Application of Cleaner Technology Concepts in the Arm Coil Assembly Process of Hard Disk Drive Manufacturing

Rungchat Chompu-inwai and Premchai Moolla

***Abstract*— The objectives of this research are to improve raw material and energy consumption efficiency, as well as reduce defects and the use of chemicals in the arm coil assembly process of hard disk drive manufacturing in the case study company by applying the Cleaner Technology concepts. The four main sequential steps used in this research were: (1) pre-assessment, (2) assessment, (3) feasibility study, and (4) implementation. In the first step, raw data, such as process flows, raw material usage and defects data were collected. In the second step, the loss during production and causes of loss were analyzed. Opportunities to reduce raw material, chemical and energy wastage could then be recommended. The next step was to evaluate the feasibility and potential benefits of a particular Cleaner Technology opportunity. Finally, in the last step, after a thorough evaluation and implementation of the opportunities to apply clean technology, the results showed that Arm Coil defects could be reduced by improving the production process using the ECRS technique. ECRS stands for Eliminate, Combine, Rearrange and Simplify. This improvement reduced arm coil defect rates from 0.48% to 0.15%, thus saving approximately 139,638 Thai Baht per month. In addition, production stoppage decision made by workers was used to increase employee involvement in defect detection. Allowing workers to participate in such a decision was an effective way to reduce defect rate and could motivate workers to produce a better quality job. This resulted in arm coil defects reducing from 0.41% to 0.025%, with about 74,562 Thai Baht per month saving. Additionally, an increase in the efficiency of electricity consumption occurred, by increasing the speed of the infrared oven conveyor belt, improving average productivity from 533 pieces/hour to 560 pieces/hour, without adversely affecting product costs and quality, thus producing products of up to the value of 206,242 Thai Baht per month. Furthermore, the new 2-layer curing equipment was designed, developed and used. The upper layer of the equipment was used for arm curing and the lower layer was used for arm coil curing. The result of using such equipment led to a saving of approximately 25,502 Thai Baht per month in electricity costs, without affecting product quality. The outcome of these Cleaner Technology applications was that total costs of approximately 239,702 Thai Baht per month were able to be saved.**

***Index Terms*— Cleaner Technology, Hard Disk Drive, Defect Reduction, Efficiency Improvement**

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I. INTRODUCTION

In hard disk drive manufacturing industry, it is common to find the production of small parts 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, and each process step incurs a considerable number of losses during production. The ineffective use of raw materials, energy and chemicals, as well as losses incurred during processing, cause higher than expected production costs. The use of Cleaner Technology is a strategy to continuously improve the production process, so as to increase the effectiveness of production and the use of resources [1], [2]. Thailand has adopted Cleaner Technology applications in order to be consistent with government policies, such as the Industry Restructuring Plan published by the Ministry of Industry, and the Nation’s Pollution Prevention Program, published by the Ministry of Science and Technology [3], [4]. Furthermore, the application of Cleaner Technology provides foundation in moving towards Environmental Management Standard ISO 14000, a standard which will enable Thailand to compete effectively with industries and businesses internationally [2], [3], [5].

The case study company is located in the Northern Industrial Estate Zone, Lamphun province, Thailand. The products this company produces are membrane switches, magnetic coil assemblies and optical fiber components. This research was conducted at the Magnetic Coil Assembly Department, where production consists of an MCO process, a winding coil assembly process, an arm coil assembly process, and a PCCA hook up process. The products are then finally delivered to the customers, for assembly of the hard disk drives. According to consultation with the case study company and other concerned parties, the case study company pays a significant amount of attention on the arm coil assembly process for hard disk drives, as the process incurs high internal failure costs when compared to other processes. Internal failure costs incurred when the product produced is inconsistent with the required standards, for example product repairs, defects, repetitive work etc., thus incurring higher costs. Production costs in the arm coil assembly process for hard disk drives tend to be high due to the substantial use of raw materials, energy and chemicals

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during the production process. In addition, production also generates defects during each stage of the process. As a result, the case study company wished to pay attention to reducing such losses. This research therefore, introduced the concept of adopting Cleaner Technology principles, in order to solve these problems.

