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To Lessen Copper Pin Loss in the Electronics Sector Evaluate and Enhance the Copper Pin Sorting Machine's Performance

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Abstract

This article discusses the enhancement of the copper pin alignment process through several methods: reducing the size of the fixtures, adjusting the angles of each fixture, and increasing the height of the copper pins at the joints of sections 1 to 4 while cutting the copper pins feeding into the stainless-steel tray. During a 26-day trial, each machine produced 7,176,000 copper pins from 2,990 boats. Machine 1 resulted in 33,961 defective copper pins, which is 0.47%, leading to an inability to produce 16,981 diodes. With an average price of 12 baht per diode, this caused a revenue loss of 203,772 baht. In comparison, Machine 2, which is a new model, had 21,176 defective copper pins, or 0.29%, affecting the production of 10,588 diodes and resulting in a revenue loss of 127,056 baht. Machine 3, also a new model, recorded 14,148 defective copper pins, which is 0.19%, equivalent to a loss of 7,074 diodes and a revenue loss of 84,888 baht. In terms of energy consumption, the first copper pin machine uses 720.72 Kwh, resulting in an annual electrical cost of approximately 3,012.61 baht. Both the new copper pin sorting machine 2 and machine 3 consume 288.288 Kwh, translating to an annual cost of about 1,205.04 baht each. This change significantly reduces copper pin loss and leads to electricity savings.

Keywords: Copper pin sorting machine, Copper pin, Boat, Diode, Power loss in the motor, Efficiency.

1 | Introduction

Most electronics companies accept orders from international clients as contract manufacturers of electronic goods [1]. Customers specify every aspect of the product, including design, raw materials, testing equipment,

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quality testing techniques, costs, quantity needed for each production run, and the total duration of production. During the factory's planning meetings, raw materials are prepared for manufacturing, and their quality and cost are confirmed. Policies and procedures for all production operations are also established. The engineering and production departments work together to plan the production process [2–4]. To ensure that the product meets the quality or specification tests specified by the customer, the engineering department must develop instruments for testing specific production stages. Each component requires a detailed work plan to ensure that employees complete their tasks accurately. Quality assurance and quality control measures are maintained from the initial stages of production through to the packaging of the product for customer delivery [5].

However, defective items may occur during the manufacturing process, ranging from partially assembled components to finished products. Certain production days can result in a significant number of defective products, requiring the production department to assign specific employees to address these issues. The preparation of raw materials, such as die, lead sheets, and copper pins, marks the first step in the welding process for the diode's internal structure [6]. Copper pins need to be fed into a sorting machine, which aligns the pins in preparation for assembly. Operating the copper pin sorting machine involves several complex processes that can confuse employees. Each step wastes time and consumes excessive electricity, while the machine's internal processes contribute to its deterioration. Additionally, problems with machine adjustments can further damage the copper pins. To reduce the loss of copper pins, further research has been conducted to propose improvements for creating a more efficient sorting machine [7], [8].

2|Materials and Methods

2.1|Procedure for Operation

Fig. 1 depicts a machine designed for sorting copper pins, which is used in a diode manufacturing facility. All copper pins arriving at the facility are packaged in clear plastic bags. Employees pour the copper pins into a stainless-steel tray located at the top of the machine [4], [9]. This tray is equipped with a motor-powered vibration system that arranges the copper pins in a stair-step fashion. The pins move in a circular pattern and ascend to the topmost step before exiting the stainless-steel tray into four designated sections, each featuring linear grooves. The copper pins descend through the grooves in Sections 2 to 4 in succession. They are then transferred to a fixture boat, which shifts left and right to accommodate the dropping pins from Section 4. Once the boat is loaded with copper pins, it is propelled out of the sorting machine. The motor also returns some of the falling pins back to the stainless steel tray above, repeating the initial process [6], [8]. When the supply of copper pins is nearly depleted, personnel refill the stainless steel tray with new pins [10]. The copper pin sorting machine operates using three motors.

