Reduction of Electricity Consumption for Work Piece Curing of Hard Disk Drive Component Manufacturing

Premchai Moolla and Rungchat Chompu-inwai*

Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai, 50200, Thailand.

*Corresponding author. E-mail: rungchatc@hotmail.com

ABSTRACT

The aim of this research work is to reduce electricity consumption for the work piece curing step of the arm coil assembly process in the manufacturing of hard disk drives component. The research began with a study of the total electricity consumption of the production process, in order to determine the part of the process that consumes the most units of electricity. The results showed that the arm coil assembly process consumes most electricity, accounting for 53.36% of the entire process. During this production process, machines, and ovens in particular, are the main items of equipment employed. An analysis using a fish bone diagram was carried out in order to find the cause, and the results showed that electricity losses occur during the work piece curing process, before transfer to the production and adhesive curing processes, due to ineffective use of the ovens, i.e. the space is not fully utilized, there are no aids used in tandem with the product curing devices, and the ovens lose temperature during operation. This research; therefore, proposes a framework for a reduction in the use of electricity which is, first, to increase the oven conveyer speed from 170 mm per minute to 180 mm per minute, second, to design a heat-loss reduction device at the front of the oven, which in turn, can reduce temperature loss by up to 2.1 degrees Celsius, and third, to design additional curing equipment which can actually be utilized without any adverse impacts on product quality, saving approximately 90,604.80 Baht per month in electricity as a result of being able to turn off one work piece curing oven, and resulting in a payback period of 0.014 years, or approximately 6 days. This equipment can also be used with other products in the production process.

Keywords: electricity consumption, hard disk drive manufacturing

INTRODUCTION

The expansion of the hard disk drive industry is of significant importance to Thailand's economy and domestic employment. The growth in this industry is likely to continue, including the number of hard disk drive manufacturers, who will face stiff competition in respect to the technologies and production techniques used so as to survive in the market. In the hard disk drive industry, it is

common for small parts to be produced in large quantities; requiring a number of complex processes linked together. Large amounts of raw materials, energy and chemicals are utilized in these production processes, especially in the arm coil assembly process.

The case study manufacturer covers the main production processes, including Machining Center Operation (MCO), Molding, Winding the coil assembly, Arm Coil Bonding assembly, and the Print Circuit Assembly processes (PCCA). However, the consumption of raw materials, energy and chemicals at stage of the process is different. For example, the consumption of electricity between May 2009 and April 2010 for the production processes under the responsibility of the assembly division, comprising molding, winding the coil assembly, arm coil bonding assembly and PCCA assembly was 2.19%, 9.35%, 53.36% and 35.09% respectively. Thus, the arm coil assembly process accounts for the highest proportion of electricity consumption across the whole production process. In this process, the main machines used are ovens and adhesive re-fillers. Arm coil assembly begins with the transfer of arms from the MCO process to the cleaning process. All the cleaned arms are then cured in the ovens. The arms are assembled with the coils using adhesive as a binder. After the assembly, the products are cured again in the ovens, at a temperature in accordance with product specifications and customer requirements, before the finished products are delivered to the next stage in the process. The utilization of the ovens in this process requires large amounts of electricity to be used, as it is transformed to heat. As a result, ineffective use of the ovens incurs higher production costs.

From a review of the research, a study into electricity consumption within a concentrated rubber latex production process, Tangpothitham et al. (2008) carried out an analysis of the cost-effectiveness of changing equipment, and thus was a feasibility study on the costs of switching from the existing equipment to that of a higher quality. According to the study, employing higher quality equipment saved on the annual payments on electricity, giving a short payback period. Similarly, in Saelee and Kleubwannarat (2008), a proposal to save electricity through the insulation of spiral heaters in order to reduce heat loss from production activities, resulted in a reduction in energy use and was also in line with the company's energy saving policy. Also reported in Provincial Electricity Authority (2002), energy saving during industrial manufacturing requires several measures to be put in place, such as: first, a housekeeping measure - modifying machinery and work processes through the provision of proper maintenance. Typically, this method does not incur additional costs and requires a small amount of expenses to be incurred, and has a short payback period; second, improving existing processes or reducing losses, which requires a detailed evaluation to be carried out. Usually, this measure incurs a moderate amount of investment, with a 1 to 2 year payback period and third, a change of equipment or a system modification. A preliminary evaluation suggests that this measure can significantly increase performance effectiveness; nevertheless, it still requires a financial return assessment to be carried out, as this measure requires high levels of investment, with a 2 to 5 year payback period.

