Trends and Future Outlook Regarding Machine Tool Technology

S. UETAKE

The machine tool industry has made a rapid recovery from its low point in 2002 and is continuously expanding now. Needs related to "monozukuri" manufacturing have diversified in accordance with the changing characteristics of each industry (market) and the production technology policies of individual companies. In order to satisfy these widening needs of many customers, the input of new technology and new machine types has been required. This report describes JTEKT's technology and future direction corresponding to these needs.

***Key Words**: machine tool, manufacturing system, machining center, grinder, TOP center*

1. Introduction

It is predicted that the global machine tool market will grow 20% ~ 30% every year until 2015, although with temporary ups and downs (**Fig. 1**). In Japan, too, the market size of cutting-type machine tools is expected to expand while maintaining annual sales of 1.2 ~ 1.5 trillion yen. JTEKT has the advantage of being machine tool manufacturer that it also possesses steering and bearing/driveline businesses, and it is aiming to make the best use of synergy with these businesses. This paper presents a report on technical trends in the production systems market as well as technology responding to those needs.

2. Trends in Machine Tool Industry

The Japanese machine tool industry has made a rapid recovery from its low point in 2002 and now continues to expand (**Fig. 2**). The sales of the three major machine tool builders have more than doubled in those years and have exceeded the milestone of ¥150 billion. Regarding the domestic/overseas market ratio, overseas demand has already surpassed domestic demand, and it is said that the key to success will lie in expansion in the global market. The three major machine tool builders made big strides with their wide product lineups and strong production and sales networks, leaving the second group far behind. In the JTEKT group, not only JTEKT but also Koyo Machine Industries, Koyo Thermo Systems,

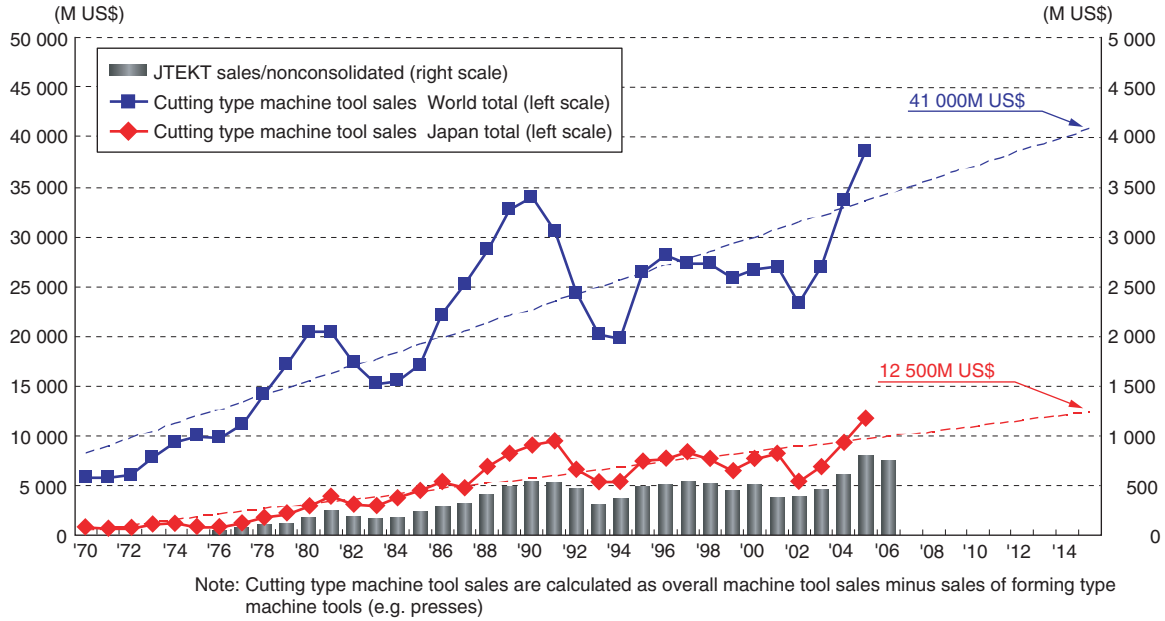


Fig. 1 Demand forecast for machine tools in 2015 (by Japan Machine Tool Builders' Association)