The motor responsible for returning copper pins to the stainless-steel tray has the following specifications: 0.15 A, 6 W, 220 V, with a quantity of one unit. The motor driving the boat is rated at 0.454 A, 40 W, 220 V, also with a quantity of one unit. Additionally, there is another motor on top of the stainless-steel tray, which is rated the same as the first: 0.15 A, 6 W, 220 V, with one unit in use. A single motor rated at 0.15 A and 220 V consumes 0.462 kW of electricity when operated for 14 hours across two shifts in one working day. Since there are two motors with ratings of 0.15 A, 6 W, and 220 V, the total electrical energy consumption for these motors is 0.924 kW over the same period. The single motor rated at 0.454 A and 220 V results in an energy loss of 1.386 kW during 14 hours across two shifts in one working day.

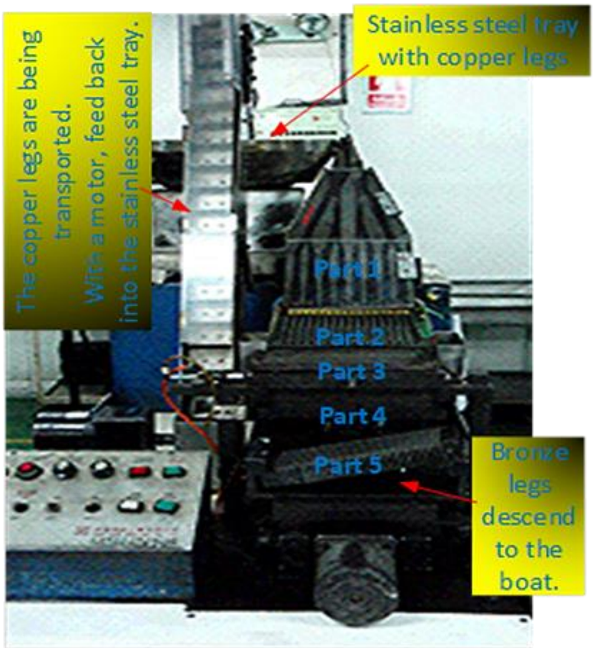

Fig. 1. Displays conventional copper pin placement equipment at an electronics production facility.

The experimental plan calls for 26 days each month to run three copper pin sorting machines, comprising both new and ancient models. Make a note of the experimental results and do a summary analysis. The fixture's height and measurements for the traditional copper pin sorting machine are as follows. Section 1 is 37 cm high, 46 cm long, and 46 cm wide. It is shaped like an obtuse triangle. Section 2 measures 42 cm in length, 46 cm in width, and 28 cm in height. Section 3 is 28 cm in length, 46 cm in width, and 25 cm in height. Section 4 is also 28 cm in length, 46 cm in width, and 25 cm in height.

The copper pins emerged from the stainless-steel tray and were positioned until they reached Section 1, which took approximately 18 seconds. The copper pin then travels from Section 1 to Section 2, reaching the upper edge at the junction of Sections 1 and 2 in about 35 seconds, plus an additional 4 seconds for the time taken to pass through the junction. In total, this segment takes 39 seconds to complete. Next, the copper pin advances from Section 2 to Section 3, reaching the upper border of the junction between these two sections in approximately 25 seconds, plus an additional 4 seconds to cross the junction between Sections 2 and 3. Thus, the total time for this transition is 29 seconds.

Following this, the copper pin moves from Section 3 to Section 4, reaching the upper edge of the junction between these sections in about 14 seconds, along with 4 seconds for the average time to pass through the junction between Sections 3 and 4. Consequently, this section takes a total of 18 seconds. The copper pin then travels from Section 4 to Section 5, ultimately reaching the upper edge of the junction, which has an angle. This transition takes approximately 14 seconds, with an additional 0.043 seconds required for the copper pin to fall to the bottom. The total time for this phase is thus 14.043 seconds. The solenoid causes the bot to move back and forth 40 times in 75 seconds, resulting in 2,400 copper pins being dispensed per bot. After this, the solenoid pushes the bot out of the machine and arranges the copper pins, which takes about 10 seconds. The copper pins that do not fall into the boat are delivered back to the stainless-steel tray above until they are moved out, a process that takes around 50 seconds. In total, the copper pin sorting machine process lasts 253.043 seconds, which is equivalent to approximately 4.217 minutes per cycle.

