

## Improvement of Intermittent Advancing Accuracy of Pneumatic Cylinder-Driven Roll Feeder

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### ARTICLE INFO

#### Article history:

Received	16	February	2016
Revised	27	April	2016
Accepted	1	June	2016

#### Keywords:

Feed pitch  
Strip stock  
Roll feeder  
Pneumatic cylinder  
Intermittent

### ABSTRACT

A proposed pneumatic cylinder-driven roll feeder and an air press were designed to be operated automatically by a PLC. The accuracy of the intermittent feed pitch of the roll feeder was evaluated by measuring lengths of cut-offs of a strip stock by a digimatic vernier caliper. At each predetermined feed pitch, the proposed roll feeder was tested 100 times by varying the feed/cut intervals as 2.0/1.5, 3.0/2.0, and 3.5/2.5 s as test sets. The lengths of the cutoffs of the strip stock ranged from 9.89-10.34, 12.1-12.65, and 15.21-15.67 mm at the predetermined 10, 12, and 15 mm feed pitch, respectively, among the total of 300 samples in each feed pitch, regardless of the feed/shear interval. Therefore, the feed/cut interval at each selected feed pitch was found to have no effect on the accuracy of the intermittent advancing of the strip stock.

## 1. Introduction

Air feeders are widely used in press working industries. Grip-type air feeders advance strip stocks precisely. However, the grip-type air feeder requires two or three times bigger pitch than actual pitch because of its double-act feed operation. Due to double-act operation of the grip-type air feeder, its size has to be bigger than a size that actually feed<sup>[1]</sup>.

Roll feeders are widely used in press working industries because of their great versatility. They are not limited by width or thickness of strip stocks<sup>[2]</sup>. Angle index cam, which is a mechanism for transforming the continuous motion associated with a crank shaft. The crank shaft drives a press slide into an intermittent motion to drive a main feed roll. The angle index cam has a smooth motion from a stopped to a rotating condition and back to the stopped condition. Shape

of the cam provides a high dependability of precision of feeding operation by the roll feeder. Conventional methods for changing a pitch of strip stock to be fed are exchanging the feed roll of the roll feeder or changing a variable speed gear, which is located at between an output shaft of the angle index cam and a shaft on the main feed roll. However, these methods are inconvenient in that many lengths of material to be fed cannot be accommodated. Also, it requires an extensive time for changing and adjusting the feed device regard to a given different condition.

Meanwhile, cam feeders have advantages on high-speed feeding and easy of material fixing and processing. However, the cam feeders also have inconvenience in changing gears when the feed pitch needs to be changed because these feeders operated by change of speed with the gear.

To improve disadvantages of the conventional roll feed

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devices mentioned above, Takahashi and Hachioji<sup>[3]</sup> introduced a roll feed device for feeding material to a press in which the output shaft of the angle index cam and the drive shaft of the main feed roll are connected by variable speed disks, so that it is capable of selecting a pitch of feeding freely. This roll feed device was simply needed exchanging variable speed disks to change a feed pitch of material.

NC feeders are capable of accurate feeding and are very quick to set and to adjust pitch. Also they work with very high speed and have advanced programming features such as memory and speed control. However, the NC feeders are very expensive in initial purchase and requires specialist services if maintenances are required<sup>[4,5]</sup>.

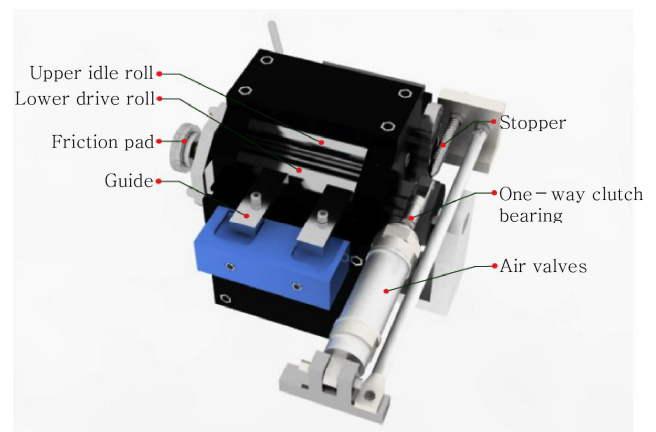
The roll feeders have barrier on high-speed feeding of material due to limited linkage rotation angles of within 90 degree, also the roll feeders are not easy to install onto the press. So and Kwon<sup>[6]</sup> introduced a pneumatic cylinder driven roll feeder that intermittently advanced strip stock. Reciprocal motion of the cylinder was converted to rotational motion to drive the roll feeder. They stated that the intermittent feed accuracy of the roll feeder was mainly affected by fluctuation of air press supplied to the cylinder.

