their analysis and prospect of customers' demands.

It is this factor of market that has compelled the Japanese machine tool builders to restructure constantly their strategies for product and process of development and production, which is possibly the case with other competitive Japanese industries.

Appendix B:
The answers to the three comments on the presentation from the audience

1. (C. Haddad) How do you think that Nima considers the manufacturing experience of engineers to be negative?

Answer: Nima is rather a traditional machine tool builder. It has specialized in high precision machine tools. So it has considered manufacturing experience of engineers to be important. But that can have a side effect. Such an experience may drive the engineers to be excessively anxious about the manufacturing capabilities.

I think there is another problem. Major customers of Nima are traditionally die and mold makers. But it was forced to expand the range of customers. So it has developed parts working machining centers. But it did not have enough experience to develop those new types of machines. So it needed new ideas and concepts.

Nevertheless I do not think that Nima considers the manufacturing experience to be completely negative. Only young engineers are allowed to avoid such experience in their initial in-house training. There are many older engineers who have traditional ideas. I think Nima will continue to develop their products mixing those two kinds of ideas and concepts.

2. (Y. Nakagawa) I think that Nima developed high speed spindles in order to meet the demands of die and mold makers to eliminate final finishing process and shorten the delivery time. Why German and American machine tool makers have not tried to develop such machines?

Answer: Not only Nima but other Japanese machining center manufacturers have developed high speed spindles, because there is a fierce competition among machining center manufacturers, as mentioned in my concluding remark. If they have not, they will lose customers.

And there seems to be another factor. Most of the Japanese die and mold manufacturers are small companies. They do not have a large cite of plant, but they need cheep and efficient machines to survive in competition. This is the market situation of machining centers in Japan. This factor drives the machine tool manufacturers to develop high speed spindles at a reasonable price.

3. (M. Cusumano) FMS was a trend of production system development in Japan 10 years ago. But according your paper, Nima disassembled its FMS. How do you think about the flexibility of FMS?

Answer: When I heard the disassembly at Nima, I was also astonished. On the contrary, Jama has several FMSs in its factories and continues to use them.

At the present situation of technology, FMS needs considerable amount of investment. During the last boom, the FMS was able to maintain high rate of operations, but after the demand dropped down, some companies was not able to absorb the idle time of FMS and failed to continue to operate them. I think Nima was one of such companies.

This is also related with the diversity of products that FMS can afford. At the present situation of technology, the diversity is limited. For example, Jama has an FMS for the production of spindles and their diversity is limited to their size and other dimension. Moreover it is used only for spindles.

Recently FM cells are salable because it needs less investment and is more flexible than FMSs including many NC machines or large unmanned warehouse.

Appendix C:
The summaries of the Conference

The following are the summaries of the Introduction Speech by Dr. U. Jürgens from WZB, four presentations on machine tool industries in various advanced countries, three comments from the panel on them and my question statement to one of them.

The Introduction Speech of Dr. Jürgens

The issue of product development has been discussed in later 1980s on various aspects: such as increasing competition and the need to improve responsiveness to diverging customer needs and so on. We have focus on how communication and cooperation between functions and companies for new product development taking account of the different strategy of companies and the experience of people at the operational level.

In the case of machine tool industry, time-to-market pressure is related not only to major customers, but to an emerging market of standard

machines developed mainly by Japanese companies. Concerning use of computer aided systems in machine tool industry, American companies are most aggressive to achieve seamless CAD/CAM data flow using 2D and 3D systems contemporarily.

Presentations on Machine Tool Industries

1. H. Hersch-Kreisen from the Institute for Social-scientific Studies in Munich made a presentation on the Problems of Innovation Networks in German Machine Tool Industry as follows:

The innovation network which had been successful by the 1980's were subjected to strong pressure to change. The pressure was caused partly by the rapid technological innovation stemmed mainly by computer science. The present innovation network has little capacity for change and adaptation. Many coordination problems arise including the contradiction between cooperation and competition within the innovation network.

Well established manufacturer-user relations are disintegrating and obstacles to knowledge transfer can be found. Cooperative and trust-based innovation relations have little scope now.

The central cause of the innovation weakness of German machine tool industry lies in the difficulty of building up new innovation networks. The former strengths now stand out as weakness.

2. I. Lippert from WZB, based on the information about two German and two American machine tool companies, made a presentation about the comparison between the two national machine tool industries as follows:

The American companies have formal project organizations added to their traditional ones, while the German companies have informal ones and have not reorganized traditional ones. The American companies combine product innovation with process innovation, while the German focus on product innovation leaving the process innovation conservative.

The American companies uses CAD/CAM systems more positively to reduce lead time than the German, although 3-dimensional systems

are used for only 10 %. The German companies utilize CAD/CAM in design activities not aiming at reducing the lead time, with lower use of 3-D CAD systems.

