Approach to Energy Saving in Machine Tools

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The power shortage triggered by the Great East Japan Earthquake, regarded as one of six major problems for the manufacturing industry, has led to greater demand for energy saving from machine tools.

To accomplish such high level energy saving, further study on new elemental, control, and machining technologies has become necessary. To this end, JTEKT has made efforts to achieve significant improvements through development of various technologies and complete evaluation by a JTEKT original "eco-scale".

This paper presents an overall picture of our approach to energy saving for machine tools and how this approach will evolve into further technical development.

***Key Words**: machine tool, energy saving, eco-scale, main spindle, wheel spindle, idle stop, mottainai*

1. Introduction

In the wake of the unprecedented disaster that was the Great East Japan Earthquake in March of 2011, reflection on various related problems revealed the vulnerability of our modern society.

In particular, the issue of "power" which stemmed from the disaster at the Fukushima No. 1 nuclear power plant, along with the strong yen faced by the manufacturing industry, high corporate tax and so on, is one of the major social issues raised as the "Six Hardships".

Machine tools can be described as objects which convert various physical energies into the task of "machining workpieces".

The supply of energy is essential for production and the supply of air, coolant and so on is necessary for efficient machining. The supply of air and coolant as well as the operation of the overall equipment all equate to "power". Energy saving and power saving have become the most important keywords when contemplating machine tools from here on.

With the above as the current situation, this report introduces the actions taken for energy saving in machine tools.

2. Energy Consumption in Machine Tools

The energies consumed by machine tools can be broadly divided into stand-by energy to maintain electric devices even when the machine is stopped, steady-state energy which is constantly required during machine operation, and dynamic energy which is sometimes required depending on movements of the machining state, etc. (**Fig. 1**).

1. Stand-by energy is consumed when power is connected therefore it is necessary to save power by turning off the power frequently, etc.
2. Steady-state energy is consumed over the entire production time, therefore if the absolute amount can be reduced, the effects increase in proportion with production time.
3. Dynamic energy changes with the machining state, etc., therefore it is both necessary to increase machining efficiency and shorten machining time and reduce the necessary energy.

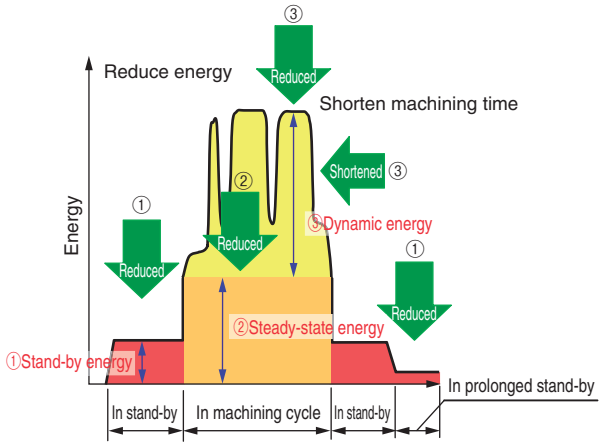

Fig. 1 Energy consumption in machine tools

3. Reduction of Stand-by Energy and Steady-state Energy

3. 1 Idle Stop Concept

As is the case with vehicles, the concept of idle stop is also applied to machine tools. Idle stop suppresses the stand-by current of motors, valves and so on. Also, regarding steady-state energy for the hydraulic pump unit, etc., by using variable control for differing motor speeds appropriate for when the actuators are in operation and when pressure is being held, the amount of energy consumed can be suppressed (**Fig. 2, 3**).

