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Automation of Production Line in Order to Increase the Productivity

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Abstract: The main goal of this research is to demonstrate a design solution of upgrading of a production line through automation of one section of the line. With this automation, the productivity was increased with lower costs per produced product. A machine for packaging was designed, which is used for final processing of the profile studs. This automation known as partial automation, where not all elements of the system are automated, is first step and it will obtain a possibility for further automation of the production line in order to reach a full automation process. Due to the very short time of return of investment, the crucial benefit of this automation is possibility of implementation in other plants of the company, which will multiply the benefit and provide more competitiveness on the market, due to the decrease of the production costs and improvement of the health and safety standards.

Keywords: automation; improvements; packaging; productivity; upgrading

1 INTRODUCTION

Automation enables application of the modern technologies in the manufacturing processes, higher productivity and increasing the company competitiveness on the market [1-3]. The basic reasons for the automation are the external demands, the continual changes that surround the process and internal factors, concerning the organizational and human resource level [4, 5].

The conceptual understanding for an automated system is being changing and at the same time it differs from the basic understanding for automation [6-11].

The industrial or manufacturing engineer is usually responsible for using the latest and the best technology on the safest and most economic manner in the process of manufacturing products. This responsibility requires an enormous knowledge and experience. Due to the continuous changing of technology, the knowledge can never be considered as completed and enough [12-14].

Many engineering applications involve some element of uncertainty [15-20]. From the other side, the modern production, requires daily and complete continuous operation of the equipment. Fulfilling these conditions is only possible, if the reliability of the equipment is set at a very high level and in the same time is enabled the reduction of the production time for a unit product. In order to achieve this goal, it is necessary to know the specifics of the production process and the technical solutions that are applied. During the production process, there is very often a need for a rapid change in the production program in order to meet the demands of the market, taking into account the stock situation and the variety of finished products. The various constructive solutions in practice showed different results in terms of the quality of the finished products and the effectiveness of the production plants under specific conditions of exploitation.

In this paper it will be presented a constructive solution - upgrading and automation of a machine for the production of dragged profiles made of galvanized sheet metal.

The research and constructive solution that will be presented in this paper demonstrates innovative upgrading and adaptation of a galvanized sheet metal production plant, through the implementation of an appropriate analysis of the efficiency of the machine and improved safety and ergonomic conditions for the operators.

The constructive solution that will be presented is an original by design and performance, and it is applied in an existing plant for the production of traction profile studs.

2 PRODUCTION PROCESS BEFORE AUTOMATION: DESCRIPTION AND ANALYSIS

Defining system performance measures is a critical step in the development of a project. The performance measures are defined before building a model. A performance measure may be defined as a metric for quantifying efficiency and/or effectiveness [21-24].

On the Fig. 1 below is presented the production line before automation.

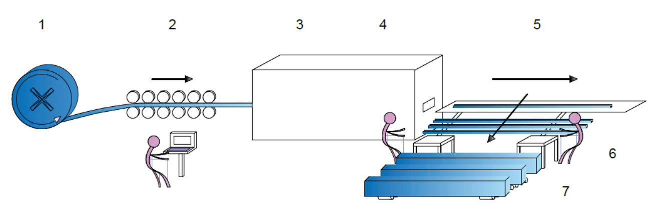

Figure 1 Production line before automation

The production of the metal profiles was operated by 1 (one) shift manager, 2 (two) operators and it was based on 7 (seven) steps:

1) **Unwinding of the steel sheet coil** – the sheet was uncoiled and dragged through the profiling rollers in order to be formed in final shape. The system worked discontinuously which means that after the coil was completely uncoiled, the production stopped and the next coil was set on the position for next production start.

2) **Profiling** – dragging the sheet through a set of rollers and the requested shape of the profile was reached. Depending on the type of the profile, there were different kind of roller sets.

One set had 8 to 12 stations. Each station maked step forward until the requested final shape.
Final station performed the calibration to the final dimensions.

3) **Punching station** – in this section the H hole was made on some of the profiles.

4) **Cutting station** - at this point, the continuous profile was cut on the requested length. The cutting tool moved on X-axes and Y-axes in the same time depending on the speed of the production line. After this operation, there was a speed-up roller, which pulled the cut piece and sent it to the next station.

5) **Cross end** – the cut piece slided longitudinal and cross on a surface which was positioned on a falling angle. At the end of this station, the profiles were gathering and the two operators paired them. The pairing process of the profiles is presented on Fig. 2.

6) **Strapping station** – created a small bundle. The two operators were preparing the defined bunch of profiles, lifting them on the strapping machine desk and processed the strapping. After that, the operators lifted the small bundle and put it down on transportation rollers.