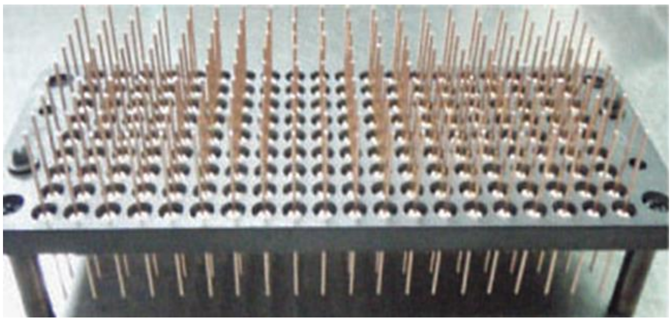

Fig. 2. The container was filled with the assembled copper pins.

Analyze the operating process of the traditional classic Copper pin sorting machine in *Fig. 1*. Design workers are forced to make visual guesses since they are unable to. determine how many copper pins are poured into the stainless-steel tray each time. Three copper pin sorting devices are available. According to the findings De Simone et al. [3], Bhattacharya and Cloutier [7], despite ongoing preventive maintenance, the copper pins continue to sustain damage in the same areas.

The following explains the situation with the copper pins that are not packed into the boat:

I. The copper pins are returned to the bottom tray and are then transferred to the upper stainless-steel tray as before. This transfer process takes approximately 50 seconds.

II. The copper pins fall into a designated dish below, which is intended to catch them. The distance from the collecting tray in the upper section to the bottom of Section 5 is around 45 cm, requiring staff to bend down to lift the tray and dump its contents into the stainless-steel tray above. Employees find this task cumbersome and are not very agile while performing it.

III. If the copper pins fall into the bottom tray and the employee bends down to lift the tray for pouring into the stainless-steel tray, some pins may drop onto the floor, where there is no tray to catch them. The employee must then gather these fallen copper pins individually, as they are now dirty. The pins must be cleaned before they can be returned to the original process.

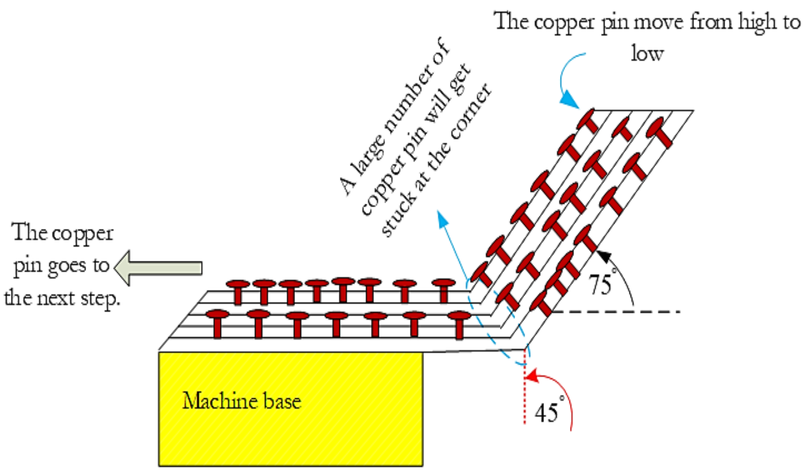

Fig. 3. Many copper pins became trapped as a result of the original 45-degree corner.

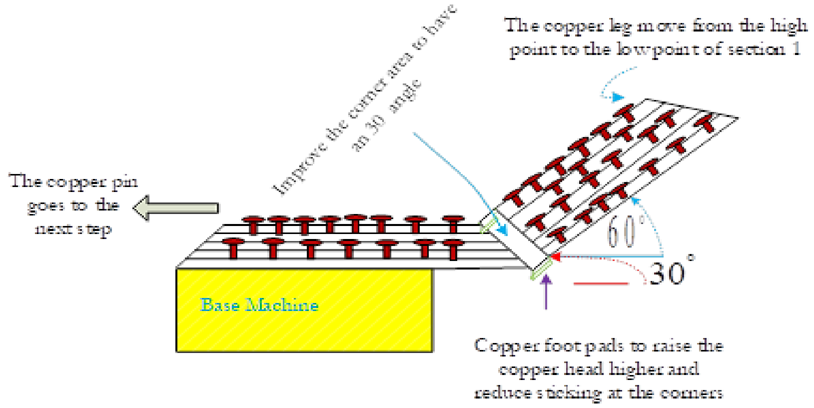

Fig. 4. Displays the updated Section 1 and the newly designed corner joint area.

