Prototyping a Fast and Precise Automation for Folding Vermicelli Process

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Abstract. This paper discusses about the design and experimental results for a precise automation system in folding vermicelli processes. The objective is to design a machine that can fold the soft and tangled flour sticks into the suitable shape that can be used in the drying box. The machine consists of four pneumatic actuators and microprocessors to perform that tasks automatically. Since there is a uncertainty on the weight of product, the effect of atmospheric humidity level, and the mixture of the vermicelli, we design the machine that can be adjusted, but still fast enough to replace a labor in this workflow. These designs are also tested with various folding technique. The spending time of the entire process is 23 seconds in order to complete the folding and dropping into testing box for the drying conveyor. The test result showed that only 0.5% of products are with defects in weight and shape.

1. Introduction
Vermicelli is the raw material which has the highest value, comparing with the same food type (such as noodle and pasta) [1]. Each year, Thai people consume vermicelli around 20,000 - 25,000 tons and export more than 3,000 tons [2]. Vermicelli is made of green bean and its process consists of 4 steps which are mixing, threshing flour, squeezing, and drying the vermicelli. From the industrial survey, there are the main 4 processes in drying and folding process that are time-consuming included (1) Cutting long line vermicelli into 34-37 cm (2) Weighting wet vermicelli products into 105 grams for 40-45 grams dried-products (3) Folding vermicelli into the packaging, and (4) Putting vermicelli in aluminium boxes in order to be used in drying process.

From the current survey, it was found that there are numerous staffs in vermicelli production in Thai industry [3]. The problem of using labour is difficult to control the factors such as speed, cutting accuracy, weighing, and dexterous in folding processes. Moreover, vermicelli is a food product which have to concern about food safety in terms of cleanliness such as matter of hair or microbials from staffs that can cause contaminations and microbiological infection. According to Thai Industrial Standards Institute, the standard of vermicelli (TIS. 444-2549) [4] has established with these criteria (a) a good vermicelli must have an appropriate ingredients (b) colour and size of the vermicelli are consistent (c) the product is clean, no physical contamination and scentless. (d) moisture should be below 12 percent by weight, and (e) the manufacturing process of vermicelli has to meet the industrial standards set [5]. These factors indicate that the vermicelli process is such a delicate and complicated that also required a high accuracy.
2. Overview of automation system

Automation system aims to reduce a number of staff in the production line. It is also help to increase the speed and accuracy of making product. However, there is still mandatory to have one staff to control 3-4 folding machines at the same time. The components of automation system before the drying process consist of 3 main parts; (1) Weighing and cutting system (2) Folding and transporting and (3) Conveying to conveyer belt as shown in Figure 1.

![Figure 1. System overview for the folding machine; (1) Weighing and cutting system (2) Folding and transporting and (3) Conveying to conveyer belt.](image)

The processes for the entire automation system consist of 5 steps as follows:

- A staff picks vermicelli from the raw material rack which has already been divided into a small section (Approximated length of 120 cm and width of 5 cm).
- A staff places vermicelli on the base of cutter which is equipped with a set of two force sensors in different height location to compute the individual weight at each point. This process is used to find the positions that can divide the same weight in each section of cutting. Because vermicelli normally has different density in each area and the middle part has the maximum thickness, this might result on the heaviest weight are in the middle if the plates have the same dimensions.
- Then a microcontroller is used to calculate the position of cutting. The cutting blade will move in a straight line driven by a linear actuator from the top of vermicelli. Hence, a cutting blade can cut a vermicelli into 3 pieces with similar weight.
- The vermicelli is then folded by pulling and pushing the plate that will be described in detailed in Section B.
- Folding and conveying the vermicelli will move into the position of the aluminum boxes. There will be a rectangular container of 22 chambers on a conveyer that moves with a constant speed of 0.36-0.45 m/s.

2.1. First Prototype of Vermicelli folding set

The prototype for weighting and cutting machine consists of three 100 x150 mm weighing pads, three force sensors, and supporting base for force sensors (Model: ARD2-2151. This weighing and cutting set was fabricated in order to demonstrate how much the weight changes for each force sensor before and after the cutting process. For the folding set, this designed system is aimed for fast and compact folding which can be installed in a limited area in production lines. This machine consists of pneumatic cylinder that can move in 3 axis (XYZ). Both systems are showed in Figure 2.
2.2. Testing of First Prototype of vermicelli folding set

The following procedures are taken in order to prove a concept of cutting blades on a series of cutting pads with force sensors.