From a review of the literature, reducing electricity consumption can be achieved in a number of ways, depending upon the characteristics of the industry in question. The effective utilization of energy will result in a decrease in production costs. This research; therefore, focuses on reducing electricity consumption in the product curing stage of the arm coil assembly process.

ELECTRICITY LOSSES DURING WORK PIECE CURING IN THE ARM COIL ASSEMBLY PROCESS

The oven used in this case study employs a conveyer belt system, infrared beams to generate heat, a temperature and conveyer belt speed control panel, and six fan heaters to distribute hot air within the oven, and generates a maximum temperature of 220 Celsius. The conveyer speed ranges from 0 to 300 mm per minute. The electricity utilized by the oven is used for adhesive curing. According to the data collection and analysis carried out using a fish bone diagram technique (as shown in Figure 1), it was found that the oven employed for adhesive curing has unused space, as parts are not fully loaded on to the conveyer belt, thus incurring losses in the form of an inefficient use of energy (as shown in Figure 2). Furthermore, during the production process, products sometimes line up waiting to be fed into the oven.
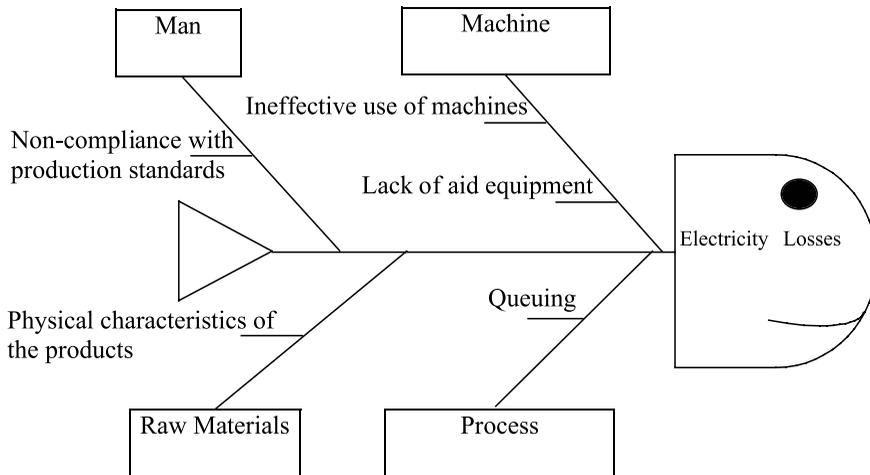

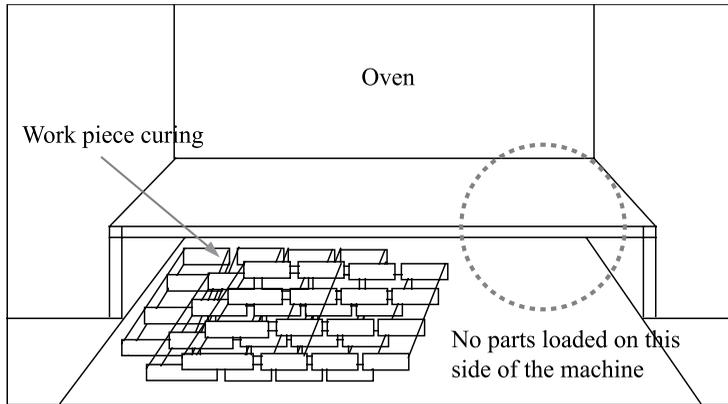**Figure 1.** Fish bone diagram showing the causes of electricity losses.

Figure 2. The adhesive curing process has redundant space, as parts are not fully loaded on to the conveyer belt.

