USE OF WITNESS SIMULATION FOR IMPROVING THE CONTINUITY OF THE FLOW

BOŻENA ZWOLINSKA

KATARZYNA SMOLINSKA

Akademia Górniczo – Hutnicza im. St. Staszica w Krakowie, al. Mickiewicza 30, 30-059 Kraków, Polska 

bzwol@agh.edu.pl

ksmol@agh.edu.pl

Abstract

This article describes an example of the use of simulation Witness to improve the continuity of the flow in production process. Production management and tasks scheduling in series – parallel systems, with minimizing wastes (muda) at the same time, may be very difficult issue. For the systems with complex manufacturing structures, without use of informatical tools, it may be arduous or even impossible task. Various processing times, changeover times, availability, number of operators changing in time, and other randomly occurring parameters (e.g. failures), significantly affects the level of difficulty. The aim of the study was to obtain the highest productivity in a mixed (serial-parallel) system, taking into account the minimization of inventory in interoperable buffers and minimize the downtime of machines and operators.

Keywords: Production system, improvement of flow continuity, productivity

1. INTRODUCTION

The production system is individual for every enterprise because it depends on the type of the product, production and technological processes, stability and repetitiveness of orders and social and economical factors. On the first stage of defining the structure of material flow it is necessary to identify the co-dependent subsystems of production system [1, 2].

The processes in the analysed system have discrete character. However, regarding the big variety of output assortment, flows are characterised by high volatility index. It is hard to obtain identical states of production system within a relatively long period of time. Moreover, there is a wide range of available options to choose from by the final customer, which has also a major impact not only on the production system but also on the construction design. Technological processes implemented in production are complex [3] so the structure of particular units producing intermediate and final goods has to include proper connections (so-called relations) required by the stream of flowing materials. Consequently, the first and primary criterion of the division of production system should define the single manufacturing stage in which a single consistent process is realised, e.g.: trimming, varnishing etc.
2. THE CHARACTERISTICS OF ANALYSED PRODUCTION SYSTEM

The subject of the analysis is a section of production line consisting of nine machines set in a mixed (parallel - series) connection system (Fig. 1). The model includes production stations and in-process buffers (warehouses). The buffers are located between the machine areas. The operation of model line requires 11 workers: 9 operators (one on each machine), a foreman and a specialist that fixes any malfunction that may occur. The foreman is responsible for rearming and replacing tools and assisting the specialist during the malfunction removal. Work in the considered department is scheduled in 3 shift rotation pattern.

The input materials are metal sheet coils delivered from the component warehouse. The first stage is cutting to required dimensions. To minimize the amount of generated scrap in the latter trimming stage, the cutting of metal sheets results in creating around 80 different format sized varying in length, width, thickness and type of sheets. In Witness analyses the changes of characteristics of processed material will be included in order to reflect the real system.

![The chart of materials flow in analyzed model](image)

For reliable reflecting of the system work parameters in Witness simulator, the following data had to be gathered: work cycle time (c/t), preparing and finishing time (t_{pz}), rearming time (c/o), defects, breakdown and downtime time (t_{a}), net work time (t_{netto}) for each shift, and average time for cleaning the station and preparing of the documentation and reports (t_{5S}). Regarding the big variety of production components it was significant to determine the parameters of station effectiveness. For instance, during one shift on the trimming stage around 2 000 intermediate products are being produced from different types of sheets measuring from few centimetres to four meters. The variety of dimensions had a major impact on the above listed times. Given such wide range of parameters (types, quantity and times) a number of variables defined by various probability distributions were used. Data gathered over one month was the base of the analysis that led to choosing of the distribution.