Ductile cast iron is used to make parts 1 through 5. Two friction coefficients are produced by the movement of the copper foot in contact with the ductile cast iron surface: 0.29 kinetic and 1.05 static. The frictional force is independent of the copper foot's speed because it acts in the opposite direction of its movement [11–13].

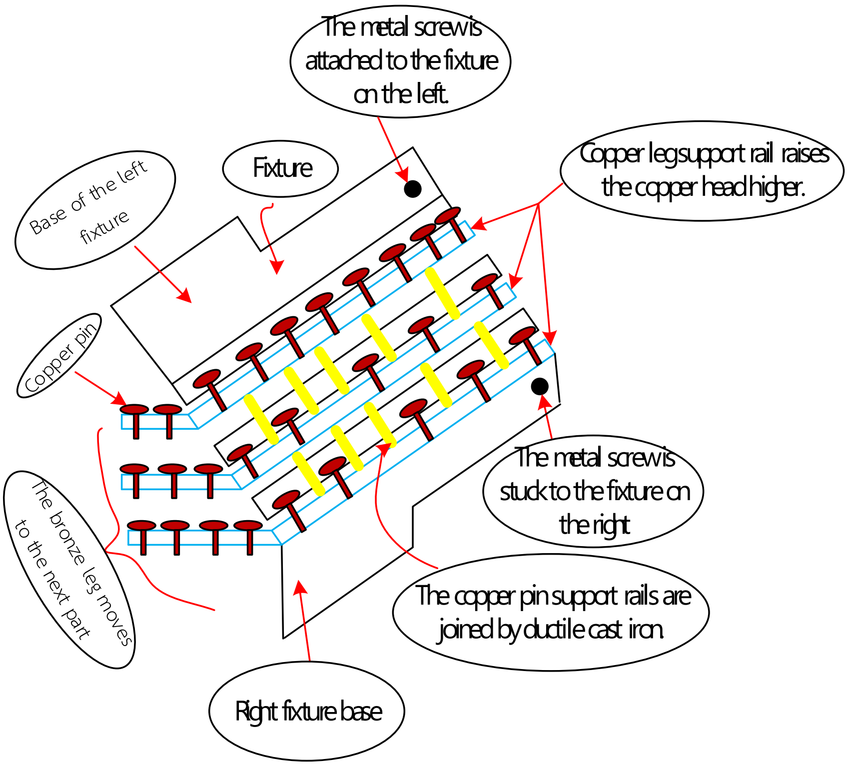

Fig. 5. The redesigned corner joint fixture features.