- Use the 40-gram dry vermicelli, and soak for 5 minutes.
- Spread the vermicelli in a straight line (length~40 cm and width~5 cm).
- Place the vermicelli on the weighing set and record the values for each load cells.
- Separate the vermicelli by cutting blades and weight them again on each weighing plate. Then, each experiment is repeated for 3 times and the results after cutting are recorded and compared.

From the results, the weights on each pad are has slightly changed, which are within the acceptable range of ± 2 grams for the wet vermicelli. The concept of folding vermicelli consists of four steps as shown in Figure. 3. The detailed explanations for each step are described below.

**Figure 2.** *(Left)* The components for the first prototype of vermicelli folding set; (1) a 100x150 mm weighing pad, (2) three force sensors, and (3) force sensors base. *(Right)* The first prototype for folding machine for vermicelli; (1) and (2) pneumatic cylinder in X axis, (3) pneumatic cylinder in Z axis, and (4) pneumatic cylinder in Y axis.

**Figure 3.** Vermicelli folding step: **Step 1**: The steel rod no.1 is push underneath the center of the vermicelli and lift vermicelli up 5 cm. The steel rod no.2 is placed at the top of vermicelli and moved to the left. **Step 2**: Folding the left end of the vermicelli by moving the pad to the right. The friction that occurs between the vermicelli and pad will fold the vermicelli down to the bottom. **Step 3**: The rod no.1 and no.2 are removed to the initial positions. **Step 4**: Then the vermicelli is removed from the folding set by pulling the container.
After folding the vermicelli with the folding set, the data has been collected by taking pictures from the top view and side view. The result showed in Table 1. From the results, the shape of the folded vermicelli is observed that there is some extending vermicelli in the red circles, which is called "mustache" and will affect the packaging process. This problem can be solved by cutting the ending tip of the vermicelli to the appropriate length before folding the vermicelli.

Table 1. Testing results of first prototype of Vermicelli folding set

| No. | Top View | Side View |
|-----|----------|-----------|
| 1   | ![Image 1](image1.png) | ![Image 2](image2.png) |
| 2   | ![Image 3](image3.png) | ![Image 4](image4.png) |
| 3   | ![Image 5](image5.png) | ![Image 6](image6.png) |
| 4   | ![Image 7](image7.png) | ![Image 8](image8.png) |
| 5   | ![Image 9](image9.png) | ![Image 10](image10.png) |

From the results of folding set, the averaged total time for only folding process is about 19 s as shown in Table 2. It is found that step 1 and step 3 that are fully automatic system, (in step 1 which is the process of folding vermicelli has an average time of 3.13 s and step 3 that is the process of vermicelli release to the tray has an average time of 2.71 s. However, the spending time in step 2 and step 4 that are majority of the spending time. These steps can be faster by improving to a fully automatic system.

Table 2. Spending time for first prototype of vermicelli folding set (unit: second)

|       | Step 1 | Step 2 | Step 3 | Step 4 | Total |
|-------|--------|--------|--------|--------|-------|
| Average time (sec) | 3.13 | 7.25 | 2.71 | 5.78 | 18.87 |
3. The modifications and testing results

3.1. Folding and conveying set
After the folding process in the first prototype, it is observed that the shape of vermicelli has change because the vermicelli is soft, tangle, and messy. Therefore, folding and conveying set are redesigned into one combined set as shown in Figure 4. and 5. By using a Cartesian structure, DC motor and belt transmission, and the pneumatic actuators, the modified design is compact. Unlike the previous model, this design can complete the entire task without the problem of moving the folded vermicelli into the aluminum boxes.

![Modified prototype for folding machine with transporting system.](image1)

**Figure 4.** The modified prototype for folding machine with transporting system.

![Components of folding and conveying set.](image2)

**Figure 5.** The components of folding and conveying set; (1) folding set, (2) conveyor set, (3) vermicelli base, and (4) testing box.

According to the vermicelli manufacturer, it is suggested that the shape should be changed. The reason for changing the folding technique is to reduce the overlapping parts that can cause the humidified spot after the drying process. These parts are shown in red circles in Figure 6. This is a crucial cause for unqualified products in vermicelli in production line.

![Overlapping parts in modified folding technique.](image3)

**Figure 6.** Overlapping parts in the modified folding technique, compared to the previous folding technique.
3.2. Testing of folding and conveying set (Transverse test)
The testing of folding and conveying set is examined by using dried vermicelli that is soaked in water for 5 minutes. Then, the vermicelli is arranged in a straight line with a length of 36 cm and weight of 110 grams. The vermicelli is placed on base station, the procedure for folding are described in these following steps:

- The folding set moves from the HOME position to the vermicelli base.
- The folding set grips and folds the vermicelli, then moves into the testing box as shown in Figure 7. The spending time is recorded, and the experiments are repeated for 30 times.