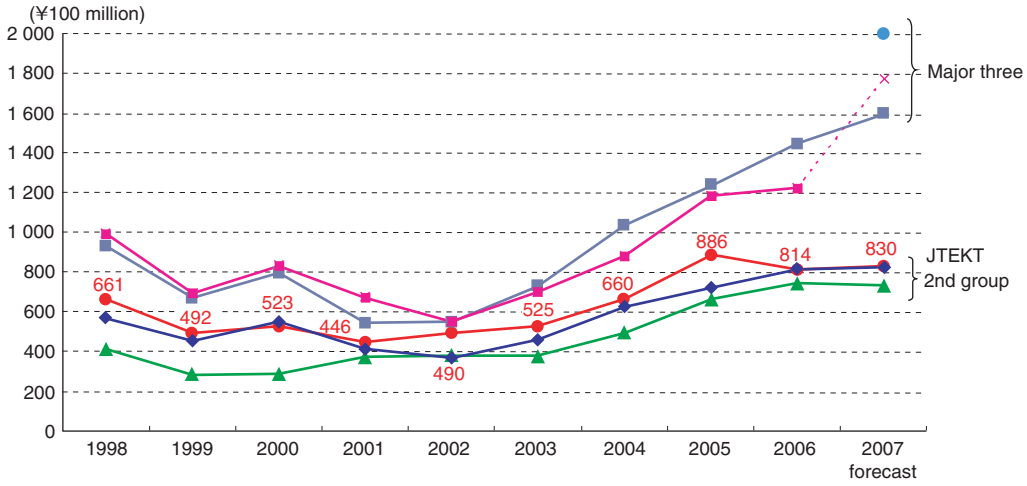


Fig. 2 Sales of machine tools by major companies (1998-2007)

Koyo Electronics Industries, Houko, Mitsui Seiki Kogyo and others are active in the machine tools industry. It is necessary for each company to expand its product lineup, enhance marketing strength, reconstruct its production system, and strengthen its global sales network, making the best use of its particular strong points. There is now fierce competition in the machine tool industry as machine tool builders compete to respond best to the needs of the global market "monozukuri" production sites.

3. Trends in Production Systems

Needs of "monozukuri" production sites are widely diversified depending on the characteristics of each industry (market) as well as the production engineering policies of individual companies. For that reason, machine tool manufacturers need to understand the characteristics of each industry (market) and clarify their technical directions based on the needs of "monozukuri" production sites.

3. 1 Automobiles

Production systems needs in the automobile industry vary greatly and are widely diversified depending on whether the customer is a completed car manufacturer or component manufacturer, whether it makes engines, transmissions or other small parts, whether the vehicles are trucks, passenger cars or subcompact cars, whether the production is domestic or overseas, etc. Also, we are in a new age in which each company creates machines fitting its own production policy through collaboration with machine tool builders (customized universal machines). Furthermore, in the midst of today's intensifying globalization, it is necessary to consider production in BRICs countries in the business plans. Specifically, it is desired that the unit product price be reduced by half through flexible response to volume fluctuations, coping with the trend toward material casting, lowered equipment costs resulting from cost competition, etc.

Development in 2006: TOP Center (TH555F3/4/5), cam grinder (GC32M), crank grinder (GF32M), FH800SX

Development in 2007: Transmission grinder (GL32J), compact machining center (FH400J/500J), compact vertical machining center (#25 & #30 model PV400J), vertical machining center (PV500S/600S)

3. 2 Construction & Agricultural Equipment

We can almost say that FMS systems are for construction and agricultural equipment makers because these industries have long histories of adopting flexible manufacturing systems. Also, because the materials for machined parts are mainly castings, they have traditionally used machining centers with high stiffness. This tendency still prevails, and the same equipment is being used in their overseas expansion of production.