The American standard machine tool companies will take over mass production techniques known in Japan in the near future.

3. M. Kobayashi made a presentation titled "Changing Strategy and Process of Product Development in the Japanese Machine Tool Builders" attached to this report, based on the information of two major Japanese companies.

After that he answered three questions from the panel as described below in the later part of this report.

4. S. Rolfo from CERIS, based on the information about four small Italian machine tool companies, made a presentation on the Product Development Networks of the Italian Machine Tool Industry as follows:

Italian firms returned to the 1970's development model after the 80's crisis of a few Italian examples that had been acquired by German firms, a model of small-sized firms, highly specialized products. In addition they have begun to undertake outsourcing strategies.

Their product development process is characterized by a continuous improvement of the existing machines. The product life-span is three to four years in most firms. They have no project teams for the product development. In the initial concept phase the marketing department plays an important roll to take full account of the market requests. Although several workstations are installed for CAD, they are mainly used for mechanical design. CAD/CAM integration is not available now.

Comments from the Panel on the presentations above

1. A. Ciacca from UCIMU (イタリア工作機械工業会) made a short comment on the historical development of Italian machine tool industry and some of its characteristics such as the small size of companies, organizational structure, suppliers relationship and products.

2. Udo Blum from IG Metall commented as follows:

The main reason for the crisis in the German machine tool industry lies in that major German machine tool manufacturers have been too much based on the needs of the financially strong customers such as automobile, armaments and space industries. As the result, CNC machines and controls are not designed to respond to the logic of skilled workers. From now on, German manufacturers should supply more double functional machine tools which combine the function of conventional machines with that of CNC machines.

3. R. Hahn from Deckel Maho, one of the prominent milling- and boring-machine-tool builder in Germany, made a comment on its recent product development activities. He showed the product development process as Product Development Committee (PDC) – Design Release – Simultaneous Engineering (SE) – Prototype Making. He stated that PDC consists of representatives from Sales and Engineering Departments and SE is carried out by the people from mechanics, electronics, software and so on. He added that tradition is also a weakness for innovation.

My question statement to Mr. Hahn and his reply

Question:

1. What your reactions to the Mr. Blum's remark that major German machine tool manufacturers have been too much based on the needs of the financially strong industries?
2. Show us concretely the activities in your company to reduce cost.

Answer:

1. As far as Deckel Maho, the opinion was true a few years ago. Several CNC controls have more handling-oriented functions these days.
2. The cost reduction activities are carried out mainly in the cross functional committee.

NOTES

1 This is the paper presented on March 21 in 1997, at the International Conference on "New Product Development and Production Networks—Learning from Experiences in Different Industries and Countries" held from March 20 to 22 in 1997 at the Wissenschaftzentrum Berlin für Sozialforschung. In the Conference nearly 120 researchers and businessmen participated, 15 presentations were delivered, on which 7 people from the panel made comments.

My presentation dealing with Japanese machine tool industry is derived from an international joint research with German researchers: Dr. Ulrich Jürgens and Inge Lippert, and based on the detailed hearings at two Japanese machine tool companies held mainly on November 21 and 25 in 1994 and December 4 in 1995, as well as some new and precious materials reflecting the companies' business activities. In addition I undertook hearing at Jama by myself on September 4, 1997. We would like to appreciate deeply the intimate cooperation by the executives, engineers and workers with our joint research.

Furthermore, before the Conference Mr. Stephen Wright Horn, one of my colleagues, gave me many pieces of instructive advice on the expressions in English. I can never thank him enough. Naturally enough, I am alone responsible for the content of the paper.

Finally, explaining certain part of the discussions at the Conference, this paper in the appendices contains my concluding remark made at the end of my presentation, my answer to the three questions offered after my presentation and the summaries of other presentations related with machine tool industries in Germany, the United States and Italy, as well as some comments on them including mine.

2 The statistical information is based on Japanese Machine Tool Builders' Association, *Machine Tool Statistics Handbook,* 1995, 1996, etc.

3 *Ibid.*

4 See *The Nihonkeizai-shinbun,* October 16, 1996, p. 3.

5 According to one of the statistics arranged by Japanese Machine Tool Builders' Association, the average rate of ordinary profit for the major members was 1.7% in the first half of the year 1996 while it was 10.3% for the former peak in the first half of the year 1990. See *Kosaku-kikai Nyuhsu,* No. 108, March 1997, p. 7.

6 See *The Nihonkeizai-shinbun,* November 21 (p. 15), 22 (p. 13), 23 (p. 9), 1997.

7 This section of 2.7 is based on the hearing at Okuma after the Conference, on September 4, 1997.