L-49

A Proposal of An Automatic Distribution System for Improved Production Efficiency in the Fastener Manufacturing Industry

*Shogo Urakabe[1], Takahiro Hoshino[2], Yoshio Hamamatsu[2]

Abstract: We propose a new SCADA system using time series prediction methods to the fastener manufacturing industry for the improvement of its production efficiency. Customers sometimes irregularly place orders with short delivery periods and large quantities, so fastener manufacturers must adopt production methods that can accommodate. If major troubles occur in a specific process, a traditional method is often used. The proposed system is contrived for dealing with such situations more strategically. An experiment system which can simulate such situations is constituted including a laboratory miniature production site. We performed experiments of the proposed system. As a result, the proposed system was found to be capable of improving the production efficiency.

1. Introduction

There has recently been significant progress toward factory automation in the fastener manufacturing industry. SCADA (Supervisory Control and Data Acquisition) systems are currently being adopted into this industry. It is a form of industrial automation in which monitors and controls are placed on each production line (hereafter, called line). It links lines on production site, programmable logic controllers (PLCs) in charge of them, and PCs[1].

In contrast, single-order products are generally manufactured on a single line in this industry. We call this one-order-one-line production. However fastener manufacturers sometimes simultaneously produce products for an order on two lines, which we call one-order-two-line production. In that case, long-term significant decreases in processing speed, S_p for a given process significantly lowers production efficiency, E_p. E_p is average number of production from the beginning to the end per unit time. We call E_p of the one-order-two-line production overall production efficiency, E_{op} in this research. In the above situations manufacturers sometimes apply a method to improve E_{op} that work-in-progress goods in a line are manually moved to the appropriate region in the other line. We call this Manual Distribution System (MDS). MDS has some problems, such as limitations on improvement to E_{op}.

Utilization of the SCADA systems is expected to lead to superior new methods that address the problems of MDS. Because academic research on improving MDS is rare and this field has been considered only in individual places, the authors have no chance to get any information on preceding research in this industry.

In this research we propose a new method in which a SCADA system continuously monitors and controls factors on one-order-two-line production. In the situation where E_{op} is lowered to some extent, the proposed method improves it by automatically predicting it and distributing work-in-progress goods from one line to the other line. We call this proposed method Automatic Distribution System (ADS).

The purpose of this research is to establish ADS, and validate that ADS can be an alternative of MDS in actual factories.

2. Production Management for Irregular Orders

There are processes named header and rolling in this industry. The headrer and rolling are the first and second processes, respectively. They are connected with conveyors. The work-in-progress goods after the header are moved automatically the rolling. This is called a header-rolling system.

Fastener industry manufacturers generally take orders in units with an individual lot number, and produce goods in single lots. An order with one lot number is generally manufatured on the one-order-one-line production from the point of view of quality management in this industry.

Salespersons irregularly receive an order with a short delivery period and large quantity which we call an OSL in this research. One of traditional methods for dealing with an irregular OSL while elevating E_p to keep to the delivery date is splitting the order into two lots, and manufacturing them on the one-order-two-line production.

2.1 MDS

S_p of one of the rolling processes on one-order-two-line production for an irregular OSL occasionally lowers significantly for a long time. If left unaddressed, E_{op} is significantly lowered, because time needed to complete production for both lines, T_{ncpbl} is affected. To meet delivery periods in those situations, there are cases where MDS is applied. MDS is performed as follows:

Predict the spent time with manual calculation by periodical check-up of the production number. Judge that because of disfunction of a specific rolling process, the prediction value of the spent time will exceed a configured limitation value. Stop the problem rolling process and remove it from the line. Manually distribute all of work-in-progress goods at the back of the header process prior to the problem one in the line to the associated region in the other line. In the accepting line, increase the configuration operation speed, S_{co} of the rolling process after the accepting region. Renew lot numbers for later quality management.

But MDS has several problems.

1. E_{op} can't exceed S_{co} in the accepting rolling process because all work-in-progress goods in the dysfunction line are distributed.
2. There are difficulties in suitability of decision timing of performing MDS and accuracy of prediction for the spent time due to human limitations.
3. A lot of manpower for prediction, decision making, and manual distribution is needed.

3. Method

The conceptual diagram of ADS which we propose to address the problems of MDS is shown in Figure 1. In ADS, conveyors in the two lines respectively named Line 1 and Line 2 are connected by a distributer posterior to the header of Line 1 and a branched conveyor. Pathway leading work-in-progress goods to two lines are established. A SCADA system monitors and controls production on both lines via PLCs. Line 1 is assumed to have the problem.

"laboratory miniature production site" is made to simulate the one-order-two-line production for irregular OSLs which applies the concept of ADS. With the laboratory miniature production site, PLCs, and SCADA, an experiment system is constructed to estimate validity of ADS. The products

1:Major of Electrical Engineering, CST. , Nihon-U.
2:Department of Electrical Engineering, CST. , Nihon-U.