This research analyzed intermittent advancing accuracy of strip stock with a redesigned pneumatic cylinder driven roll feeder. Air supply system for the roll feeder was upgraded by adding an air service tank and replacing air circuits. The control unit was also replaced such that activation times of the roll feeder and the air press could be adjusted. Performance of the proposed roll feeder was analyzed regard to intermittently advancing accuracy of the strip stock by varying interlock times of the roll feeder and the air press. The intermittent advancing accuracy was compared to early version of the roll feeder<sup>[6]</sup>.

## 2. Materials and Methods

### 2.1 Pneumatic Cylinder Driven Roll Feeder

The pneumatic cylinder driven roll feeder (190 L×140 W×180 H) consisted of a pair of feed rolls, one is an upper idle roll and a lower drive roll, a lifting lever which allowing the strip stock installation between the two rolls, a circular friction plate and a tension unit, an one-way clutch bearing, two guide plates, an pneumatic cylinder and a stopper (see Fig. 1).



**Fig. 1 Rendering of prospective view of the pneumatic cylinder driven roll feeder**

The size of the upper idle roll is slightly smaller in diameter than the lower drive roll. The diameter and the length of the lower drive roll is  $\text{Ø}50$  mm and 130 mm, respectively.

The lift lever allows a space between the two rolls for easiness of installation of the strip stock. Two tension springs were installed at an upper plate in which the upper idle roll was installed. The two tension springs, inserted both side-ends of main body, maintain the pressure of the upper idle roll, thus the strip stock is pressed and maintains its position between the two rolls by friction.

The circular friction pads, which were located at one-end of the lower drive roll shaft, were installed to prevent the lower drive roll from the reverse rotation by maintaining friction at each feed cycle of the strip stock. Also, a spring is installed to adjust the friction pressure of the friction pads.

The one-way clutch bearing was inserted at one end of the lower drive roll shaft to protect the reverse rotation of the lower drive roll. The lower drive roll shaft was connected to the pneumatic cylinder actuator by means of an aluminum block wherein the one-way clutch bearing was inserted. Thus, the strip stock can be intermittently advanced in one direction between two rolls. The intermittent feed speed of the proposed roll feeder can be controlled by a timer of a custom designed controller described below.

The feed pitch of the strip stock can be adjusted by replacing the position of the stopper, which is located at opposed end of the aluminum block in which the one-way clutch bearing inserted (see Fig. 2).

The air press (380 W×160 L×425 H, left-top, see Fig. 3), which was powered by pneumatic power, consisted of an air cylinder (KCC Co., Ltd, Model ACM N-B80-S25), a die set,

and a shear. The shear was attached to the die set to cut a strip stock, which was fed by the roll feeder.

The air press was operated as liaison with the roll feeder by the controller. Thus, the roll feeder testing system (see Fig. 3) was operated by itself after the strip stock was installed between the upper idle and the lower drive roll of the roll feeder.

The proposed pneumatic cylinder driven roll feeder was designed to complement the previous version of the roll feeder<sup>[6]</sup>. Two guides were attached to the mount bed of the roll feeder to maintain straightness of the strip stock before it entered the roll feeder. The strip stock passed through a rectangular hole of a block, which was attached to the mount bed to guide the strip stock, after it passed the roll feeder. The strip stock was pressed and held by a ball spring to contact to surface of the mount bed before it advanced to the air press.

The air service tank was employed to stabilize the air pressure of the air system (see Fig. 5). Also, air hose and air

pressure regulator were replaced with higher capacity and more accurate one, respectively.

