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

*Shogo Urakabe¹, Takahiro Hoshino², Yoshio Hamamatsu²

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, $E_{op}$. $E_{op}$ is average number of production from the beginning to the end per unit time. We call $E_{op}$ of the one-order-two-line production overall production efficiency, $E_{op}$ in this research.

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 Manual Distribution System (MDS). MDS has some problems, such as limitations on improvement to $E_{op}$.

The conceptual diagram of ADS which we propose to address the problems of MDS is shown in Figure 1. In ADS, 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 $E_{op}$ 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, $T_{npbl}$, is affected. To meet delivery periods in those situations, there are cases where MDS is applied. MDS is performed as follows:

1. **$E_{op}$ can't exceed $S_{co}$ in the accepting 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 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 $E_{op}$ to keep to the delivery date is splitting the order into two lots, and manufacturing them on the one-order-two-line production.
were simulated as 5mm steel balls. A standby position control system (SPCS) is introduced only into the Line 1 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 $E_{1ip}$ and $E_{2ip}$, respectively. The concept of ADS and the outline of the experiment system are explained in the following:

1. The ADS system periodically monitors $E_{1ip}$ and $E_{2ip}$.
2. By a specific time series prediction method, it periodically predicts $E_{1ip}$ and $E_{2ip}$ in the future, and predict $T_{ncpb}$.
3. It predicts the elongation ratio, $R_e$ of needed time by prediction value of $T_{ncpb}$ and the planned needed time, $T_{pn}$.
4. If $R_e$ exceeds a configured threshold, $T_e$, the ADS system determines a residue ratio, $R_e$, 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 $R_e$ 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 $E_{1ip}$, $E_{2ip}$, and $T_{ncpb}$ 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 $E_{1ip}$ and $E_{2ip}$ respectively. We took the time series prediction method in which values of $E_{1ip}$ and $E_{2ip}$ are predicted to be always the same as those of $E_{1dp}$ and $E_{2dp}$ respectively at each sampling time until the end of the production. We also took the time series adjustment method for the $R_e$ control in which it is decided to be the ratio of $E_{1dp}$ 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 $T_{ncpb}$ and inspect product flow on the experiment 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 %. $T_e$ 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 $E_{1ip}$, $E_{2ip}$ into the prediction values led to improved accuracy of prediction and significantly improving $T_{ncpb}$.

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 $T_{ncpb}$.

An experiment procedure for MDS on the experiment system is currently 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>
<thead>
<tr>
<th>Method</th>
<th>Experiment No.</th>
<th>Spent Time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No intervention</td>
<td>N1</td>
<td>8.1</td>
</tr>
<tr>
<td></td>
<td>N2</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>Ave.</td>
<td>8.0</td>
</tr>
<tr>
<td>ADS</td>
<td>A1</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>Ave.</td>
<td>5.4</td>
</tr>
</tbody>
</table>

References