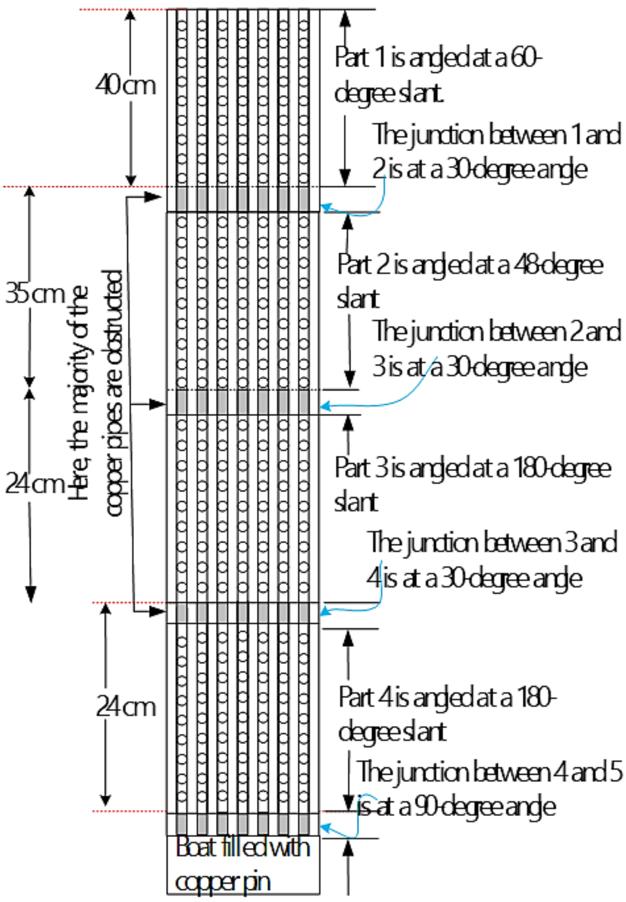

Fig. 6. Modifies the angles and joints of sections 2 through 5 in a new way.

Fig. 6 illustrates the following:

I. Section 1 measures 40 cm in length and 40 cm in width, has an obtuse triangle shape, and is 40 cm tall.

II. Section 2 measures 35 cm in length, 40 cm in width, and 30 cm in height.

III. Section 3 has dimensions of 24 cm in length, 40 cm in width, and 27 cm in height.

3 | The Operating Process of the New Copper Pin Sorting Machine

Fig. 6 shows the operation of the new copper pin sorting machine. Identify the problem and conduct additional research [14]. Experiment by adjusting the angle values according to *Tables 1–5*, record the results, and create a flowchart similar to that in *Fig. 8*. This involves improving the slope levels of Sections 1 and 2, adjusting the angle levels at all joints except those in Sections 4 and 5, which should remain at a right angle. Additionally, a support mechanism for the copper pins at the joints should be provided, as illustrated in *Fig. 5*. This will raise the copper pins higher and prevent the copper heads from becoming trapped in the grooves at the joints of parts 1–3, which are the angled corners. If the copper pins are not inserted into the bot, they will fall into a clear plastic tray designed as an upper and lower drawer, thereby facilitating the work for employees. Workers can simply open the upper plastic tray drawer and place the copper pins on the upper stainless-steel tray. When the tongue is removed from the upper plastic tray, the copper pins will drop into the lower plastic tray drawer [12]. This method eliminates the need for a feedback mechanism, which previously required time to transport the copper pins back to the upper stainless-steel tray. It takes approximately 50 seconds per cycle for the copper pins to travel out of the stainless-steel tray. Consequently, a 0.15A, 6W, 220V motor is employed to transfer the copper pins back to the upper stainless-steel tray, reducing the motor's annual electrical energy loss by 144.144 kW.

Set to:

I. A is a standard copper leg product processed using the original type of Machine 1.

II. B is a standard copper leg product processed with new second-generation machinery 2.

III. C is a standard copper leg product processed with the latest third-generation machinery 3.

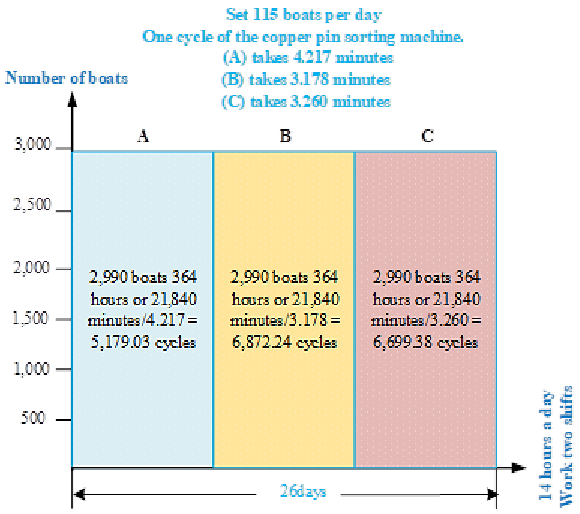

Fig. 7. A graph of the number of days and cycles for each of the three kinds of copper leg sorting machines is displayed.