GUIDELINES FOR THE REDUCTION OF ELECTRICITY CONSUMPTION

The guidelines for reducing electricity consumption are as follows:

Increase the speed of the oven conveyer belt

The current speed of the conveyor belt used for curing the work pieces is 170 mm per minute. The work pieces are cured at a temperature in line with the product specifications, and in order to meet required quality standards, which means achieving the certain quality characteristic required by customers (Moola and Chompu-inwai, 2010). The current speed of the conveyer belt cannot cure the work pieces on time, which results in products queuing. Therefore, in the study, a calculation of the oven cycle time, which means the time taken from the product entering the oven to when it leaves the oven (minute), was carried out using the formula in equation (1) (or determined through direct time measurement in the production process). The feed rate is the number of work pieces loaded onto the oven conveyer belt in one minute, but leaving enough space (pitch) in order to generate a hot air flow in the oven (pieces/minute). The feed rate calculation was carried out using the formula in equation (2). A calculation of the capacity of the oven, which is the number of work pieces the oven can produce in one hour, determined from the number of work pieces loaded onto the conveyer belt in one hour (pieces/hour), was carried out using the formula in equation (3). As a result, the daily outputs of the curing oven were able to be calculated using a worker performance effectiveness level of 95% (normally, workers will take breaks, such as when going to the restroom or waiting for work) and substituted in equation (4). The results of the calculation are shown in Table 1, as compared to the outputs prior to the actual adjustment of the conveyer belt speed.

$$\text{Oven Cycle Time} \quad = \quad \frac{L_c}{V_c} \qquad \qquad \text{.... (1)}$$

$$\text{Feed Rate} \quad = \quad \frac{V_c \times N}{S} \qquad \qquad \text{.... (2)}$$

Capacity of the Oven = Feed Rate × 60 .... (3)

Output = Capacity × Working time × Efficiency .... (4)

where: V_c = Conveyer Speed (mm/min)

L_c = Conveyer Length (mm)

S = Pitch from Jig to Jig (mm)

N = Number of Columns (pcs)

Working time = 20.5 hours; efficiency 95%

Table 1. Calculation of conveyer belt speeds and outputs.

V_c (mm/min)	170	180	190
L_c (mm)	***	***	***
S (mm)	***	***	***
N (pcs)	***	***	***
Cycle Time (min)	47	44	42
Feed Rate (pcs/min)	***	***	***
Takt Time (min/pcs)	***	***	***
Capacity (pcs/h)	***	***	***
Output 95% (pcs/day)	***	***	***

*** Certain information on this table has been omitted for confidentiality.

As shown in Table 1, an experiment was conducted at conveyer belt speeds of 180 and 190 mm per minute, and the temperature was measured by dividing the oven into six zones (Figure 3) and using a temperature meter, as shown in Figure 4. From the experiment (Table 2), it can be seen that at a conveyer belt speed of 190 mm per minute, the temperatures in zone 1 and 6 were inconsistent with product specifications, where a drop in temperature was found in the measurements on the left, center and right parts of the oven. The appropriate speed required to generate a temperature consistent with customer requirements, was 180 mm per minute. This speed did not affect the quality of the arm coil bonding force, and reduced the curing time as part of the oven cycle from 47 minutes per cycle, to 43 minutes per cycle.
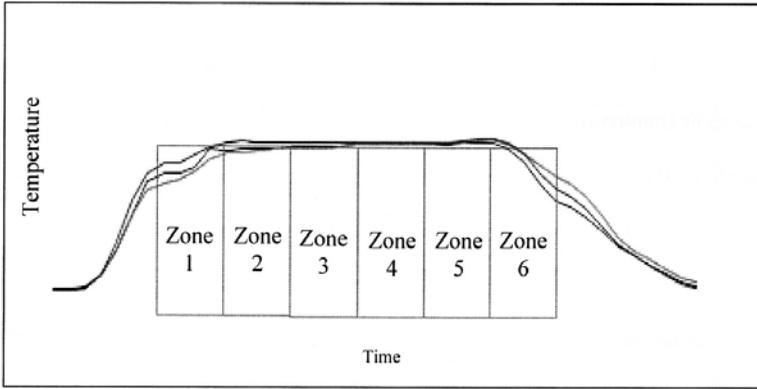
Figure 3. Temperature in each zone of the oven.

Figure 4. Temperature meter.

Table 2. Temperature measurement results for each zone.