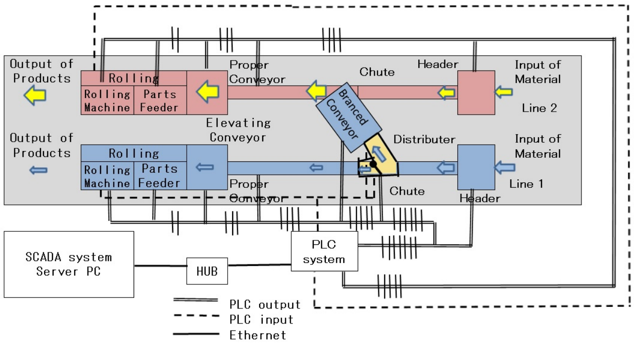

Figure 1: Conceptual diagram of ADS.

were simulated as 5mm steel balls. A standby position control system (SPCS) is introduced only into the Line1 rolling machine. The SPCS is a system that controls the existence of the work-in-progress goods in the standby position to undergo rolling. This can significantly lower S_p of the Line 1 rolling machine, and thus can lower instantaneous production efficiency which is instantaneous production numbers per unit time. Those of Line 1 and Line 2 are defined as E_{l1ip} and E_{l2ip}, respectively.
The concept of ADS and the outline of the experiment system are explained in the following:

1. The ADS system periodically monitors E_{l1ip} and E_{l2ip}.
2. By a specific time series prediction method, it periodically predicts E_{l1ip} and E_{l2ip} in the future, and predict T_{ncpbl}.
3. It predicts the elongation ratio, R_e of needed time by prediction value of T_{ncpbl} and the planned needed time, T_{pn}
4. If R_e exceeds a configured threshold, T_c, the ADS system determines a residue ratio, R_r, which is ratio of numbers of work-in-progress left in the same line, and begins the distribution.
5. The distributor repeatedly sends all work-in-progress goods into one of the two pathways for a certain time, and then into the other pathway for a certain time. This realizes R_r and allows the change of it during production. At the same time, the Line 2 rolling machine is set to high speed mode.
6. The system continues prediction of E_{l1ip}, E_{l2ip}, and T_{ncpbl} until the end of the production.

4. Results and Consideration

The following experiments were done using this experiment system. Vijeo Citect ver 7.30 (Schneider Electric Co.) was used as the SCADA software. Melsec Q (Mitsubishi) was used as the PLC. The SCADA monitor during the experiment is shown in Figure 2. The laboratory miniature production siteThe experiment system was made using wood materials, a belt, a DC 3V motor, and aluminum plates. The machines of the header and rolling processes were simulated as discrete product-releasing machines.

The system was programmed to periodically calculate production efficiencies during production which are called in this research and mean the average number of production from the beginning until the spot per unit time. Those of Line 1 and Line 2 are expressed as E_{l1dp} and E_{l2dp} respectively. We took the time series prediction method in which values of E_{l1ip} and E_{l2ip} are predicted to be always the same as those of E_{l1dp} and E_{l2dp} respectively at each sampling time until the end of the production. We also took the time series adjustment method for the R_r control in which it is decided to be the ratio of E_{l1dp} at the beginning of the distribution against S_{co}, and fixed until the end of the production. The SPCS was realized as follows. In the SCADA system, random time series data were input, and the program outputs corresponding signals. In the material pathway of the rolling machine in Line 1, a valve to disturb the movement of materials was equipped, and a signal controlled the existence of material in the standby position using the valve.

A no-intervention experiment which is without distribution, but whose other conditions are the same as ones on an ADS experiment was performed to make a standard value of T_{ncpbl} and inspect product flow on the experimaent system.

150 items were assigned to each line, representing an order of 300 items. S_{co} for all processes was 30 products/min. On calculation, T_{pn} was 5 min. Only the Line 2 rolling machine used the high-speed (60 items/min) mode after distribution began. The frequency at which the work-in-progress goods exist in the standby position, as controlled by the SPCS, was set to 60 % . T_c of R_e to initiate distribution was set to 150 % .

Two no-intervention and two ADS experiments were performed. Table 1 shows the results. In comparison with the no-intervention experiments, production finished 2.6 min earlier in ADS. Averages of R_e were 160 % with no intervention, and 108 % in ADS.

Because the time series data in the SPCS were random, variation was relatively equal. We thus consider that applying E_{l1pdp} and E_{l2pdp} into the prediction values led to improved accuracy of prediction and significantly improving T_{ncpbl}.

5. Conclusion

We analyzed the traditional method for coping with reduced overall production efficiency in one-order-two-line production for irregular OSLs in the fastener manufacturing industry which is called MDS in this research. We contrived and modeled an alternative coping method using SCADA called ADS, and performed experiments to assess it. Results indicated that ADS significantly improves E_{op} and reduces T_{ncpbl}.

An experiment procedure for MDS on the experiment system is currenly being constructed. We will perform MDS experiments based on the procedure, do improvements such as applying ARIMA (Autoregressive Integrated Moving Average) methods, and estimate the practicality of ADS.

Table 1: Results of the experiments.

Method	Experiment No.	Spent Time (min.)
No intervention	N1	8.1
	N2	7.8
	Ave.	8.0
ADS	A1	5.3
	A2	5.4
	Ave.	5.4

References

[1] A. L. Sangeetha et al. ; Experimental validation of PID based cascade control system through SCADA-PLC-OPC and internet architectures, Measurement, 45, pp. 643--649, 2000.