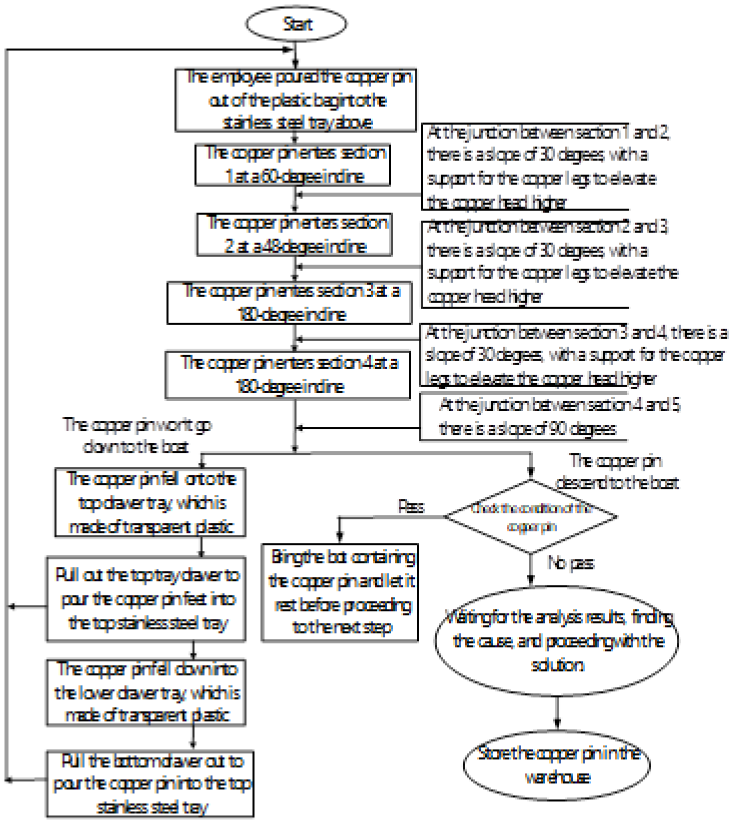

Fig. 8. The operation of the new copper pin sorting machine.

4 | Fill in the Table with the Experimental Results

Table 1. Machine 1, fig. 1 (26 working days).

Specifics	Copper Pins to Reach the Upper Edge Junctions	Moving for Copper Pin, Stuck	Number Copper Pins and Overall of Trial Days
Part1: 67 degrees Junction 1–2 38 degrees	203,143.41 Sec	4,853 workpieces	
Part2: 53 degrees Junction 2–3 38 degrees	159,438.96 Sec	3,105 workpieces	7,176,000 Pieces, 115 bands/day
Part3: 180 degrees Junction 3–4 38 degrees	324,466.58 Sec	3,218 workpieces	Total damaged copper pin from employing the straight pull pins at joints 1–5 is 11,176/26 days
Part4: 100 degrees Junction 4–5 90 degrees	81,092.43 Sec	0 workpieces	

Table 2. Machine 2 (26 working days).

Specifics	Copper Pins to Reach the Upper Edge Junctions	Moving for Copper Pin, Stuck	Number Copper Pins and Overall of Trial Days
Part1: 67 degrees Junction 1–2 38 degrees	203,143.41 Sec	4,853 workpieces	
Part2: 52 degrees Junction 2–3 38 degrees	159,435.96 Sec	3,105 workpieces	7,176,000 Pieces, 115 boats/day
Part3: 180 degrees Junction 3–4 38 degrees	82,466.88 Sec	3,218 workpieces	Total damaged copper pin from employing the straight pull pliers at joints 1–5 is 11,176 / 26 days
Part4: 180 degrees Junction 4–5 90 degrees	81,092.43 Sec	0 workpieces	

Table 3. Machine 3 (26 working days).