From the literature review, up to now, many industries have adopted the concepts of Cleaner Technology, as they aim to employ these tools to increase energy efficiency and reduce chemicals and raw materials usage, as well as the incidence of defects, all of which will lead to lower production costs. For instance, [6] applied Cleaner Technology to reduce the defects experienced in the electronics production process. First, a pre-assessment was conducted to gather useful information, followed by an assessment on the causes of problems. Later, technical, economic and environmental feasibility studies were carried out. These resulted in defects to the value of 43,890.46 Thai Baht per month being saved, with a payback period of 0.48 year. Similarly, [7] utilized Cleaner Technology concept using similar approach. Five improvement opportunities were identified as having potential for improvement, these being: on-site reuse, technological changes, raw material changes, good housekeeping and product changes. Economic savings were achieved in water, energy and material usage. In addition, [8] also applied Cleaner Technology using similar sequential steps. This project included the conducting of in-plant assessments using a tailor-made tool for Cleaner Technology benchmarking. Typical assessments indicated potential water savings of 78%, with chemical savings of approximately 30%.

II. Methodology for Cleaner Technology Implementation

The application of Cleaner Technology is comprised of four sequential steps [1], [3], as follows: (A) Pre-assessment, (B) Assessment, (C) Feasibility Study, and (D) Implementation and Monitoring. In this research, product A was studied, as it had the highest production rate and the case study company was interested in studying it as a pilot study and later applying the methodology to other products. Brief production process is shown in Fig. 1.

A. Pre-assessment

A pre-assessment is conducted to gather useful information. Pre-assessment consists of four sub-assessment; Technical assessment, Economic assessment, Environmental impact assessment, and Pre-assessment conclusion.

1) Technical Assessment

This assessment is carried out by using Internal Benchmarking, which is to compare key factors against the best practice from past production. The best index, the index in the month in which the raw material consumption for the processed products is lowest, is calculated for a technical percentage.

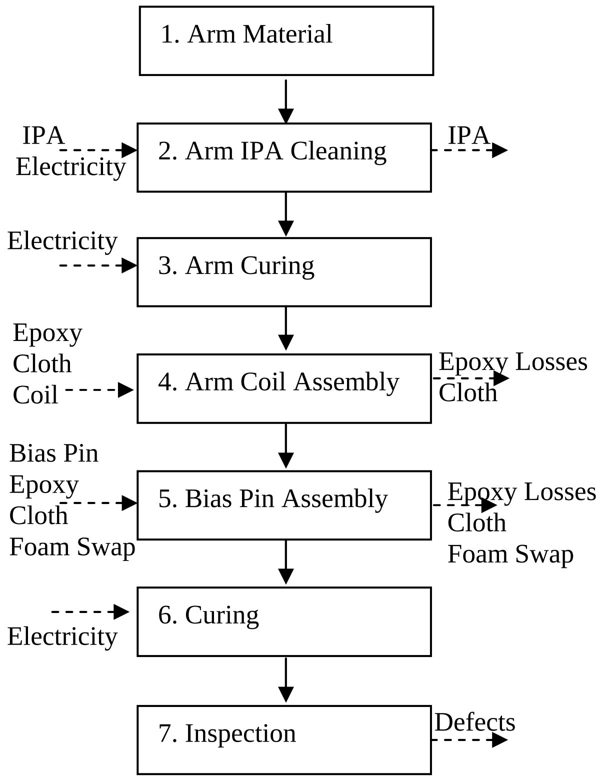

Fig. 1 Arm coil assembly process for product A

2) Economic Assessment

This assessment is conducted to reveal the related costs of each index, and to calculate the costs the manufacturer can save, provided that the performance is as good as that in the best month.

3) Environmental Impact Assessment

This is used to determine the impacts of both pollution and defects created during production process activities on the environment, and assesses the quantity of pollution that occurs (Q), the effects on the environment of each type of pollution (E), and pollution dispersion (D).

4) Pre-assessment Conclusion

The results of the pre-assessment derived from technical, economic and environmental assessment of the indexes used in the production processes, are identified using a scoring range to determine the significance of problems found in the company, and weighted against all three effects. The averages are then weighted in line with the significance given to the problems by the case study company.