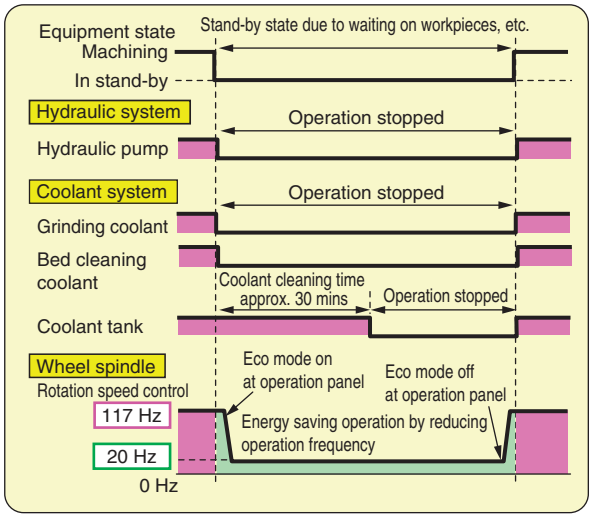

Fig. 2 Reduction of stand-by energy

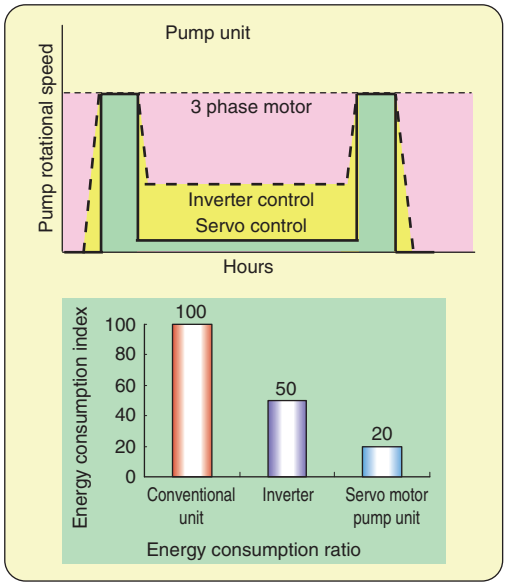

Fig. 3 Reduction of pump unit energy consumption

4. Reduction of Dynamic Energy

4. 1 Reduction of Air Consumption

A large amount of the energy consumed during operation is related to lubrication of the main spindle, for example main spindle lubrication air and cooling air. Therefore, technological development that reduces energy consumption without sacrificing the reliability of lubrication is required.

Currently, the oil-air method is the mainstream form of lubrication for the main spindle of cutting machines and machining centers, however this method uses a large amount of air and has a high energy consumption (**Fig. 4**).

As such, the Machine Tool Department and Bearing Department have worked together to develop a highly reliable, long-life grease-lubricated main spindle (**Fig. 5**). If oil-air lubrication can be changed to grease-lubrication, the air which accounts for 20% of energy consumption (**Fig. 4**) can be removed from the equation.

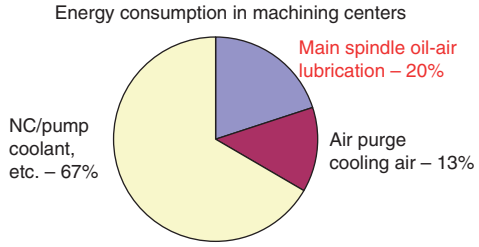

Fig. 4 Energy consumption machining centers

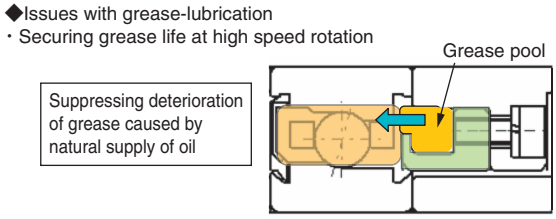

Fig. 5 Development of grease-lubricated main spindle

4. 2 Reduction of Lubricant (Evolution of the Hydrostatic Fluid Bearing)

Meanwhile, hydrostatic fluid bearings which do not use air are adopted for the wheel spindles, etc., of grinders. The hydrostatic fluid bearing increases accuracy and rigidity and is a key technology to the high accuracy machining that is demanded of grinding. It is also JTEKT's core technology, however, there are the trade-offs of a large amount of power loss caused by the viscosity of the lubricant and a high energy consumption by the drive motor (**Fig. 6**).