Conveyer Speed (mm/min)	Temp (Zone)					
	1	**2**	**3**	**4**	**5**	**6**
170 (Current)	Temp OK	Temp OK	Temp OK	Temp OK	Temp OK	Temp OK
180	Temp OK	Temp OK	Temp OK	Temp OK	Temp OK	Temp OK
190	Temp drop	Temp OK	Temp OK	Temp OK	Temp OK	Temp drop

$$\text{Productivity} \quad = \frac{Output}{Input} \qquad \text{.... (5)}$$

According to the 9 days of data collected from the actual production processes prior to the adjustment, a conveyer belt speed of 170 mm per minute produced a total of 38,969 work pieces over 73.05 hours, and the average productivity (substituted in Equation 5) was 533 pieces per hour. After adjusting the speed to 180 mm per minute, the total number of work pieces produced

over 41.65 hours was 23,208 pieces, and the average productivity rate was 557 pieces per hour (5-day data collection).

Design of a heat loss reduction device

A device was designed to reduce heat loss in the front part of the oven, as the height of the 1st position of the current device (shown in Figure 5) is incorrect, causing a temperature loss in the oven due to the over-rapid turning of the fan heaters in zone 1. Thus, the temperature in zone 1 is inconsistent with the specifications. Also, the 2nd position presents an inflow of cooled air from the air conditioners, thus resulting in a temperature in zone 1 which is inconsistent with product specifications. The design of the device (shown in Figure 6) increased the height of the 1st position, in order to improve the circulation of hot air in the oven, thus reducing the rapid outflow of hot air. The device designed for the second position was used to seal the area where an inflow of cool air occurred, in order to reduce temperature losses in zone 1. Employing these devices reduced the losses of heat, which then flow out to workers, by up to 2.1 Celsius.
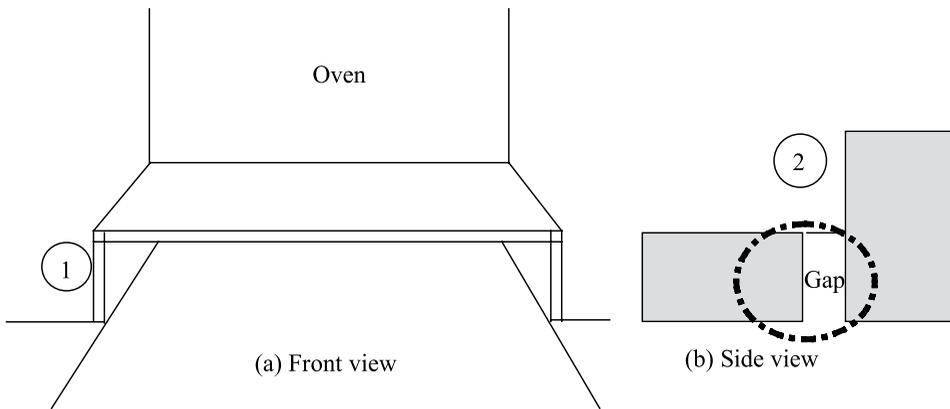

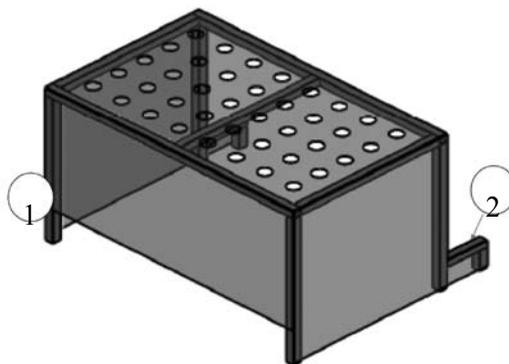**Figure 5.** The current heat loss reduction device (a) Front view (b) Side view.

Figure 6. New heat loss reduction device.

Design of work piece curing equipment

A detailed study of the specifications showed that the height in the oven is 120 mm. Presently, there are two types of work piece curing equipment, these being: a first type employed to cure up to 210 pieces, and a second type employed to cure up to 270 pieces. The equipment cannot be operated together with adhesive curing. In reality; however, curing require the same oven used at the same temperature.