Specifics	Copper Pins to Reach the Upper Edge Junctions	Average Time Moving for Copper Pin, Stuck	Number Copper Pins and Overall of Trial Days
Part1: 60 degrees Junction 1–2 30 degrees	215,586.04 Sec	2,716 workpieces	
Part2: 48 degrees Junction 2–3 30 degrees	169,494.31 Sec	2,109 workpieces	7,176,000 Pieces, 115 boats/day
Part3: 180 degrees Junction 3–4 30 degrees	80,727.52 Sec	2,005 workpieces	Total damaged copper pin from employing the straight pull pliers at joints 1–5 is 6,830/26 days
Part4: 180 degrees Junction 4–5 90 degrees	80,392.56 Sec	0 workpieces	

Table 4. The electrical energy loss of machine 1, averaged over one year.

Working 26 Days, Average of 14 hr/Day	Electricity Loss (Kw-hr) 312 Days	Electricity Unit Cost 4.18 Baht/Unit/Tear
Motor 0.15A,6W,220V	144.144	602.521
Motor 0.45A,40W,220V	432.432	1,807.565
Motor 0.15A,6W,220V	144.144	602.521
Total	720.72	3,012.607

Table 5. The electrical energy loss of machine 1 and 2 are the same calculations averaged over a year.

Working 26 Days, Average of 14 hr/Day	Electricity Loss (Kw-hr) 312 Days	Electricity Unit Cost 4.18 Baht/Unit/Year
Motor 0.15A,6W,220V	144.144	602.521
Motor 0.15A,6W,220V	144.144	602.521
Total	288.288	1,205.042

Table 6. Characteristics of three machines arranged in copper feet.

26 Days	The Machine 1	The Machine 2	The Machine 3
Total number of copper pins fed into the machine	7,176,000 2,990 Boats	7,176,000 2,990 Boats	7,176,000 2,990 Boats
How many copper pins have been damaged?	15,460 of part1 9,375 of part2 9,126 of part3 0 of part4	8,853 of part1 6,105 of part2 6,218 of part3 0 of part4	5,716 of part1 5,427 of part2 3,005 of part3 0 of part4
Total number of damaged copper pins	33,961 or 0.47%	21,176 or 0.29%	14,148 or 0.19%

Table 6 for machine 1 illustrates the characteristics of a damaged copper pin, which is twisted and deformed. A 45-degree inclination caused several copper pins to become jammed. Workers had to use pliers to remove the pins from the groove, resulting in additional bending. In the case of machine 2, the copper pins are also twisted and malformed. The sloped section along the joint causes the motor to vibrate, preventing the red pin from moving at all. The third machine is twisted and malformed. Lower the slope level at the 30-degree joint,

increase the motor vibration force, and the copper pins move faster than in the second machine, although some of them become stuck.

5|Compare the Advantages and Disadvantages of the Three Machines

5.1|The Advantage of the Machine 1

At the joint between 1 and 4, the copper pins fully engage with the groove, resulting in increased motor vibration and speed for the copper pins.

Employees are accustomed to the traditional way of working.

5.2|The Disadvantage of the Machine 1

Friction is increased because the copper pins fully contact the grooves. Because of this, there is a significant chance that the copper pins will become lodged in the overlapping grooves.

The copper pins are at serious risk of being damaged. The copper pins are at serious risk of being damaged [13], [15]. Sometimes employees don't work effectively. Total cost of preventive maintenance for the system [10], [15]. Squandered time on a thorough system fix. The machine's assessment of improvement [11], [16].

5.3|The Advantage of the Machine 2

Reduce the size of fixtures 1–4, resulting in cheaper machinery expenses. Even though the slope and speed are lower than on the previous machine, the smaller fixture size compensates for the speed with a shorter distance. Joint fixings By raising the copper pins, 1-4 lessen friction and significantly lessen copper pin jamming. No time or electrical energy is lost, and there are no spare parts needed, when the copper pin conveyor system is cut into the stainless-steel tray. Lower the costs of preventive maintenance [13], [16–18].

5.4|Disadvantages of Machine 2

The copper pins should be raised higher at joints 1-4 to reduce motor vibration. Although this will cause the copper pins to move more slowly, there remains a risk of clogging at the joints. There is a potential for the copper pin to become trapped in the groove as it moves past the joint, but this risk is negligible. A solution to this issue is recommended based on the third machine's goal of reducing copper pin losses.