Development in 2006: FH550SX/630SX

Development in 2007: FA800S/1050S, FH800SXL

3. 3 Aircraft

In recent years, aircraft builders also have introduced the Toyota production system, with part procurement by the kanban system and review of supply chains for improvements in efficiency. As a consequence, their suppliers have been forced to shorten their part supply lead times, and as a result they are now more in need of flexible production systems such as FMS systems with stackers that can store materials (**Fig. 3**). In addition, the materials used for aircraft parts have changed to materials with lighter weight and greater strength, but this makes them harder and tougher to cut. Machine tool needs have also grown more diverse, ranging from high-speed light

cutting to high-torque heavy cutting, and from 4-axis indexing processing to 5-axis simultaneous processing.
Development in 2006: FH550SX/630SX
Development in 2007: FA800S/1050S, FH800SXL, FH1250SX

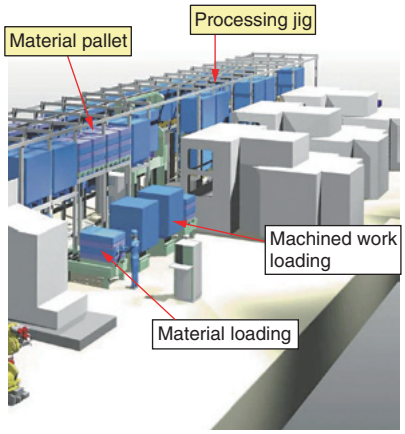


Fig. 3 Stacker system FMS capable of storing raw materials

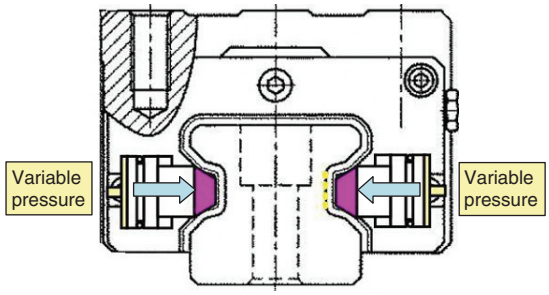
3. 4 Energy (Petroleum, Wind Power, Power Generation)

Energy-related projects are said to be increasing 30% every year. Because of the heavy weight of the products required in this industry, expensive horizontal boring machines and large gantry type machines have been used because of a lack of appropriate machines. With the increase of production volumes down the road, the need for machining centers with higher efficiency will increase. Also there is potential of needs for coping with large FMS in the future because of various production types but small amount of production. In addition, since the material is predominantly inconel and castings that are tough to machine, machining centers with high machine stiffness are desired.
Development in 2007: FA800S/1050S, FH800SXL, FH1250SX

4. Trends in Machine Tool Technology

4. 1 Addresses for Productivity

After the tidal wave of desire for higher speeds and quicker acceleration that started around 1995 and continued for ten years, this desire seems to have plateaued at each machine tool manufacturer. Currently they are having fierce competition for shorter non-cutting times, although practically none of the builders has yet succeeded in achieving any significant differentiation in this area. Down the road, it is expected that differentiation will be sought in the following areas: ① reliability (MTBF), ② running cost (cost and service life of tools), and ③ processing efficiency. Specifically, reliability improvement programs for each machine element as well as projects for extending the truing interval utilizing CBN grinding wheels[1] have been launched. As the new initiatives, development of basic technology aimed at extending tool life, improving processing efficiency and achieving higher accuracy are considered necessary. An example is shown in **Fig. 4**. This is a roller guide gripping system used in the feeding mechanism of a machine tools whereby gripping force can be variably controlled to suit the machining situation.