## 2.2 Controller and Electric Circuit

The custom designed controller consisted of a programmable logic controller (PLC; Model K7-DR10S, LS Industrial Systems Co. Ltd), HMI (XP30-TTA/DC, LS Industrial Systems Co. Ltd), a counter (Model FX6Y-1, Autonics), two power relay controllers (Model GPL2L, GSR), and a terminal lug. Figure 4 shows a schematic diagram of the controller and electrical wiring with the PLC to power and control the roll feeder testing system. The controller was designed and manufactured to operate the roll feeder either in auto-mode or manual-mode by switching over an auto/manual switch.

When the strip stock was installed between the drive and the idle roll, the controller initiated the roll feeder by switching the power on. Then the roll feeder, which was rotated intermittently by the pneumatic cylinder, fed the strip stock as a predetermined feed pitch. The feed pitch of the strip stock was determined by adjusting a stopper position. Then, the shear, which was installed onto the air press, was lowered and cut the strip stock, and reversed to return to its initial position. This procedure repeated until the power of the roll feeder turned off or a preset number of counts on the HMI fulfilled. Intervals of a strip stock feed by the roll feeder and strip stock cut by the vertical motion of the shear were as

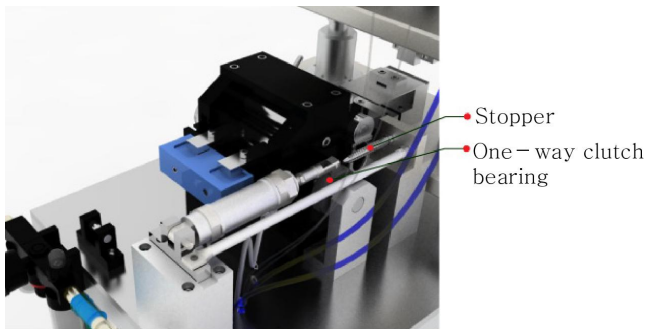


Fig. 2 Rendering of connecting feature of the pneumatic cylinder actuator to the lower drive roll and the stopper

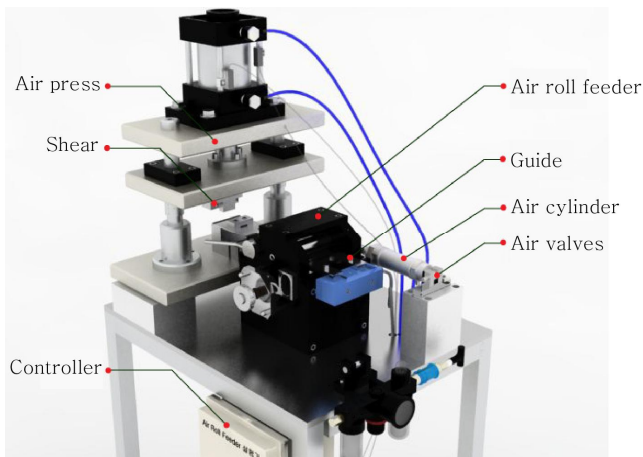


Fig. 3 Rendering of prospective view of the pneumatic cylinder driven roll feeder testing system

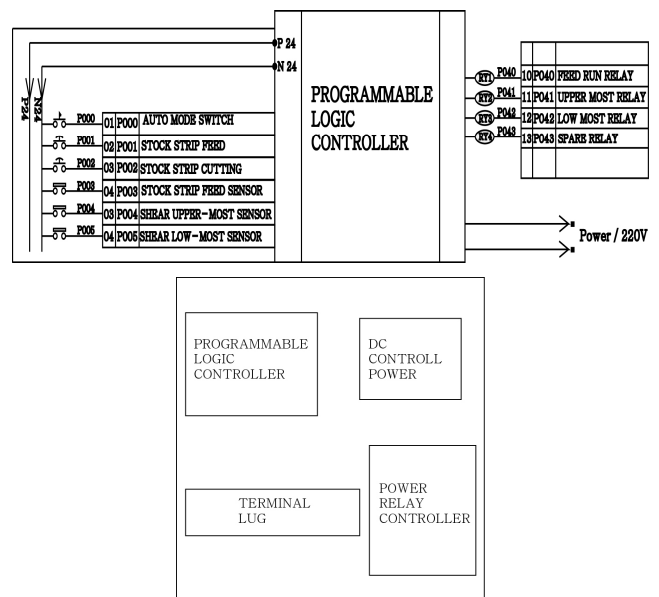


Fig. 4 Electrical components and connections with the PLC for the roll feeder operation control

designed to be adjusted by a timer of the HMI.