That is why efforts are being made to develop technologies which control the lubricant flow and optimize it by using acting load. Energy is saved by changing the amount consumed during grinding and non-grinding times and optimizing the overall energy consumption (**Fig. 7**).

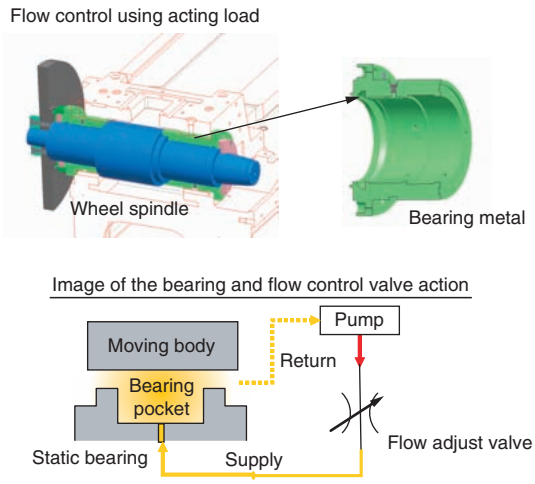

Fig. 6 Flow control for wheel spindle

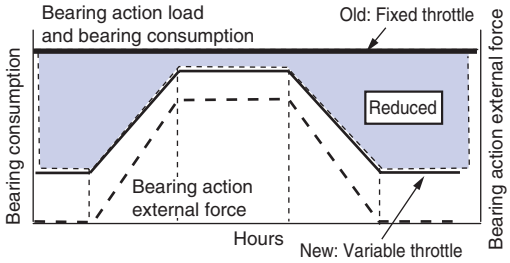

Fig. 7 Effect of oil flow reduction by flow control

4. 3 Efforts to Reduce Grinding/Cutting Power

In product design also, it is necessary to reduce the grinding/cutting power by reducing stock removal, reduce the no. of machining points by revising processes and product profile, etc.

For example, in the rough boring operation of cylinder blocks (C/B), machining power has been reduced over the years due to efforts to increase the accuracy of the base material higher, etc. (**Fig. 8**).

These efforts have been effective in keeping machining power low as well as helped to eliminate special tools and make general purpose tooling and equipment possible.

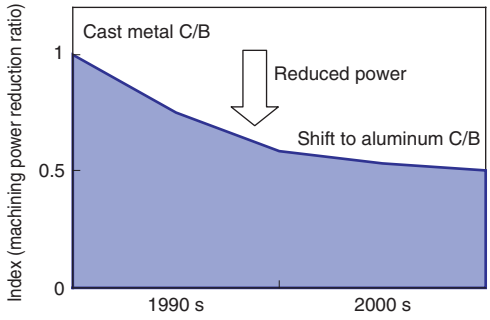

Fig. 8 Reduction of machining power

5. Creation of an Indicator for Energy Saving

5. 1 Eco-scale

Currently, JTEKT's Machine Tool department uses an "eco-scale" in the development of equipment. This eco-scale is an independent set of criteria used as an indicator to assess and reduce the environmental load of our products.

As indicated in **Table 1**, the eco-scale uses power, air consumption, weight, oil consumption and so on as indicators to make comparative assessments.

JTEKT has taken action to lower the eco-scale for grinders, cutting machines and machining centers.

We will continue to strengthen our development of energy saving technologies in the future and as 2015 VISION, we aim to accomplish a 70% reduction compared with the year 2000 (**Fig. 9**).