After the technical, economic, and environmental aspects were weighted, the economic aspect showed the highest weighted average of 3, as the case study company gave priority to a reduction in production costs. Technical and environmental topics were given the same weighted average of 2. As results, *defects problem was ranked number 1*. Electricity and epoxy consumption was the second highest. The consumption of Bias Pin material and IPA substance, foam swap and clean cloth, were third and fourth respectively, and the last was arm coil material consumption (Table I). The research; therefore, opted for those defects which showed the highest score, as the top priority for application of Cleaner Technology, with the consumption of electricity and epoxy as a secondary priority, possibly for further study and in the future.

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Table I Topics prioritization

Topics	Technical (W1) = 2		Economic (W2) =3		Environmental (W3) = 2		Total	Priorities
	Score	Weight	Score	Weight	Score	Weight		
1.Arm Coil Material	1	2	1	3	2	2	7	5
2.Bias Pin Material	2	4	2	6	1	2	12	3
3.Electricity	2	4	1	3	3	6	13	2
4.Defects	3	6	1	3	3	6	15	1
5.IPA	1	2	1	3	3	6	11	4
6.Epoxy	3	6	1	3	2	4	13	2
7.Foam Swap	3	6	1	3	1	2	11	4
8.Clean Cloth	3	6	1	3	1	2	11	4

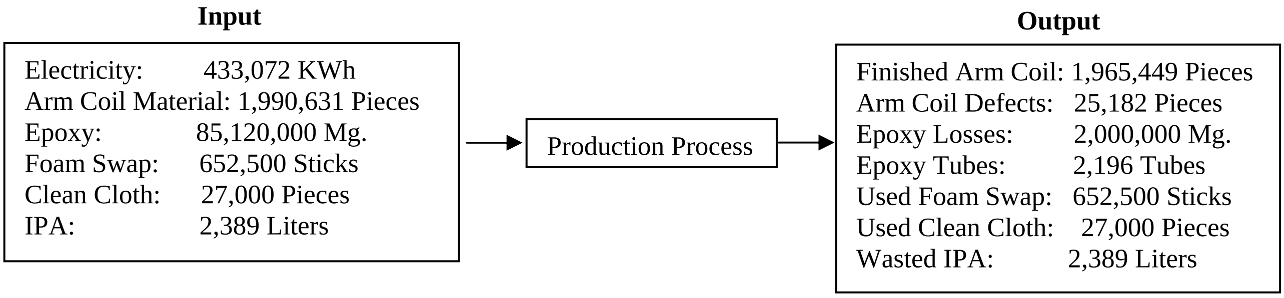

Fig. 2 Material balance of arm coil assembly for product A

B. Assessment

In this assessment, a flow chart of materials used during arm coil assembly, and a chart of materials or the energy balance found within the production unit in question, are produced (Fig. 2), in order to reveal the material and energy losses for each unit. The area or unit which incurs the most loss is then assessed in order to identify causes, as well as to select a viable Cleaner Technology for implementation. The results of this step are explained as follows.

1) Material Balance in Arm Coil Assembly

According to the data collected for Product A during March and April 2009, it was found that the consumption of arm coil used was 1,990,631 pieces, the electricity used for curing the work pieces was 433,072 KWh, the epoxy used in the production process was 85,120,000 mg. (2,196 tubes), the foam swap and clean cloth used for excessive epoxy cleaning was 652,500 sticks (1,305 packs) and 27,000 pieces of cloth (45 packs) used, respectively. After the process, it was found that arm coil defects during the production process amounted to 25,182 pieces, wasted IPA substance use was 2,389 liters, epoxy lost from excessive epoxy cleaning was 2,000,000 mg. (25 tubes), empty epoxy tubes found was 2,196 tubes, used foam swap was 652,500 sticks (1,305 packs), and clean cloth used was 27,000 pieces of cloth (45 packs), as shown in Fig. 2

2) Arm Coil Defects

The defects can be divided into two categories. The first category is defects occurring during the production process, in which the production process itself causes the defects. The second category is defects which occur outside the production process; defects caused by other processes or from a previous process which, when feeding raw materials into the production process, generates waste or further defects. The first five defects are defects in the 1^{st}, 2^{nd}, 3^{rd}, 4^{th} and 5^{th} positions, as shown in Fig. 3