A design allowing for curing equipment to be used together with adhesive curing equipment was produced, in which the upper part was used for work piece curing and the lower part for adhesive curing, after arm coil assembly. This design can load 5 adhesive filled work pieces in the lower part of the oven, as shown in Figure 7.
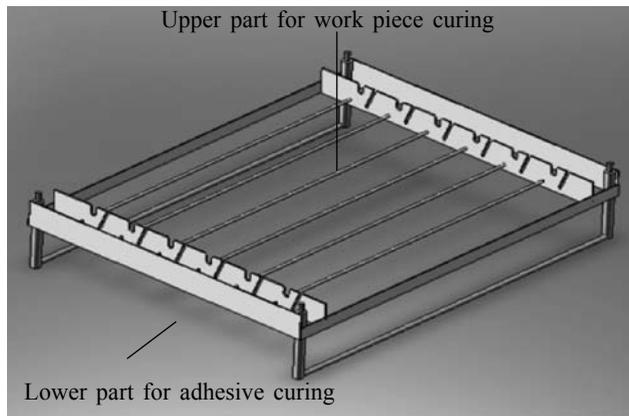

Figure 7. Work piece curing equipment utilization

The designed equipment was employed in the actual production process, and an impact assessment found that this equipment can be used at the same time as the adhesive curing process, after arm coil assembly has been completed, and that there are no adverse impacts on product quality. In the experiment, one of the ovens employed for work piece curing could therefore be turned off, and this will save 90,604.80 Baht per month (details of the calculation for this process are shown in economic analysis part). Furthermore, this equipment helps to increase the number of cured work piece, from a previous number of 210, to 336 pieces, and can be used for all products in the work piece curing process.

ECONOMIC ANALYSIS

By utilizing the work piece curing equipment, one of the curing ovens can be turned off, thus saving electricity as follows:

1 unit of electricity   = 1000 watt × 1 hour   .... (6)
Monthly electricity bill = Monthly use of electricity (units) × Electricity

rate per unit   .... (7)

Payback period (years) = Cost of an investment / Annual return   .... (8)

where:

Electricity costs = *** Baht/unit

Oven's electricity usage = *** kVA

Conveyer belt speed = 180 mm. / minute and the curing time of the oven cycle = 44 min.

The manufacturing process operates for 22 days, then the ovens are turned on for 24 hours (the ovens are not turned off during the shift rotation)

Purchase of 10 sets of equipment = 15,515 Baht

*** Certain information has been omitted for confidentiality.

Calculate the units of electricity by substituting in equation 6 and 7. The electricity costs saved 90,604.80 Baht/month. Payback period substituted in equation 8

$$= \frac{15,515}{90,604.80 \times 12} = 0.014 \text{ years, or approximately 6 days}$$

CONCLUSION

From the research held on energy consumption during the arm coil assembly process, the aim of which was to propose a method to reduce this consumption, it can be concluded as follows: First, the speed of the oven conveyer belt should be increased. The proper speed required for the process is 180 mm per minute, which does not affect product quality and reduces the oven cycle time for curing from 47 to 43 minutes; increasing average productivity from 533 pieces/hour to 557 pieces/hour. Second, a device designed to reduce heat loss should be used. This device reduces heat lost from the oven by 2.1 Celsius. Third, a work piece curing equipment design should be used that allows it to be operated together with the adhesive curing oven after the arm coil assembly process. In the research, the equipment was employed in the actual production process, and defect monitoring was also carried out. By utilizing the this aid equipment in the process, one of the ovens can be turned off, thus saving 90,604.80 Baht's worth of electricity per month, with a payback period of 0.014 years or approximately 6 days. The use of this equipment also results in an increase in the number of work piece that can be treated after curing, from 210 pieces to 336 pieces, and can be used with other products in the work piece curing process.

REFERENCES

P.Moolla, and R.Chompu-inwai. 2010. Application of Cleaner Technology and Experimental Design for the Reduction of Chemical Substance Consumption in the Hard Disk Drive Arm Coil Assembly Process. In Proceeding of The 40th International Conference on Computers and Industrial Engineering (CIE40), Japan, 26- 28 July 2010. The Awaji Yumebutai International Conference Center, Awaji Island, Japan.

Provincial Electricity Authority. 2002. Electrical Energy Saving in Industrial Manufactures. Sai Jai Faifa Journal.

S.Tangpothitham, A. Prasertsit, K.Tubtimtong, and S. Tantaweewong. 2008. A Study of Electrical Energy in Concentrated Rubber Latex Production Process. p.529-534. In proceeding of Industrial Engineering Network Conference, Thailand. 20-22 October 2008. Thailand.

W.Saelee and P. Kleubwannarat. 2008. Results of Electrical Power Saving through Insulation of Spiral Heaters for a Plastic Mold Casting Machine for Industrial Work. p.548-553. In proceeding of Industrial Engineering Network Conference, Thailand. 20-22 October 2008. Thailand