USE OF WITNESS SYMULATION FOR IMPROVING THE CONTINUITY OF THE FLOW

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Abstract

The article describes an example of applying the Witness simulation to ensure a smoother production process flow. The goal of this study had been obtaining the highest productivity in a mixed (serial-parallel) system while taking into account the minimization of supplies in interoperational buffers as well as minimizing the downtime of machines and operators. Further expectations included shortening the lead time of transit between each manufacturing stage. The limiting factor had been maintaining production volume at the level of 2000 products per shift. Managing production and timing tasks in a serial-parallel system while minimizing losses tends to be a challenging task. The factors decisive of the difficulty had been variables in processing time, refitting, availability, varying number of available operators and other random parameters (e.g. malfunctions).

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. In the first stage of defining the structure of material flow it is necessary to identify the co-dependent subsystems of the production system [1, 2, 8].

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 also has a major impact not only on the production system but also on the construction design. Technological processes implemented in the 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 [8]. Consequently, the first and primary criterion of the division of the production system should define the single manufacturing stage in which a single consistent process is realised [6], 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.

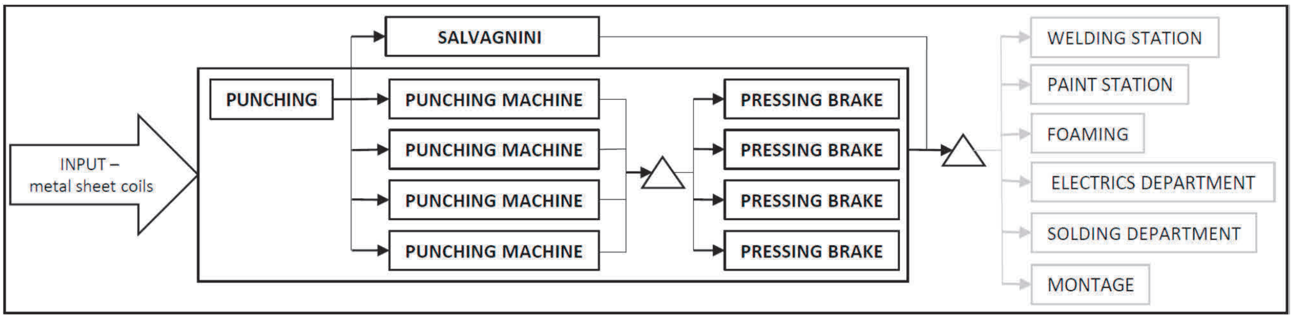

Fig. 1 The chart of materials flow in analyzed model

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}) [9]. Regarding the big variety of production components it was significant to determine the parameters of station effectiveness [7]. For instance, during one shift in 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):

$$\text{Uitlisation} = \frac{\text{manufactured products}}{\text{output capacity}} \qquad (1)$$

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. I has been calculated with:

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

Subsequently, for the high variability and variety of time parameters, the 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).

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

The quality indicator is represented by the ratio of correctly manufactured elements to all manufactured elements.

The scheduled rearming time was 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 the picture 2.