3. SELECTED DATA ANALYSIS

One of parameters describing the production process is the operating time utilisation indicator, is given by the formula (1):

\[ \text{Operating Time Utilisation} = \frac{t_{netto}}{t_{netto} + t_{5S}} \]
The output capacity has been calculated according to the formula (2). The manufactured products are the sum of all manufactured elements during one shift. The output capacity represents the number of products manufactured by a worker during the entire shift. It has been calculated with:

\[ \text{Output capacity} = \frac{24000 \text{ [s]}}{\text{average cycle time [s]}} \] (2)

Subsequently, for the high variability and variety of time parameters, an average cycle time has been determined as the ratio of the average preparation and finishing time \( t'_{pz} \) and the processing time to the quantity of manufactured elements during one shift. Calculations have been done according to the formula (3).

\[ \text{Average cycle time} = \frac{\sum (\text{preparation time} + \text{processing time})}{\text{manufactured elements}} \text{ [s]} \] (3)

The quality indicator is expressed as the ratio of correctly manufactured elements to all manufactured elements.

The scheduled rearming time has been determined after the analysis of all rearming times recorded within a specific period of time. A list of the sums of all rearming times has been shown in Fig. 2.

As the result of an analysis of the gathered data the work schedule for all 9 machines has been obtained. The graph 3 shows the ValueAdded actions marked with a yellow colour, and NonValueAdded actions with red colour.

4. **WITNESS SIMULATION**

In the Witness model the cycle time and number of manufactured sheets on each station have been represented by variables. The values of variables differ depending on the type of cut metal sheets, length and width of the sheet, quantity and complexity of manufactured products. Time cycles
described by variables (e.g. x1, y1) are not given plain but by distributions. The picture 4 shows exemplary distributions used to model the analysed subsystem.

![Fig. 4 Example of applied statistical distributions](image)

The result of using variables dependent on the input parameters of material and on probability distributions for operating times, times for breakdowns, downtimes, repairs etc. for all 9 machines is the model that includes many different work statuses. The results of system status after one shift - 480 min gross time - are given below. In should be noted, that for each simulation the measurements will slightly differ. That results from the use of the pseudo random number generator.

**Table 1** and **Table 2** show the parameters obtained after a preset operating time of 4 punching machines and 4 press brakes. The ultimate output is about 2200 products. It can also be noticed that there is a direct relation between the workload and efficiency of machines. It is also worth noting that: for machines “Wykrawarka1000” and “Wykrawarka500” the final output was 4 times bigger with nearly the same machine occupation. It indicates the range of products’ complexity and labour consumption.

![Tab. 1. The simulation results for punching](image)

**Table 1.** The simulation results for punching

![Tab. 2. The simulation results for bending machines](image)

**Table 2.** The simulation results for bending machines
The workload of workers can be described in the similar way - Table 3 and Fig. 4.

**Tab. 3.** The use of operators shown in tabular form

<table>
<thead>
<tr>
<th>Nazwa</th>
<th>Operator Y</th>
<th>Operator K</th>
<th>Brygietzeta</th>
<th>Operator Cięcia</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Zaznacze</td>
<td>80.35</td>
<td>89.65</td>
<td>34.90</td>
<td>75.24</td>
</tr>
<tr>
<td>% Błędne</td>
<td>10.65</td>
<td>10.35</td>
<td>68.10</td>
<td>24.78</td>
</tr>
<tr>
<td>Rocz</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>IL Zadaw Zadan</td>
<td>57.11</td>
<td>2224</td>
<td>41</td>
<td>46.13</td>
</tr>
<tr>
<td>IL Zadaw Zadan 2</td>
<td>567</td>
<td>2220</td>
<td>41</td>
<td>44.1</td>
</tr>
<tr>
<td>L Zadaw Ablinie</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IL Zadaw Przerwanych</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Śred Czas Zadania</td>
<td>0.04</td>
<td>2.32</td>
<td>13.25</td>
<td>24.21</td>
</tr>
</tbody>
</table>

**Fig. 6** Graph of operators workload

5. **RESULTS OF WITNESS ANALYSES**

The Witness analysis indicates that the cutting station is put to operation for 78% of the simulation time. The downtime begins after cutting the last coil from the warehouse and lasts until the delivery of the second stock of material. Above that, 1.6% time of the simulation was consumed by setting up the machine, and nearly 4% by the malfunction of the machine resulting from a breakdown (foreman wait and repair time). During the entire simulation, the cutting station has completed 45 operations.