① Non-moving axis in maching is locked
② Active axis in maching is provided with additional gripping force
③ Gripping force can be changed for quick feed, light cutting or heavy cutting

Fig. 4 Variable Grip Guide (patent pending)

4. 2 Solution to Thermal Displacement

The basic concept concerning thermal displacement consists of the following steps: ① restrain heat generation → ② prevent the generated heat from being transmitted → ③ control the effects of heat generated → ④ cool down the heat generated. While following this order of steps, it is necessary to clarify the effect of heat built up in the machine and provide controlled compensation for such effects without using energy. The ball screw, in particular, can have a temperature rise of 10℃ in 30 minutes from a cold start, causing it to expand by 0.05mm ~ 0.1mm. **Figures 5** and **6** illustrate an example of utilizing a compensation system of ball screw thermal displacement to achieve stable accuracy from a cold start[2), 3)].

4. 3 Trend toward Compactness

The trend toward compactness has accelerated in recent years. As far as the TOP Center Models are concerned, while the MAS-BT40 (#40) originally dominated cylinder block manufacturing sites, the picture changed with the advent of MAS-BT30 (#30): TOP-F3[4)] which now carries out nearly 70% of cylinder block manufacturing work. We have made efforts to increase the stiffness of this machine so that it can undertake processes that cannot be handled by the market's standard #30 machines. However, there still are processes that cannot be handled by the TOP-F3, which is a technological challenge for which we need to develop a solution. So far it has been found that the major factor is the extremely inadequate clamping force of the tool holder. In upcoming development projects,

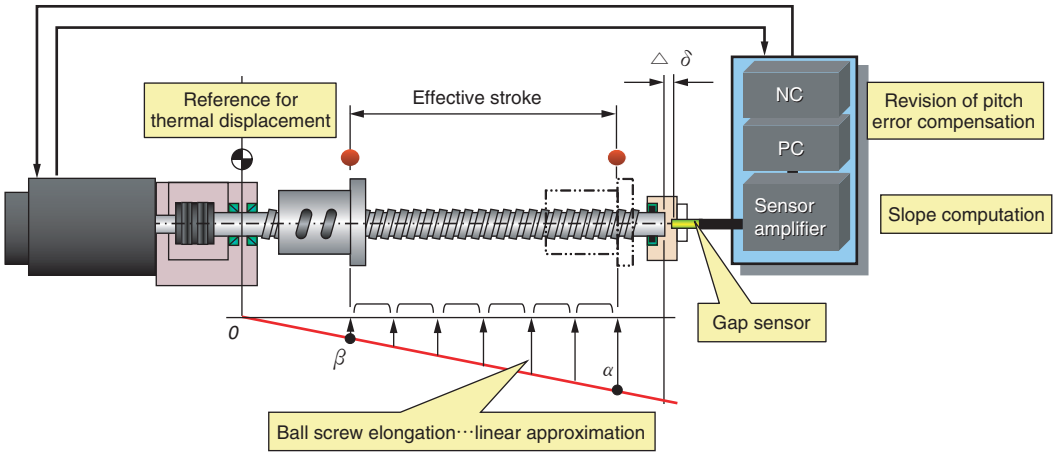


Fig. 5 Compensation system of ball screw thermal displacement

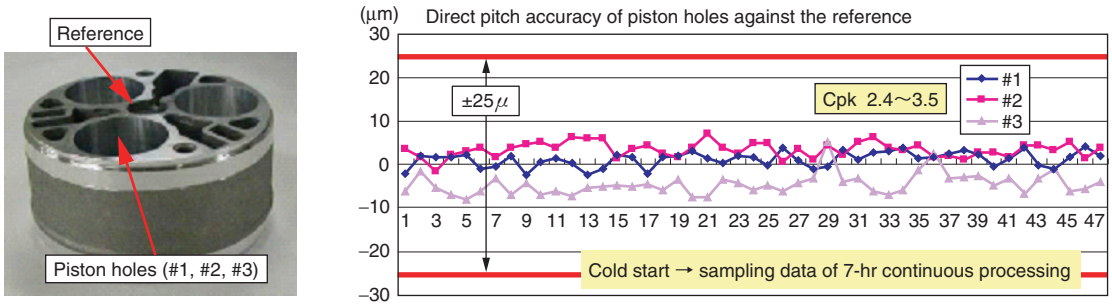


Fig. 6 Compensation effect of ball screw thermal displacement (body of compressor cylinder)

it will be necessary to pay attention to the tool holder. To solve this drawback of inadequate strength, it will be necessary to increase holder strength. It is obvious there is a requirement for such technology that will enable #40 machines to handle processing jobs conventionally done by #50 machines and for #25 machines to take over #30 machine's jobs.