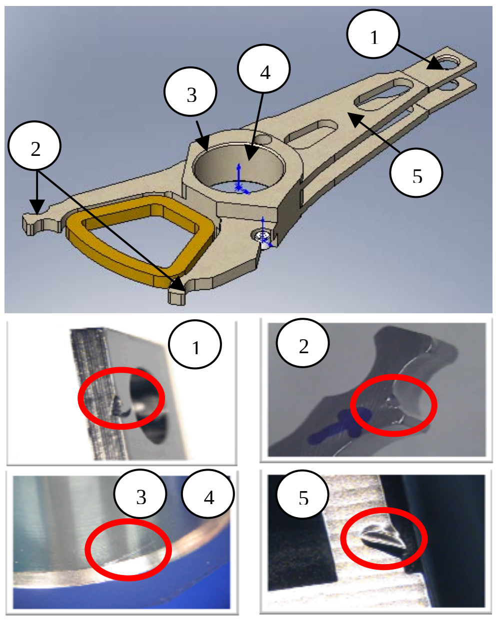

Fig. 3 Defects on the product

3) Electricity Consumption

When assessing electricity consumption, this can be divided into two categories for the ineffective use of electricity. The first category is the ineffective use of machinery at full capacity. The second category is the lack of supporting equipment. Fig. 4 shows the ineffective electricity consumption for the curing process causing by the ineffective use of machinery.

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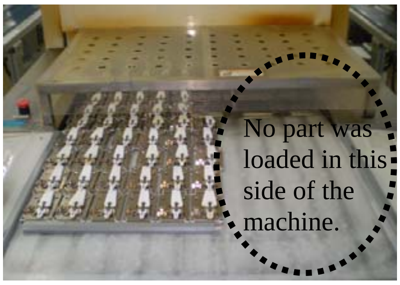

Fig. 4 Ineffective electricity consumption

C. Feasibility Study

The objective of this step is to evaluate the feasibility and potential benefits of a particular Cleaner Technology proposal. The feasibility study is conducted in three main aspects; Technical, Economic, and Environmental. Then, the Cleaner Technology proposals were assessed and ranked.

1) Technical Feasibility Study

This study aims at determining the appropriateness of the proposals, by evaluating the technical effects on production.

2) Economic Feasibility Study

This study aims at determining the cost-effectiveness of the proposed Cleaner Technology improvement opportunities, by comparing costs incurred with financial inputs and outputs.

3) Environmental Feasibility Study

This study aims at determining both positive and negative effects on the environment.

4) Cleaner Technology Proposal Ranking

The results of the technical, economic and environmental feasibility studies are assessed, in order to rank the appropriateness of implementing a Cleaner Technology proposal at appropriate implementation stages.

D. Implementation and Monitoring

In this stage, the implementation is carried out, collecting data with respect to both the pre- and post-application of the Cleaner Technology.

III. IMPLEMENTATION AND RESULTS OF CLEANER TECHNOLOGY APPLICATION

The results from the pre-assessment step showed that defects problem was ranked number 1. Electricity and epoxy consumption was the second highest. The research; therefore, opted for those defects which showed the highest score, as the top priority for application of Cleaner Technology, with the consumption of electricity and epoxy as a secondary priority. The implementation and results of Cleaner Technology applications are as follows:

A. Production Process Adjustment

One of the causes of the arm coil defects was from the raw materials, especially during the arm coil assembly process. As a result, the researcher added the inspection step before feeding the arm into the production process.

In addition, in order to reduce defect rate, process control and improvement activity are vital. Control of the production process consists of managing the total process so that it creates a level of quality that conforms to the design. First step is to creating a work flow, setting operation standards and training operators [9]. ECRS concept was applied to improve the process flow and operation standards. ECRS stands for Eliminate, Combine, Rearrange and Simplify. First, ECRS was applied to the arm coil inspection task assignment, which could be decomposed into 15 work elements (Fig. 5), in order to balance the line, whilst maintaining the same number of workers. Table II compares the task assignment of seven operators before and after the ECRS application. After the implementation, the workload of the operators was balanced.