The biggest utilisation ratio was obtained for machines: Wykrawarka1500 and Wykrawarka1000_2. Their operating time is respectively 87% and 88% of the simulation time, and the spare parts wait time is only several dozen minutes of initial work cycle of the line which results in downtime of merely 1.45% of the simulation time. It is worth to note that the wait and breakdown repair time for Wykrawarka1000_2 is long (6.3%) and the Wykrawarka1500 has to be set up quite often, which consumes nearly 10% of the simulation time. Wykrawarka1000 is in operation for only 67% of the simulation time, it is caused by very frequent rearming procedures, which consume almost 22% of the simulation time. Also, the machine is idle during the spare parts wait time for about 10% of the line operation period. Machine most prone to breakdown is Wykrawarka500 for which the repair time and wait time is about 8% of the simulation time. For nearly 21% of line operating time the machine is idle, waiting for spare parts. During the simulated 480 minutes of production line operation the station has completed 49 cuttings of elements - the least of all punching machines.

The ratio of station utilisation is very similar for all press brakes and ranges from 80.7% (Krawędziarka1) to 86.1% (Krawędziarka3). The substantial amount of time for the first press brake is consumed by rearming (5%) and wait time for worker (foreman) who helps the operator repair or set the machine up (10% combined). Of all press brakes, the biggest number of operations have been completed by Krawędziarka1 - 774 elements. It is connected with the short cycle time of the machine stemming from the low complexity and small measurements of processed metal elements. The press brakes work nonstop from the moment of receiving the metal sheets from the first stock, without waiting for parts. Because of the big difference of times of cutting and bending of metal sheets, the so called “bottle neck” effect emerges. The buffers between press brakes and punching machines fill up very fast. After approximately 5 days of 3 shift rotation pattern the overproduction causes the blocking of stations.

6. **SUMMARY**

The main purpose of conducted analyses is to minimise the lead time from the moment of the input to the considered subsystem to the output. Additional assumption is to decrease the overproduction both on the level of cutting the metal sheets and the overproduction occurring between the punching machine and the press brake. The second goal is to maximise the utilisation of machine operating time, and to reduce the rearming and repair times. The limitation resulting from the company's demand for metal parts is the
minimum production capacity of 2000 final elements per shift. The above specified condition has to be met when applying any modifications.

The number of coils delivered from the input warehouse to the start of production line differs depending on the type of the metal sheet. Too big stocks of material cause very rapid infill of the warehouse space behind the cutting station and the necessity to store the materials for a long time. To avoid storing big amounts of metal sheets in the beginning of the production process the stock of coils has been reduced and standardised to 4 coils every 3 shifts.

Along with limiting the input stock of material, the level of machine utilisation has substantially decreased, especially regarding punching machines and metal sheet cutting stations. In order to sustain the operating time utilisation on the present level and to minimise the costs the number of punching machines has been reduced from four to three. The machine the most expediently to forgo is Wykrawarka500. This station is most prone to malfunctions, is equipped with the smallest working table and requires frequent servicing. Elimination of one of the punching machines is bound with the reassigning of one the operators. It was found most advantageous to provide training on rearming (setting up) the machines in order to reduce time of those operations, which in turn will increase the punching machines’ operating time utilisation. During one-person operation the rearming and pressure setup of the punching machine takes on average 4 minutes. In case of two-persons operation (the operator and the worker responsible for rearming), the average rearming time is approximately 2.5 minutes.

Along with the reduction of the number of punching machines, the input queuing system on pressing stations is changed. After the adjustment, the analysed production line manufactures 2290 final elements per shift, thus meeting the minimal required units of 2000 per shift with a minor excess. Additionally, the general efficiency of the production system is sustained without blocking the stations caused by overfilling the buffers.

The doubts concerning eliminating the least efficient punching machine were caused by the fear of decreasing the general efficiency on this stage. However, in result of changing the input queuing system and shortening the time of rearming the machine, the obtained capacity is on the same level while decreasing the amount of stored material in in-process buffers (punching machines - press brakes).

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REFERENCES