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Energy Consumption Reduction by Machining Process Improvement

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Abstract

Reduction of energy consumption has played a significant role in industry. This paper describes a study on reducing energy consumption by machining process improvements. Methods of reducing energy consumption in a manufacturing line consisting of multiple machines are verified. First, to consolidate the processes, a series of horizontal machining centers are replaced with a 5-axis machining center. The energy consumption can be reduced by approximately 8 %. The cycle time also becomes shorter by approximately 20 %. Since transfer equipment is not needed in the process, reduction of energy consumption by eliminating the equipment can also be expected. Second, energy consumption in the machine tool is classified in detail. As a result, it is found that coolant related equipment consumed approximately 54 % of the overall energy. Thus, the efforts are focused on the equipment. Coolant consumption of each pump is investigated. Based on the result, the coolant pumps can be concentrated in a single unit. In addition, energy consumption of the through-spindle coolant system is reduced and coolant pressure is optimized. Herewith energy consumption can be reduced by approximately 26 %. Finally, the inverter frequency is optimized. As a result, the overall energy consumption in the manufacturing line is reduced by approximately 42 %.

Keywords: Energy consumption; Process consolidation

1. Preface

The safety of nuclear plants is being questioned in Japan because of the accident occurred in the Great East Japan Earthquake in 2011. Therefore, operations of many nuclear plants are stopped and the situation of energy supply is seriously strained. The safety issue of nuclear power generation has affected the whole world, leading to active movements to reduce dependence on nuclear power generation and increase use of renewable energy such as wind power and solar power. However, the technology of renewable energy generation is still in the developing stage; accordingly the energy supply is far behind nuclear power and thermal power. Therefore, energy saving is the most important issue for many industries; needless to say, for the manufacturing industry and the machine tool industry. Machine tool manufacturers have recently released various machines aiming for energy saving. Also, various effects have been reported in the recent study papers. Inasaki [1] investigated reducing cutting oil usage during machining. D.Dornfeld proposed an efficient tool path and workpiece setup method [2] and explored power consumption monitoring on machine tools [3]. N.Diaz et al. [4] investigated the reuse of energy regenerated from the spindle motor. The authors were working on optimizing cutting conditions such as the feedrate and cutting speed of a 3-axis vertical machining center [5] and the inclined angle between the tool - workpiece on a 5-axis control vertical machining center [6] aiming to suppress the energy consumption.

On the other hand, most of the manufacturing lines consisting of multiple machines at manufacturing sites, especially, for automobile parts are operated for 24 hours, consuming massive amount of electricity. Therefore, suppressing the energy supply in these manufacturing lines is considered to be significantly

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effective for energy saving. Although reducing machining time and securing the operation rate are emphasized in these machining lines, the energy consumption is not emphasized.

This paper describes manufacturing lines consisting of multiple machines aiming at energy saving; the authors strived to reduce energy consumption through improvement of peripheral equipment and reducing machining time by process consolidation.

2. Machine Tools and Measurement Result of Energy Consumption

2.1. Machine Tools

Fig. 1 shows the overview of the manufacturing line introduced in this paper. The line consists of nine machines: eight compact horizontal machining centers and a medium horizontal machining center. Compact machining centers are used in the first process and a medium machining center is used in the second process. Also, five robots are used to transfer workpieces between the machines. Table 1 and Table 2 are machine specifications and Fig. 2 shows develop figure of machined workpiece. As in Fig. 2, machining of the 5 faces except for the reference face and the drilling is done by the first process and the finishing of the reference hole is done by the second process. An electric power meter is connected to the secondary side of the main power of the machine and the devices to be measured, and then measured the energy consumption for machining one workpiece.

2.2. Results of Energy Consumption and Cycle Time

Table 3 shows the measurement result of energy consumption and cycle time in the current machining line. The energy consumption in the first process is 2588 Wh and 271 Wh in the second process as shown in the table. And the cycle time is 22 min. 39 sec. in the first process and 2 min. 28 sec. in the second process. Measures for energy saving are described in the next chapters.

Fig. 1. Overview of manufacturing line

Table 1. Specification of compact horizontal machining center

Spindle power (kW)	3.7
Spindle speed (min^{-1})	12000
Spindle bearing material	Stainless steel
Spindle diameter (mm)	60
Type of spindle taper	HSK A50
Maximum feed rate (m/min)	50
Feed acceleration (G)	1.8 / 1.5 / 2.0
Stroke X/Y/Z (mm)	300 × 350 × 350
Guide way	Liner roller guide

Table 2. Specification of medium horizontal machining center

Spindle power (kW)	18.5
Spindle speed (min^{-1})	14000
Spindle bearing material	Stainless steel
Spindle diameter (mm)	70
Type of spindle taper	7/24 Taper No.40
Maximum feed rate (m/min)	50
Feed acceleration (G)	0.6 / 0.9 / 0.6
Stroke X/Y/Z (mm)	560 × 560 × 630
Guide way	Liner roller guide

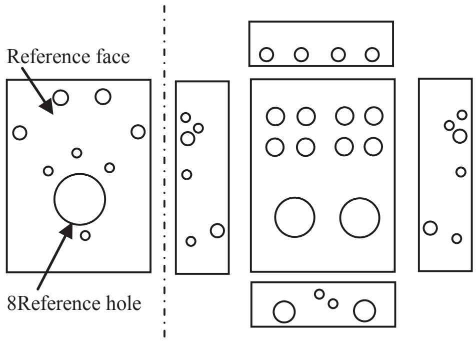

Fig. 2. Develop figure of machined workpiece

Table 3. Result of energy consumption

Process	Power consumption (Wh)	Cycle time
OP1	2588	22 min.39 sec.
OP2	271	2 min. 28 sec.