Two position sensors were installed at the pneumatic cylinder of the air press to locate the upper- and low- most position of the shear. The controller controlled the direction of motion of the shear attached to the pneumatic cylinder actuator by scanning of the signals from the two sensors. During the test, the operation mode of the roll feeder testing system, as described below, was set as auto-mode thus the controller operated the roll feeder testing system automatically by activating the roll feeder and the air press to feed and cut the strip stock.

### 2.3 Roll Feeder Testing System

The accuracy of the strip stock feed pitch of the proposed roll feeder was tested by using the air press with the shear which was manufactured by this research. The air press was mounted at the same table where the roll feeder mounted such that the strip stock was allowed to maintain horizontal extension after it passed through the roll feeder until it



Fig. 5 Roll feeder testing system

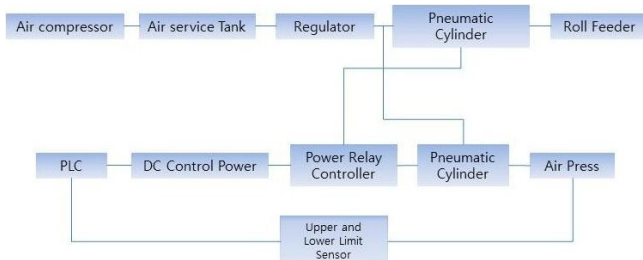


Fig. 6 Schematic diagram of the pneumatic cylinder driven roll feeder testing system

reached to the shear (see Fig. 5).

The roll feeder and the air press were operated as a sequential procedure by interlocking two systems with a combination of pneumatic system and the controller which was described as above (see Fig. 6).

### 2.4 Sample

Sample of the strip stock was made of brass. The thickness and the width of the strip stock were 0.2 mm and 15 mm, respectively. The strip stock was set onto a roller which was located beside of the system. The strip stock was released by itself during the test.

### 2.5 Test Methods

Accuracy of intermittent advancing length of the strip stock by the proposed roll feeder was analyzed by measuring lengths of cut offs of the strip stock by the air press. The feed pitch was set as approximately 10.0, 12.0, and 15.0 mm by adjusting a position of the stopper. Air pressure of the proposed roll feeder was set as  $49.05 \text{ N/cm}^2$  ( $5 \text{ kg/cm}^2$ ) by adjusting the regulator of air pressure.

Test was replicated by varying feed/cut intervals in each selected feed pitch as shown in Table 1. The feed/cut interval was set as 2.0/1.5 (30/40 SPM), 3.0/2.0 (20/30 SPM), and 3.5/2.5 (17/24 SPM) seconds. In each trial, the test was carried out by obtaining 100 observations. Thus, the total number of the observations was 300 in each selected feed pitch. The length of the strip stock cut off was measured with a digimatic caliper (Model CD-20CX, Mitutoyo) of the resolution of 0.01 mm.

An average length of the strip stock cut off in each trial was calculated, and it was used for the feed pitch accuracy analysis. As the proposed roll feeder testing system operated automatically, this experiment let the proposed roll feeder ran

Table 1 Operating conditions of intermittent strip stock feed of the proposed pneumatic cylinder driven roll feeder

Conditions	Values
Strip stock width (mm)	15
Strip stock thickness (mm)	0.2
Feeding rate (SPM)	30, 20, 17
Cutting rate (SPM)	40, 30, 24
Feed pitch (mm)	10, 12, 15
Air pressure ( $\text{N/cm}^2$ )	49.05

by itself in each trial. Each strip stock cut off was then gathered, and its length was measured.