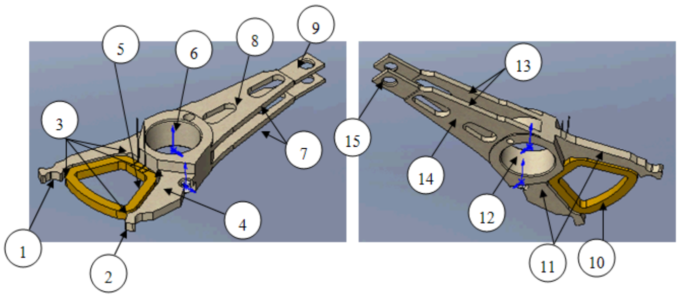

Fig. 5 Arm coil inspection work elements

Table II Task assignment in the arm coil inspection process

Operator	Arm Coil Inspection Position	
	Before	After
1	1	1
2	2	2
3	3	3
4	5,10	4
5	4,11	5
6	6,12	6
7	7,8,9,13,14,15	7

Furthermore, ECRS was also applied on arm coil inspection and assembly process flow. Fig.6 presents the comparison of arm coil inspection and assembly process flow before and after the improvement. The improved process flow optimized the worker workload while reduced defect rate.

Using these improvements resulted in a reduction in the number of defects found during the arm coil assembly process from 0.48% to 0.15%, thus saving 139,638 Thai Baht per month.

B. Temporary Process Stoppage when a Defect Occurs

Production stoppage decision made by workers was used to increase employee involvement in defect detection. Allowing workers to participate in such a decision was an effective way to reduce defect rate and could motivate workers to produce a better quality job. Fig.7 shows the decision flow chart and the details are described below:

- When an arm inspection worker (process step 4) detected a defect, the worker informed the supervisor. The supervisor then undertook an MCO process to carry out further problem solving.
- When a pre-curing inspection worker (process step 7) detected an epoxy-related defect, the worker informed an arm coil assembly worker (process step 6), so that this worker could give detailed information to the supervisor for further problem solving.
- When a post-curing inspection worker detected a defect (process step 9), this worker informed the supervisor

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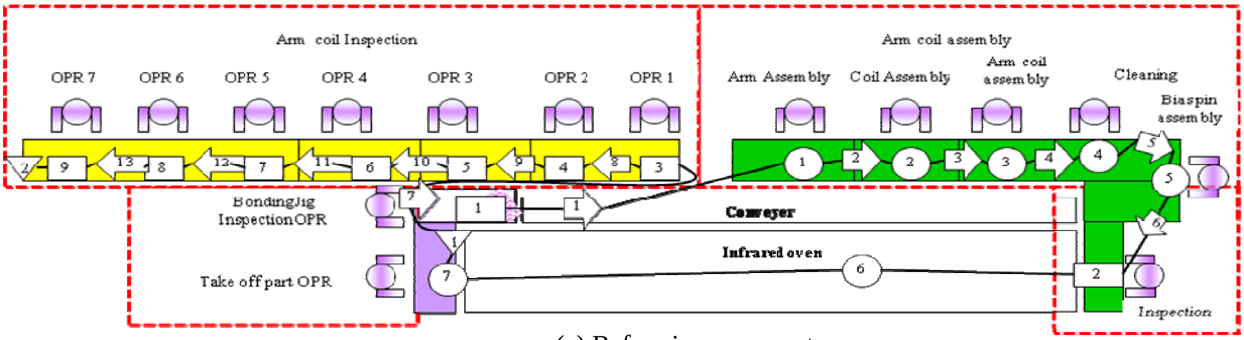
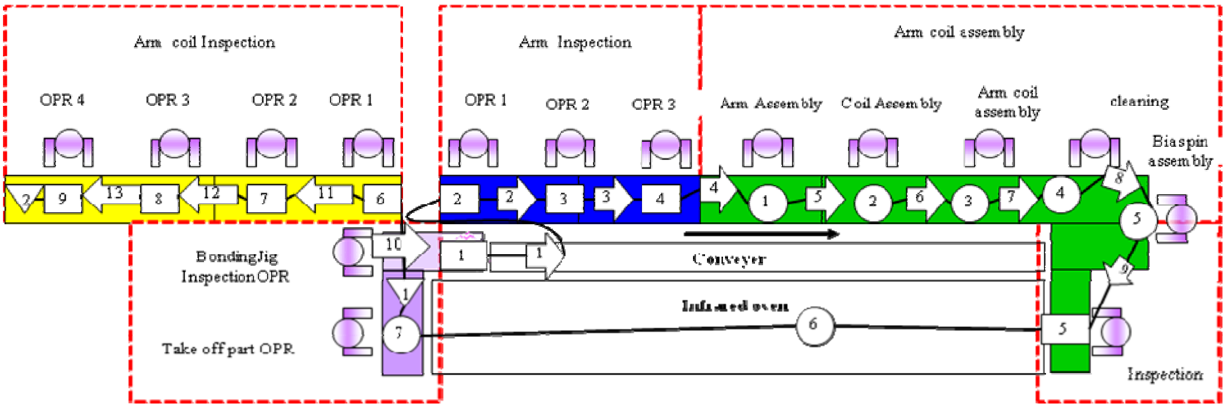