After folding vermicelli with the fabricated folding and conveying machine, the data has been collected by taking pictures from the top view and side view. The examples of results are showed in Table 3.

![Figure 7. The steps for a folding and conveying set in transverse tests.](image)

From the result of top and side view, it is noted that the shape of folding vermicelli is appropriate and neat. Unlike the previous method, the problem with "mustache" mostly disappeared, if the vermicelli is cut consistently as shown in Table 3.

Table 3. Testing results of the modified prototype for folding and conveying set in transverse tests

| Trial No. | Top View | Side View |
|-----------|----------|-----------|
| 1         | ![Top View](image) | ![Side View](image) |
| 2         | ![Top View](image) | ![Side View](image) |
| 3         | ![Top View](image) | ![Side View](image) |
| 4         | ![Top View](image) | ![Side View](image) |
| 5         | ![Top View](image) | ![Side View](image) |
From the spending time of the folding and conveying machine, it can be seen that all 30 trails have the same spending time of 23 s. as shown in Table 4. This proves the concept of automation that are driven from the same power supply and applied pressure. In step 1, the movement from HOME position to the base of vermicelli cutting station has an average time of 7 s. In step 2, folding vermicelli and transporting process have an average time of 16 s.

**Table 4.** Spending time for the modified prototype of vermicelli folding and conveying set transverse tests (unit: second)

| Step 1 | Step 2 | Total |
|--------|--------|-------|
| Moving | Folding|       |
| Average time (sec) | 7 | 16 | 23 |

4. Testing of folding and conveying set (Continuous test)

Another testing of folding and conveying set is continuous test by arranging the folded vermicelli in a linear pattern. The pattern begins from the Home position and the vermicelli is moved from position A to a, B to b, and C to c respectively. The procedures for folding are described in these following steps;

- Arrange vermicelli in a straight line with a length of 36 cm and weight of 110 grams and place on vermicelli base on position A, B, and C.
- The folding set moves from the HOME position to grip the vermicelli on position A base and places into testing box a, then moves from testing box a to position B base and place into testing box b. Then, the folding set moves from testing box b to position C base and place into testing box c as shown in Fig. 8. The spending time are recorded from the beginning until the arrangement in each box is complete. These experiments are repeated for 3 times.

![Figure 8. The steps for a folding and conveying set in Continuous tests.](image)

The testing results are shown in Table 5. From the result, the shapes are in appropriate pattern, similarly to the linear pattern experiment. From the spending time of the folding and conveying machine in continuous test, it can be seen that there is some difference in time in each point due to the difference in moving distances. The average time for the entire process is 28 s as shown in Table 6.
Table 5. Testing results of the modified prototype of vermicelli folding and conveying set in continuous tests

| Test no. | 1     | 2     | 3     |
|----------|-------|-------|-------|
| Top View | ![Image](image1) | ![Image](image2) | ![Image](image3) |

Table 6. Spending time for the modified prototype of vermicelli folding and conveying set in continuous tests (unit: second)

|          | A → a |       | B → b |       | C → c |       | Avg. | Total |
|----------|-------|-------|-------|-------|-------|-------|------|-------|
|          | Step 1 Moving | Step 2 Folding | Total | Step 1 Moving | Step 2 Folding | Total | Step 1 Moving | Step 2 Folding | Total |
| Avg.     | 7      | 16    | 23    | 11     | 15    | 26    | 16   | 19    | 35    | 28    |

5. Conclusion
In the fabricated prototype, the folding and conveying set can pick all vermicelli from the base of the cutting station. No vermicelli falls during the folding and conveying process in the machine. The time-consuming for the transverse test was 23 seconds. For the continuous test; the average time for the complete arrangement was 28 seconds, due to the difference in travel distance. The problem in this design were the placement of vermicelli in the drying box that are not fit inside the testing box because the vermicelli's tip touched the box during conveying. This was resulted from the direction that the vermicelli was placed from the side view of the testing box. Alternatively, the vermicelli should be dropped from a higher position without touching the drying box. Another issue was the spending time for the folding and conveying set that is 28 seconds, compared to the spending time of 10-12 seconds in conventional process by human. However, the average spending time can be reduced if the folding and conveying set move in parallel. Moreover, if we added three more folding set in the same structure, the spending time can be reduced to 9.3 seconds per piece, which is approximately to the original process.

6. References
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