### 2.6 Results and Discussion

Table 2 shows a statistic status of the strip stock cut offs of the proposed roll feeder. The average of the strip stock cut off length from the total of 100 samples was 10.11 mm, 10.14 mm, and 10.16 mm with the feed/cut rate of 30/40, 20/30, and 17/24 SPM, respectively, at the feed pitch of 10.0 mm. And other feed pitches, results of accuracy were obtained as shown in Table 2. The mean of the cut off length increased as the feed/cut rate decreased at the feed pitch of 10 mm and 12 mm. Meanwhile, the mean of the cut off length of the feed pitch of 15 mm was almost the same. From the result, the feed/cut rate of the roll feeder and the air press did not significantly affect the advancing accuracy of the strip stock.

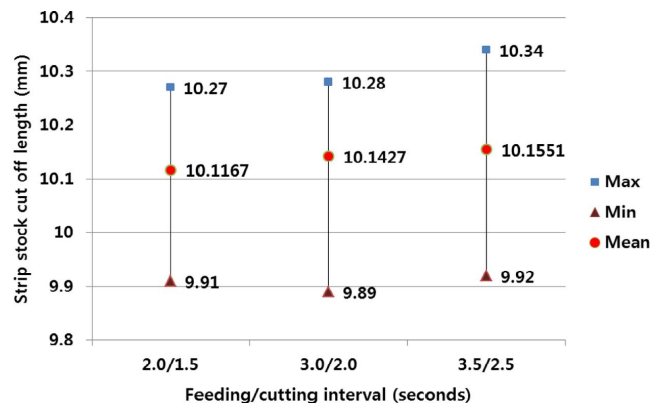
The strip stock cut off length range between the maximum and minimum significantly decreased approximately in half compare to previous research<sup>[6]</sup> at the same feed pitch. The standard deviation of the cut off length ranged from 0.107 to 0.120, from 0.091 to 0.107, and from 0.103 to 0.130 in 10 mm, 12 mm and 15 mm of feed pitch, respectively, in previous research<sup>[6]</sup>. Meanwhile, regardless the feed/cut rate, the standard deviation of the cut off length in this research was much less than that of previous research as shown in Table 2. Reasons of this results considered to be that stabilized air pressure and minimized slip of the strip stock during the roll feeder operation were key factors increasing accuracy of the intermittent advancing the strip stock.

Figures 7, 8, and 9 show the max., min. and average of the

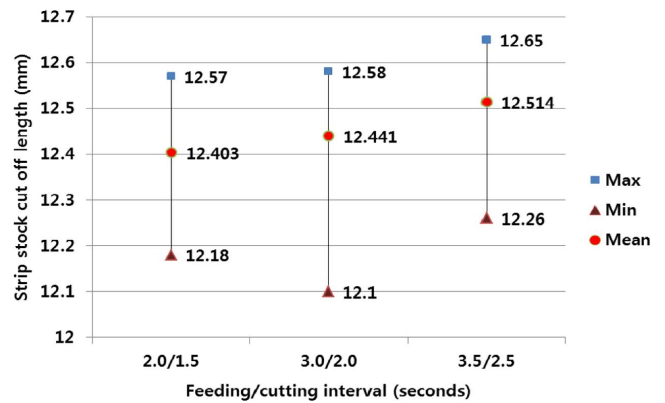
**Table 2** Statistic status of the cut off lengths of the strip stock by the proposed roll feeder in each feed pitch

Feed pitch (mm)	Feed/cut rate (SPM)	Total number of samples	Cut off length (mm)			Standard deviation (mm)
			Min.	Max.	Average	
10.0	30/40	100	9.91	10.27	10.11	0.084
	20/30	100	9.89	10.28	10.14	0.085
	17/24	100	9.92	10.34	10.16	0.095
12.0	30/40	100	12.18	12.57	12.51	0.091
	20/30	100	12.10	12.58	12.57	0.090
	17/24	100	12.26	12.65	12.42	0.077
15.0	30/40	100	15.28	15.67	15.48	0.075
	20/30	100	15.21	15.62	15.47	0.082
	17/24	100	15.23	15.67	15.47	0.087