(a) Before improvement



(b) After improvement

Fig.6 Comparison of process flow before and after improvement

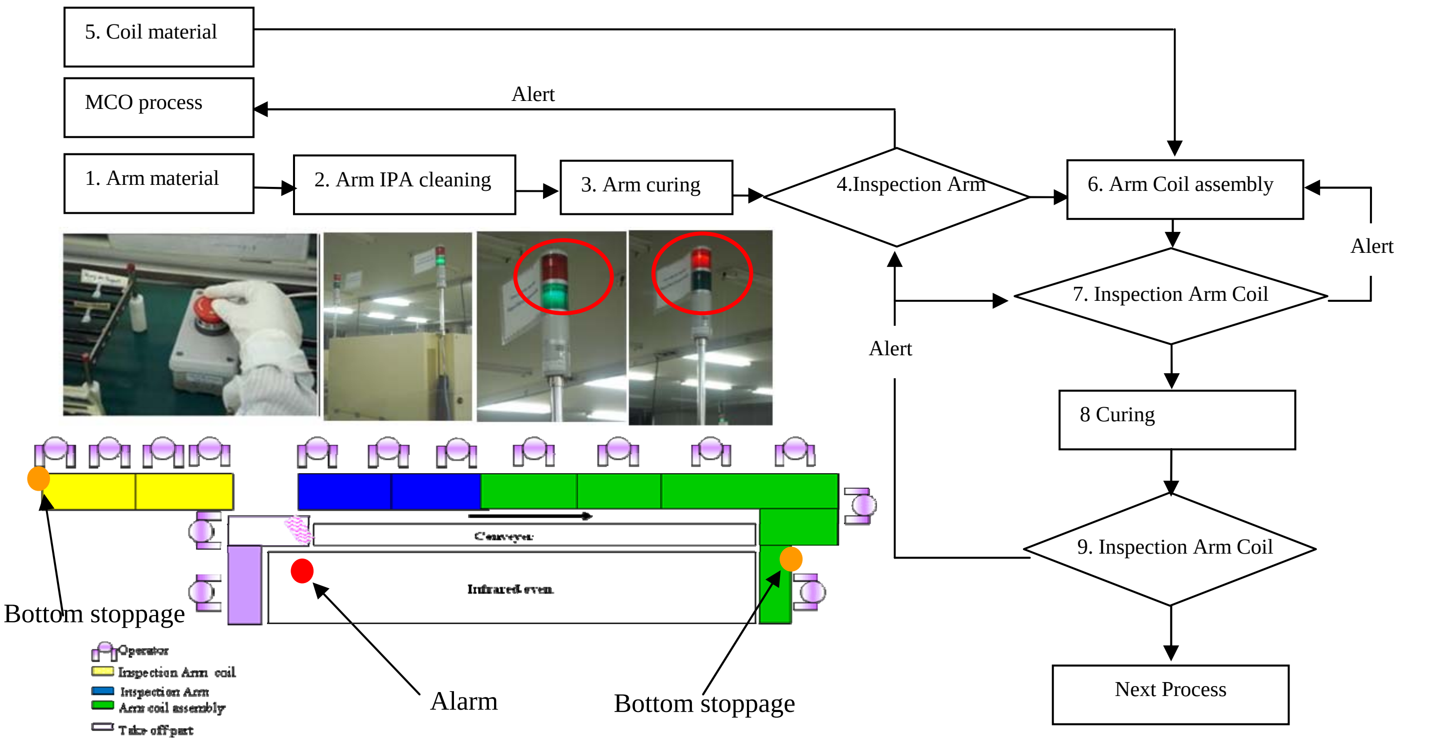


Fig. 7 Temporary process stoppage when a defect occurred in production

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about the type of defect found and the area where the defect was found.

- Epoxy-related defects were reported to a pre-curing inspection worker.
- Arm-related defects were reported to an arm curing worker.

The data collection revealed that epoxy-stained defects were the first ranked among the defects. The results of the inspection showed that the process of excessive epoxy cleaning and epoxy filling during arm coil assembly, caused defects in which the excessive filling of epoxy required further cleaning to take place. Excessive epoxy cleaning resulted in an epoxy-stained product. This was solved by changing the cleaning method, and this activity reduced the instance of epoxy-stained products from 0.41% to 0.025%, thus saving 74,562 Baht per month. Nevertheless, excessive epoxy cleaning still generated losses during the production process and this will therefore require further study.

C. An Increase in Speed of the Infrared Oven Conveyor Belt

During the normal production process, the speed of the conveyor belt used for curing the work pieces is normally 170 mm per min. In the design of experiment (DOE) study, after changing the speed to 180 mm per min., the productivity increased from 533 pieces/hour to 560 pieces/hour, without affecting product costs and quality, thus increasing products of 206,242 Thai Baht/month in value.

D. Design of Two-layered Curing Equipment