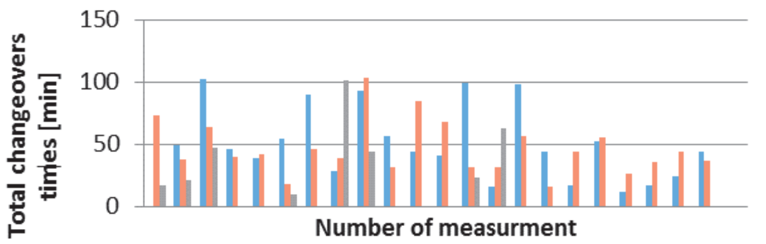

Fig. 2 Summary of retooling Times during the observation period

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

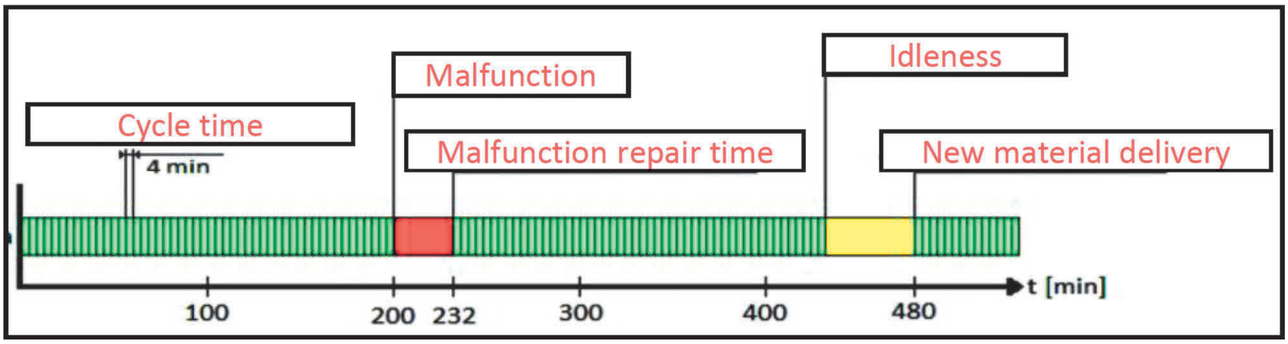

Fig. 3 The schedule of working time, failures and blockades of workstation

4. WITNESS SIMULATION

In the Witness model the cycle time and the 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 the manufactured products. Time cycles described by variables (e.g. x_1, y_1) are not given plain but by distributions. The picture 4 shows exemplary distributions used for modeling of the analysed subsystem.

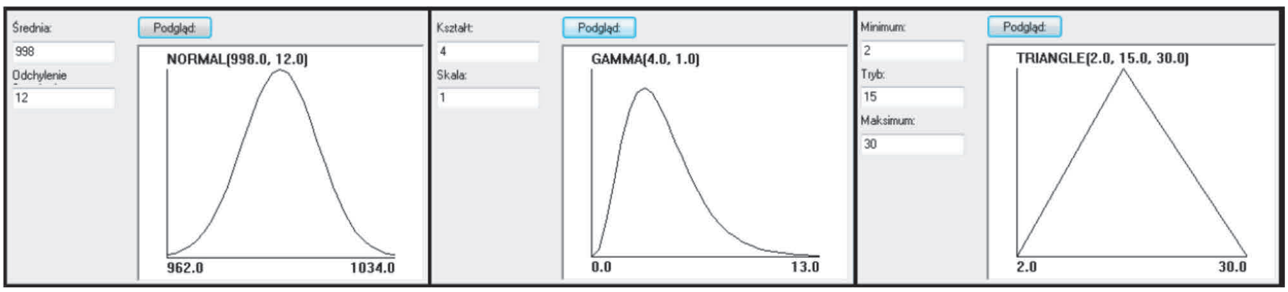

Fig. 4 Example of applied statistical distributions

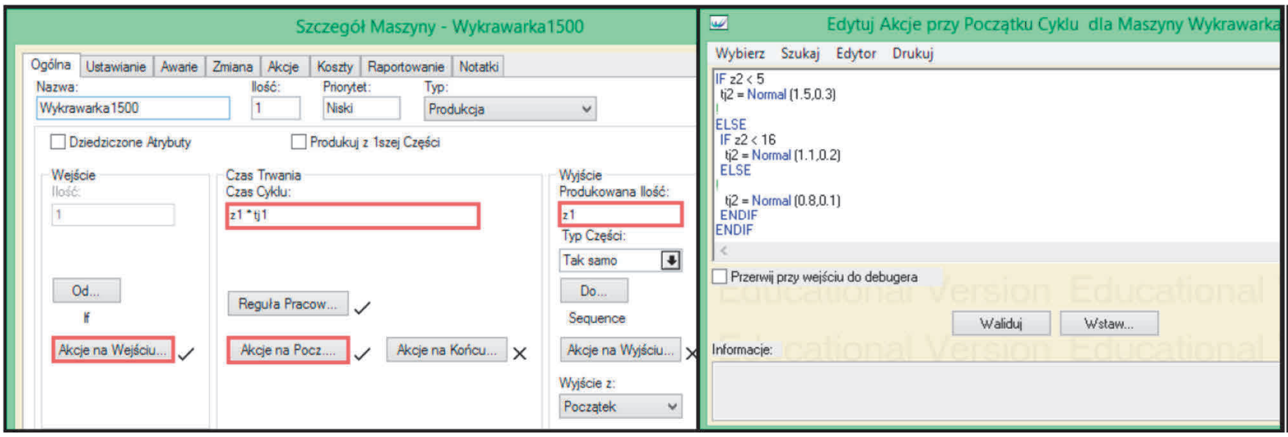

Fig. 5 Witness windows with applied variables and statistical distributions

The result of using the variables dependent on the input parameters of the material and on the 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 for system status after one shift - 480 min gross time - are given below. It 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 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.