4. 4 Living with Globalization

In 1998, JTEKT machine tools with European specifications costed more than those with Japanese domestic specifications. Thanks to a globalization project inaugurated in 1999, we have attained a level of globalization where the prices of standard machines are almost even, although some differences in specifications still remain. Conformance to the CE marking (European Safety Standard) and UL standard (USA) used to cause extra costs, but the price differences have been absorbed through standardization and using common specifications for all models. In most recent cases when customers request customized machines, they have accepted standard specifications. In addition, through this standardization and use of common specs, control panel sizes have been reduced 30% ~ 50%.

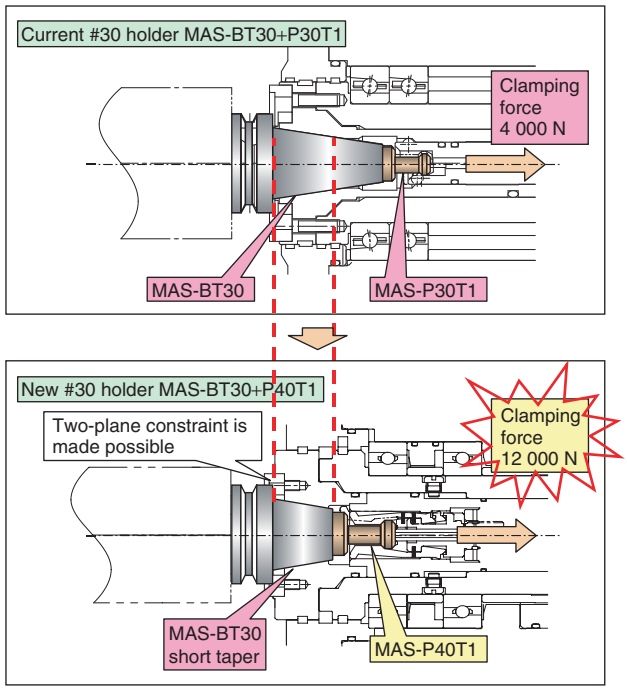


Fig. 7 Clamping mechanism of short taper holder

4. 5 Improvement in Maintainability

Although the basic concept underlying improvement in maintainability consists of life extension and maintenance-free performance, because everything has a finite life, we have been working to achieve visualization for maintenance and service. The "next-generation HMI (Human-Machine Interface)," which can be installed on the JTEKT CNC: GC50, features the ultimate visualization, including use of 3D graphics[1)] to achieve visualization of machine operating conditions as well as location of abnormalities. Future projects will include advanced failure prediction and preventive maintenance, for which development of technology will be required to identify machine traceability more accurately. It will also be necessary to develop a system for detecting precursors of abnormality by tracing the normal values for loaded current, vibration and temperature.

4. 6 Safety Consideration

"Safety takes top priority" is our fundamental philosophy concerning safety. It goes without saying that all laws and regulation concerning machine tools safety listed in **Table 1** must be observed. In the development of machine tools, it is necessary to go through the risk assessment outlined in **Fig. 8** followed by risk categorization based on the risk estimation method (JIS B 9705-1:2000, ISO13849) as well as the corresponding safety measure categories to ensure safety. TOYOPUC-PCS/PCS-J is expected to be a PLC with the world's highest level of safety, meeting category 4 of the European Safety Standard EN954-1[5)].