During the arm curing process, the infrared oven is normally opened resulted in ineffective electricity consumption for the curing process. The research team designed equipment for curing the work pieces, in which the upper layer was used for arm curing and the lower layer was used for arm coil curing (Fig. 8). Utilizing this equipment produced electricity savings of 25,502.40Thai Baht per month, without adversely affecting product quality.

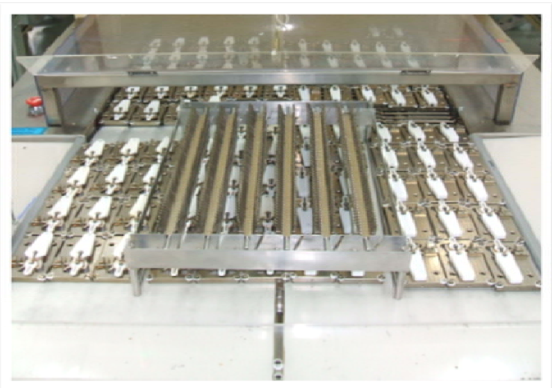

Fig.8 Two-layered curing equipment

IV. Conclusion

In this study, the Cleaner Technology was applied in the arm coil assembly process in the hard disk drives manufacturing company, in the order to improve energy consumption efficiency, as well as reducing defects. The results showed that arm coil defects could be reduced by improving the production process using the ECRS technique. This improvement reduced arm coil defect rates from 0.48% to 0.15%, thus saving approximately 139,638 Thai Baht per month. In addition, production stoppage decision made by workers was used to increase employee involvement in defect detection. This resulted in arm coil defects reducing from 0.41% to 0.025%, with about 74,562 Thai Baht per month saving. Additionally, an increase in the efficiency of electricity consumption occurred, by increasing the speed of the infrared oven conveyor belt, improving average productivity from 533 pieces/hour to 560 pieces/hour, without adversely affecting product costs and quality, thus producing products of up to 206,242 Thai Baht per month. Furthermore, a new 2-layer curing equipment was designed, developed and used. The upper layer of the equipment was used for arm curing and the lower layer was used for arm coil curing. The result of using such equipment led to a saving of approximately 25,502 Thai Baht per month in electricity costs, without affecting product quality. The outcome of these Cleaner Technology applications was that total costs of approximately 239,702 Thai Baht per month were able to be saved.

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