Table 1 The simulation results for punching

NAME	Wykrawarka1500	Wykrawarka1000	Wykrawarka1000_2	Wykrawarka500
% Idleness	1.45	10.14	1.45	20.80
% Occupied	87.31	66.93	88.26	71.28
% Settings	9.55	21.83	2.52	0.24
% Malfunction	1.69	0.63	1.47	5.72
% Repair awaiting worker	0.00	0.48	6.30	1.96
Operation number	82	211	92	49

Table 2 The simulation results for bending machines

NAME	Krawędziarka1	Krawędziarka2	Krawędziarka3	Krawędziarka4
% Idleness	2.18	3.52	2.18	2.50
% Occupied	80.73	83.71	86.13	83.65
% Settings	5.08	3.61	2.51	2.41
% Awaiting worker	5.14	2.45	4.90	4.69
% Malfunction	2.21	2.93	2.70	2.93
% Repair awaiting worker	4.66	3.78	1.58	3.82
Operation number	774	605	411	400

The workload of workers can be described in similar way - **Table 3** and picture 4.

Table 3 The use of operators shown in tabular form

NAME	Operator_W	Operator_K	Brygadzista	Operator_Cięcie
% Occupied	89.35	89.65	34.90	75.24
% Idleness	10.65	10.35	65.10	24.76
Amount	4	4	1	1
Number of initiated tasks	571	2224	41	45
Number of completed tasks	567	2220	41	44
Number of tasks being executed	4	4	0	1
Avarage work time	9.04	2.32	12.26	24.21

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 of 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 time. The machine most prone to breakdown is „Wykrawarka500“ for which the repair time and the 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 the 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. CONCLUSION

The The main goal of the undertaken analysis had been the minimizing the lead time from the moment of input to an analyzed subsystem to output. A minimization of overproduction on the level of cutting the sheets of metal had also been assumed, as well as the overproduction between cutting and folding machines. The second goal had been optimizing the operational time of the machines and minimizing the refitting and repair times. The limitation had been the company`s minimal requirement of 2000 sheets produced per shift. Any changes had to be introduced with this condition in mind.

The amount of coils delivered from the input warehouse at production entry depends on the type of sheets. Too large portions of the material cause exceeding storage space at the cutting station and require long-term storing. In order to achieve the goal, storing material at the start of the production process had to be avoided, which meant limiting the delivery to 4 coils every 3 shifts.

Reducing delivery volume had caused a significant drop in machinery utilization, which mainly concerned the cutting and folding stations. In order to maintain the work time on the present level and to minimize cost, the production line had been reduced from four cutters to three. It had been most profitable to discontinue the utilization of cutter 500. This station had been the most prone to failure, offered the least work space and required frequent servicing. This decision forced the consideration of organizing the work time for the machine`s operator, the most optimal choice was to reskill him for refitting (adjusting) the remaining machines, which shortened the process and increased the work time of the cutters. Resetting the machine and adjusting the downforce takes an average of 4 minutes for a one-man station. In the case of a two-man station (the operator and worker responsible for resetting the machine) an average of 2.5 minutes had been achieved.

With the reduction of cutting machines, the queuing system for the cutting stations input had changed. After the changed had been applied, the discussed production line manufactured 2290 elements during a single shift, which brings the number above the required minimum of 2000 elements per shift. Moreover, the assumed productivity of the entire system had been maintained while avoiding blockage of the stations, caused by overfilling the buffers.

Eliminating the least productive cutter had raised concerns of reducing production efficiency. However rearranging the queuing input upon the entry to the system and minimizing resetting time the production efficiency had remained at the same level while reducing supplies at the interoperational buffers (cutters - folding machines).

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