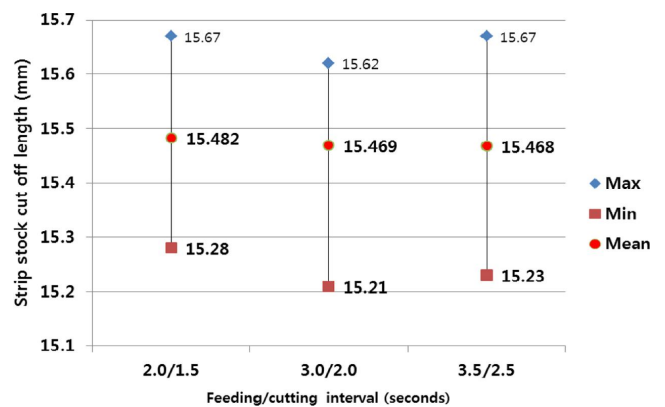
strip stock cut off length of the 100 measurements in each selected strip stock feed pitch of 10.0 mm, 12.0 mm and 15.0 mm, respectively, with 3 selected feed/cut intervals. The largest difference between the maximum and the minimum measurement of the cut off length of 0.48 mm was appeared with the feed pith of 12 mm among the total of 300 measure-



**Fig. 7** The max., min. and mean of the cut off length of the strip stock with the feed pitch of 10.0 mm



**Fig. 8** The max., min. and mean of the cut off length of the strip stock with the feed pitch of 12.0 mm



**Fig. 9** Result of the max., min. and mean of the cut off length of the strip stock with the feed pitch of 15.0 mm

ments. The cut off lengths ranged 0.39-0.44 mm with the feed pitch of 15 mm, 0.39-0.48 mm with the feed pitch of 12 mm, and 0.36-0.42 mm with the feed pitch of 10 mm.

In previous research<sup>[6]</sup>, the air pressure fluctuation was a major problem affected the accuracy of the feed pitch of the intermittent strip stock feeding by the pneumatic cylinder driven roll feeder. However, in this research the air pressure fluctuation did not affect the accuracy. From Figs. 7, 8, and 9, there were no significant range differences between the max. and min. length of the cut off regardless the selected feed pitch 10 mm, 12 mm and 15 mm.

The difference of the min. and max. of the cut off length is slightly larger as the feed/cut rate decreased. This research rather considered to be that the feed/cut rate of the proposed system did not significantly affect the intermittent strip stock feed accuracy.

The air compressor used for previous study<sup>[6]</sup> restricted the air delivering to the system while the proposed roll feeder was still running such as the continuously-operating unloading controls in the air compressor<sup>[5]</sup>. When the test system pressure was at or near the lowest level of the control band of the compressor, the compressor restarted to run until the air pressure reached to the highest level. This periodic kick in and out of the compressor was continued during the test run. From this phenomenon, an air pressure fluctuation was read from the pressure gauge. This pressure fluctuation caused variations of the stroke of the actuator of the pneumatic cylinder<sup>[7]</sup>, resulted less feed pitch accuracy. Figures 10, 11, and 12 shows results of the max., min. and mean of the cut off length of the strip stock in previous research<sup>[6]</sup>. The largest

difference between the max. and min. of the cut off lengths were found when the compressor kicked in while the test system running as shown the 6th replication in Fig. 10, the 8th replication in Fig. 11, and the 2nd and the 8th replications in Fig. 12. Here, one replication was 30 observations.

By comparing results of previous and current research, the air delivery restriction problem due to kick in and out of the compressor was a major factor lowering the feed pitch accuracy. Thus, this research considered to be that the air delivery problem was improved by connecting the air service tank between the air supply and the roll feeder as well as the replaced air pressure regulator and the air hoses in the air circuit of the system. Also, the guide and the ball spring, which were installed onto the system to minimize the slip and friction of the strip stock, also improved the feeding accuracy of the proposed roll feeder.

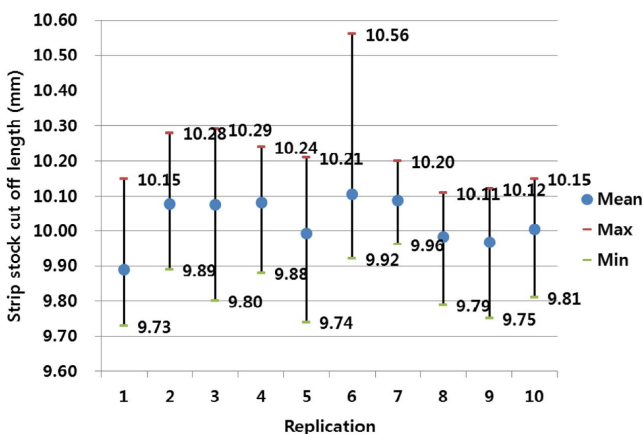


Fig. 10 Result of the max., min. and mean of the cut off length of the strip stock with the feed pitch of 10.0 mm in previous research<sup>[6]</sup>