Table 1 Safety regulations applied to machine tools

Classification	Laws, regulations and standards
Japan	① Product Liability Law
	② Occupational Safety and Health Law
	1) Part II, Chapter 1
	Section 2 Machine tools
	Section 8 High speed rotors
	Section 9 Industrial robots
	③ Noise Regulation Law
	④ Waste Disposal Law
	⑤ Fire Protection Law
	⑥ JIS Standard
Overseas	① Foreign Exchange and Trade Control
	② OSHA (U.S. Occupational Safety and Health Law)
	③ ISO Standard
	④ EN Standard (European Safety Standard)
	⑤ NFPA97 (U.S.)

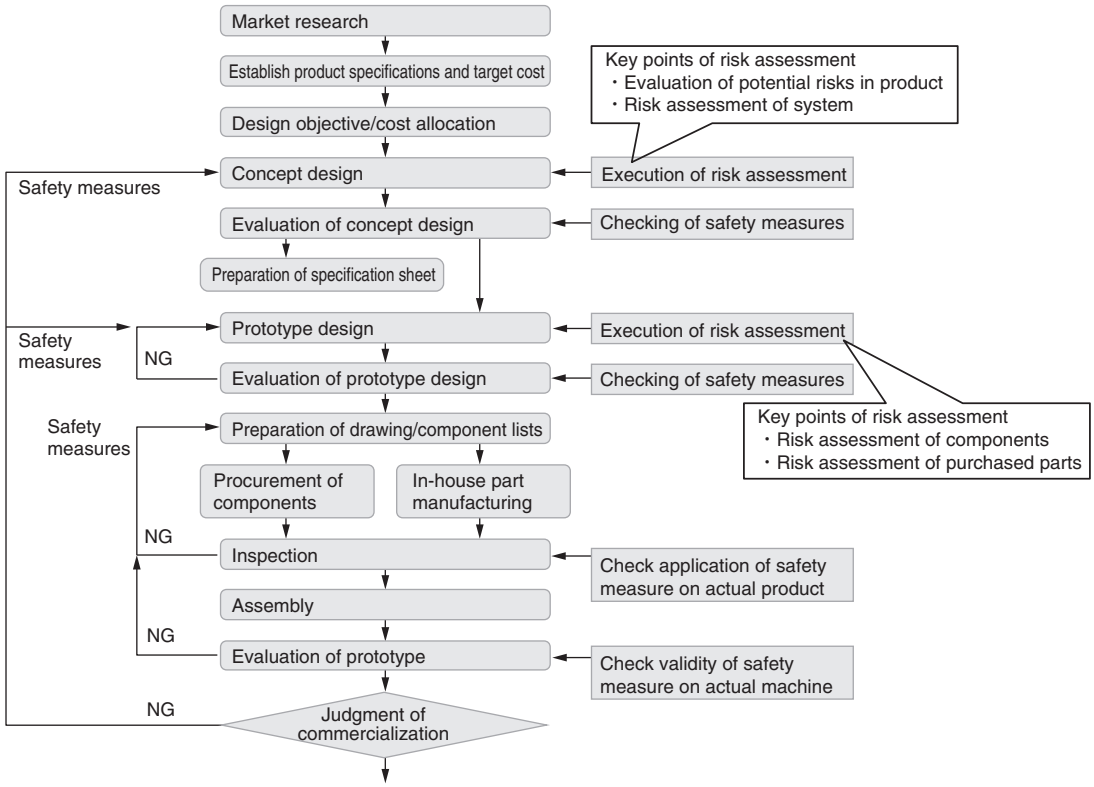


Fig. 8 Risk assessment

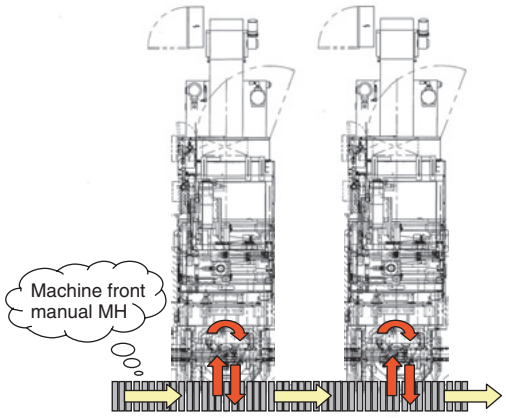
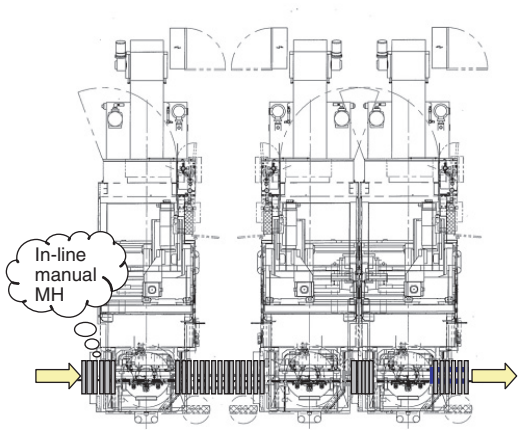
4. 7 Material Handling System

Challenges included in material handling (MH) systems are ① limited time for MH in the total time allocated for producing one workpiece (waste time is too long), ② inadequate machine flexibility, and ③ different machine specifications between automatic MH (JTEKT A spec.) and manual MH (JTEKT D spec.). In developing a manufacturing line, it is important to first establish a line of machines based on manual MH, which then should be automated in such manner that the same quality can be obtained either by manual MH or automatic MH without changing jigs. **Table 2** summarizes characteristics of an MH system using an MH conveyor in front of the machines as well as in-line (straight line) MH. Although straight line MH, which is the least wasteful, basically is preferred, in reality various MH systems are used depending on the characteristics of the workpiece such as size and cutting direction. Concerning automation of MH, high-speed MH devices based on extrapolation of the transfer machines have so far been used. Although they exhibit high speed, they are single-functioned and lack flexibility. Recently, therefore, the use of robotics MH and top-loading MH has increased. Customers these days spend a long time selecting the MH system. It appears that the key issue is shifting from the processing machine to the material handling system. Therefore it will be necessary for us to achieve differentiation in material handling systems as well.