5.5|Advantages of Machine 3

Reducing the size of fixture components 1-4 lowers machinery costs. Although the gradient and speed are lower than those of the first machine, the smaller size of the fixtures compensates for the shorter distance.

The slope level in the joint area of 1-4 is lower than in machines 1 and 2. The fixture lifts the copper pins higher, resulting in fewer copper pin jams compared to both machines. The copper pin conveyor system is integrated into a stainless-steel tray, leading to no loss of time or electrical energy, as well as no need for spare parts. This design significantly reduces preventive maintenance costs. Overall, it significantly minimizes copper pin loss.

5.6|Disadvantages of Machine 3

Raising the copper pins higher at joints 1-4 is necessary to reduce motor vibration. This adjustment will slow down the movement of the copper pins, but it still carries a risk of clogging at the joints.

There is a possibility that the copper pin may become trapped in the groove as it moves past the joint, though this risk is negligible. To address this issue, it is suggested to modify the red pin paths in parts 1-5 and create a device to retrieve the copper pin if it becomes trapped.

Table 7. Probable diode production revenue loss.

	Machine 1	Machine 2	Machine 3
Total number of defective copper pins on the machine	33,961 or 0.47% 26 days	21,176 or 0.28% 26 days	14,148 or 0.19% 26 days
Number of diodes 1N4148 costs 12 baht each.	16,981 units *12 bahts	10,588 units *12 bahts	7,074 units *12 bahts
The opportunity to lose diode creation	203,772 bahts	127,056 bahts	84,888 bahts

In *Table 7*, the percentage of copper pin loss for machine 1 is 0.47%, for machine 2 is 0.26%, and for machine 3 is 0.19%, respectively. When producing diodes of type 1N 4148, priced at approximately 12 baht each, the damaged copper pins result in the inability to produce diodes. Therefore, the estimated revenue loss at this point for machine 1 is 203,772 baht, for machine 2 is 127,056 baht, and for machine 3 is 84,888 baht from a 26-day trial.

Fig. 9. The copper pin sorting machine was used to process the damaged copper pin sample.

6 | Recommendations

The procedure for the copper pin sorting machine was redesigned in the traditional workplace to investigate potential causes of copper leg damage. These include employees not following recommended procedures, technicians failing to adjust the equipment as intended, and occurrences that lack a known explanation. Damaged copper legs are a persistent issue that cannot be resolved and are collected for disposal. The costs incurred by the organization include transporting the copper pins, finding storage space, hiring personnel for storage, and managing the remaining worthless materials. Discussions have been held regarding manufacturing procedures, more precise preventive maintenance for the machines, and better preparation of spare parts.

7 | Conclusion

In the principles and methods section of the research article, it is stated that production costs for diodes can be reduced by developing a copper leg alignment machine. This innovation eliminates the need to transport copper legs to the stainless-steel tray, a process that originally relied on a 220V, 0.15A motor, which resulted in an average energy loss of 120.12 kilowatt-hours over 3,640 hours in one year. By removing the copper leg transportation system, all associated costs are eliminated. Additionally, the wear and tear costs of all equipment within the copper foot conveyor system have been reduced, thereby minimizing time lost and increasing employee productivity by alleviating their workload. The redesign of the copper leg conveyor system has improved efficiency compared to the old copper leg sorting machine. Results from a 26-day experiment showed that the first copper pin sorting machine processed copper pins with a defect rate of 0.47%, leading to a loss of opportunity to produce 16,981 1N4148 diodes, which equated to approximately 203,772 baht from a total of 7,176,000 copper pins. In contrast, the second copper pin sorting machine had a defect rate of 0.29%, resulting in a loss of opportunity to produce 10,588 1N4148 diodes, amounting to approximately 127,056 baht. Finally, the third copper pin sorting machine achieved a defect rate of 0.19%, leading to a loss of opportunity to produce 7,074 1N4148 diodes, totaling approximately 84,888 baht from the same quantity of copper pins.

Author Contributions

The authors read and approved the final manuscript.

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Availability of Data and Materials

Not applicable

Conflicts of Interest

There is no conflict of interest, according to the authors.

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