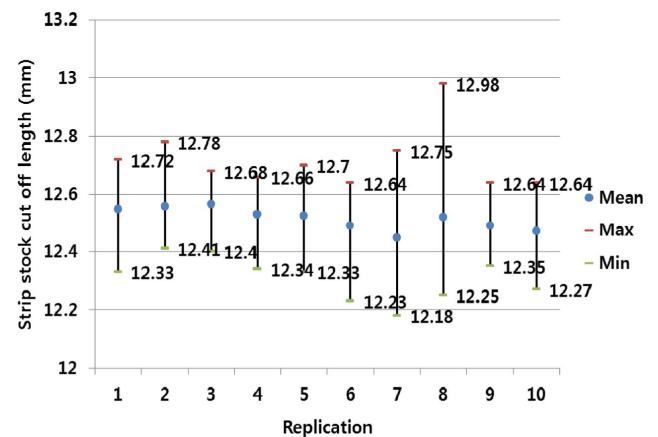


Fig. 11 Result of the max., min. and mean of the cut off length of the strip stock with the feed pitch of 12.5 mm in previous research<sup>[6]</sup>

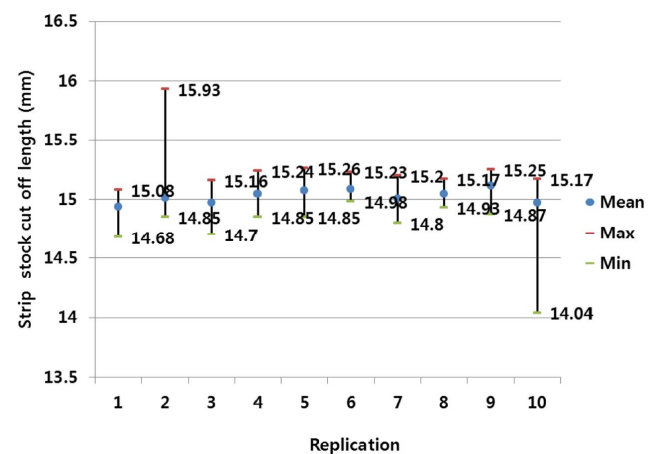


Fig. 12 Result of the max., min. and mean of the cut off length of the strip stock with the feed pitch of 15.0 mm in previous research<sup>[6]</sup>

### 3. Conclusions

This research designed and manufactured a prototype pneumatic cylinder driven roll feeder, and analyzed its feed pitch accuracy by using the shear installed at the air press by measuring the strip stock cut off length. The prototype pneumatic cylinder driven roll feeder and the air press were mounted at a table, and aligned the roll feeder and the air press to maintain the strip stock as flat as possible while the strip stock advancing. Operation of the roll feeder and the air press were designed to be controlled automatically by applying the PLC.

The proposed roll feeder's feed pitch accuracy of the strip stock was analyzed using the shear installed at the air press. Following is summarized results obtained from this research.

(1) The prototype pneumatic cylinder driven roll feeder was capable of feeding the strip stock linearly.

(2) The designed and manufactured controller for the proposed roll feeder was capable of controlling the proposed roll feeder and the air press accurately.

(3) With different feed and cut rate of the roll feeder and the shear, respectively, the intermittent feed pitch accuracy was not significantly different in the selected strip stock feed pitch of 10 mm, 12 mm, and 15 mm.

(4) Regardless the feed pitch of the strip stock and the feed/cut rate, the min. and max. difference of the strip stock

cut off lengths were less than 0.5 mm among 300 samples, which was approximately 2 times more accurate than previous report<sup>[6]</sup>.

(6) The proposed pneumatic cylinder driven roll feeder is capable of feeding strip stocks for pressworking industry which requiring relatively less accuracy such as beyond 0.5 mm.

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