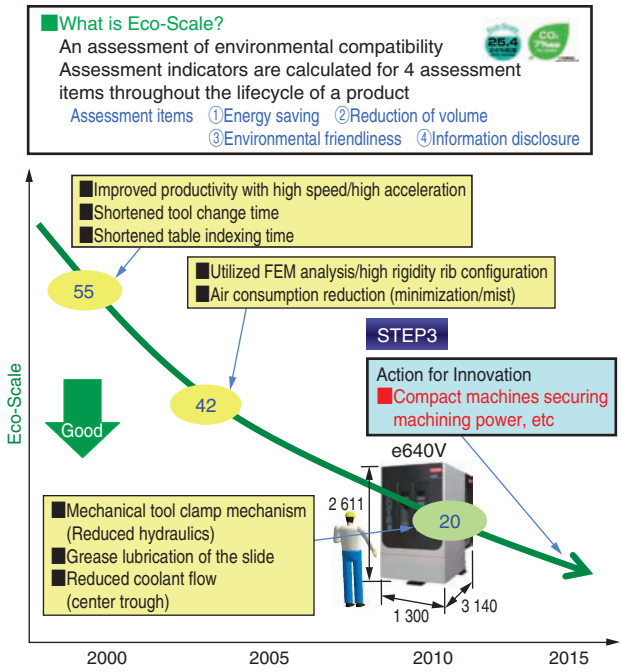

Fig. 9 Target reduction on the eco-scale

Table 1 Eco-scale

Assessment items		Criteria	Evaluation point standard		Remarks (example range)
Energy saving	1	Power capacity (kVA)	0.1×□□ kVA		1.5 to 5.8 kVA → 1.5 to 5.8 points
	2	Stand-by power consumption (%)	Under 10%	1	Electric current ratio in MASTER ON state when spindle is 100% loaded
			10% or more Under 20%	2	
			30% or more	3	
	3	Air consumption (NL/min)	0.004×□□ NL/min		0 to 900 NL/min → 0 to 3.6 points
	4	Productive effect	2003 productivity reduction percentage: A [2003 productivity: 5]×A		Evaluated ratio against 2003 productivity
Environmental friendliness (energy saving)	5	Coolant/no coolant	Minute or not used	1	Dry cut or semi-dry cut
			Used	2	
Reduction of volume	6	Bearing oil (L)	0.05×□□ L		0 to 60 L → 0 to 3.0 points
		Lubricant (L)	0.05×□□ L		0 to 75 L → 0 to 3.7 points
		Hydraulic oil (L)	0.05×□□ L		0 to 20 L → 0 to 1.0 points
Energy saving	7	Footprint (m^2)	0.4×□□ m^2		2.2 to 12.5 mm^2 → 1 to 5 points
Reduction of volume	8	Machine weight (kg)	0.0004×□□ kg		2 450 to 14 000 kg → 2 to 3.5 points
Environmental friendliness	9	Noise level (dB)	□□ dB-77 (77 dB or less is 0)		79 to 80.5 dB → 2 to 3.5 points
	10	Machine installation surface vibration (μm) P-P	Under 1 μm	1	Measure floor vibration at a point 1 m away from the cover during rapid feed
			1 μm or more Under 5 μm	2	
			5 μm or more	3	
Environmental friendliness (energy saving)	11	Transportation vehicle type	4 t normal truck	1	E.g.) No. of units used×[1]+No. of units used×[3]
			11 t normal truck	2	
			11 t low-floor truck	3	
			20 t flat trailer	4	
			20 t low-floor trailer	5	
Environmental friendliness	12	Use of hazardous material	Not used at all	1	Substances subject to reduction and banned substances as stipulated by the chemical substance environment prior evaluation procedures
			Substances subject to reduction used	2	
			Banned substances used	3	

6. Conclusion

A little while ago, the Japanese word "MOTTAINAI", which is best conveyed with the English expression "Such a waste!", was often used in the subject of ecology.

If Japan became a manufacturing giant due to using limited resources in the most efficient way possible and increasing value, then it can be said that machine tools also need a fresh injection of innovation making good use of Japanese people's sensitivity towards this "MOTTAINAI" concept.

JTEKT believe it is important to continue polishing our technology so that Japanese machine tools, which now incorporate an ecological element to accompany high productivity, high accuracy and high quality, so that they become the ultimate tool supporting the world's manufacturing industry.

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