5. Conclusions

The machine tool industry exists as the key industry supporting the foundation of "monozukuri" manufacturing. We therefore must continue not only improving technology for machine tools themselves but also keeping ourselves oriented toward contributing to customers' "monozukuri" manufacturing. As we strive to become the world's no. 1 system supplier, we will constantly endeavor to deepen our basic technology as well as applied engineering so that we can deliver the tools for "monozukuri" that will satisfy our customers. The fact that we have our own "monozukuri"

Table 2 Representative examples of manual transportation system

Material Handling System				
Method	Jig changer	Angle rest jig	Plane jig	Pallet (slipper)
Work	Knuckle	Transmission	C/B	Diff. carrier
Reason	Reduced number of machines	Horizontal MH, vertical loading	Heavy work	Stabilization of MH posture
Loading/unloading time	Os (Overlapping with machining)	12 s = 6 s + 6 s	12 s = 6 s + 6 s	12 s = 6 s + 6 s
Conveying time	Os (Overlapping with machining)	10 s	6 s	6 s
Jigs	2 sets	1 set	1 set	1 set
Turning	Required	Required	Not required (required for multi-surface machining)	Not required (required for multi-surface machining)
Base machine price	Expensive	Reasonable	Reasonable	Reasonable
Other expense	–	–	Posture change is required	Pallet return is required

manufacturing divisions, namely steering and bearing/driveline divisions, is our strength in the sense that we can experience "monozukuri" in-house. We hope to enrich our product lineups so that we may use our plants as showrooms of our machine tool/mechatronics business.

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S. UETAKE*

* *Senior General Manager, Product Development Department, Machine Tools & Mechatronics Division Headquarters*