7) **Big bundle transporter** – the small bundles were stacking in combination for obtaining a big bundle. The third operator was packaging the big bundle, strap it and after that the same operator taked the big bundle with a forklift and stored it in the warehouse.

- Observation and analyses of the production process before automation was done. Following topics of the process has been observed and analysed:
- Production line utilization
- Shift efficiency
- Production costs.
- Health and safety aspects.

The production line before automation was a concept operated by 3 persons, 1 shift manger and 2 operators on the end of the line. The shift manager had to organize the shift, changing the coil, adjusting the profile dragging station, quality control, big bond handling and storing the finished goods in warehouse. The two operators had a duty to pair the profiles, make the small bundles and to prepare the small bundles into a big bundle. They were processing in their shift the whole amount of steel, which was dragged to profile. They performed the same operations during the whole shift. The organization had no possibility to rotate the operators. The same operators had to do the same job the whole time. Because of that, sometimes operators were slowing down the speed, which impacted negatively to the productivity.

The production line was constructed for production with maximal line speed of 120 m/min. The declared speed was not able to reach for each type of profile due to following reasons:

1) Additional operation on some types such as H punching.
2) Length of the profiles: the shorter the profile was, the slower speed could be used, because of the collision of the cutted peace with the upcoming peace – shorter interval.
3) The size of the profiles: the wider the profile was, the slower speed was used due to heavier work for operator.

During the observation and gathering the data and information, following data came out as results:

- Number of persons per shift: 3 persons
- Max. achievable production speed: 110 m/min
- Average production speed: 82 m/min
- Number of changes of coils/shift 15 times
- Duration of a coil change: 5 min
- Number of changes of tools: 0.37 times
- Duration of one tool change 60 min
- Shift duration: 8 h
- Lunch break: 30 min
- Theoretically production time: 450 min
- Effective production time per shift: 352.8 min
- Shift utilization: 78.4 %
- Shift production amount: 28929.6 m
- Productivity per employee: 9.643.2 m/employee
- Employee costs shear: 1.9 %

Table 1 Advantages and disadvantages of the existing production process

Process analysis	
Advantages	Disadvantages
Simple equipment	Physical labour
Low maintenance costs	Lost time for coil change
	Higher employee costs
	Low utilisation of the shift manager

Productivity Measurement and Enhancement System (ProMES) was applied as a tool to analyze the effectiveness of existing system. ProMES is a highly effective management system for measuring and improving the productivity of work units within organizations through performance measurement and feedback [25-28]. The definition of productivity is used: how effectively an organization uses its resources to achieve its goals [29-32].

According to the analysis, a list of possible improvements was done, in order to transform the disadvantiges to advantage:

1. Automation of section 5 and 6 (Fig.1)
2. Automation of section 7 (Fig.1)
3. Automation of coil change – section 1 (Fig.1)

3 DESIGN AND CONSTRUCTION OF UPGRADES FOR AUTOMATING THE PRODUCTION PROCESS INTRODUCTION

Considering that the improving productivity and health and safety issues are the most important topics, the management of the organization has decided that the automation of the section 5 and 6 (Fig. 1) should be the first step of improvement of the process. Flexibility in manufacturing is a great concern fopr every company, because today on the market exists a great competitivness. In the fast developing industries flexibility becomes necessity. When we speak about flexibility, its concept have different meaning each time. Flexibility is defined as a different level hierarchy, starting from resources, system flexibility, production performance and overall competitiveness of the company [6-11]. First of all we observed the production line. On Fig. 2 is presented the section 5 and 6 from the production line before automation.

For the new concept was necessary manufacturing of following assemblies:

1) Longitudinal and cross conveyor incl. gravitation forces controller and positioners
2) Profile turner and matching element
3) Small bundle preparation station
4) Small bundle strapping station
5) Small bundle transportation and stacking element

Following conditions were requested to be fullfiled:

- Health and safety standards
- Full automatically control
- PLC synchronization with the existing machine

Figure 2 Section 5 and 6 of the production line before automation

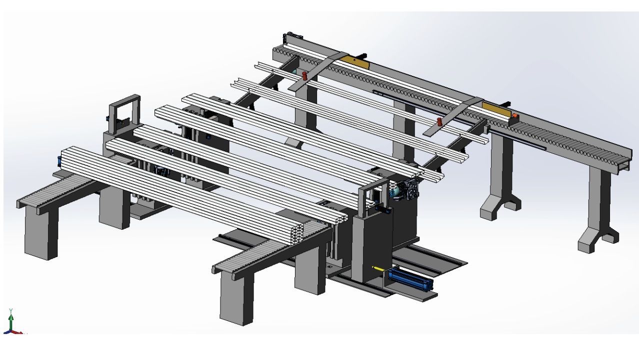

Figure 3 Upgrade of the packaging section

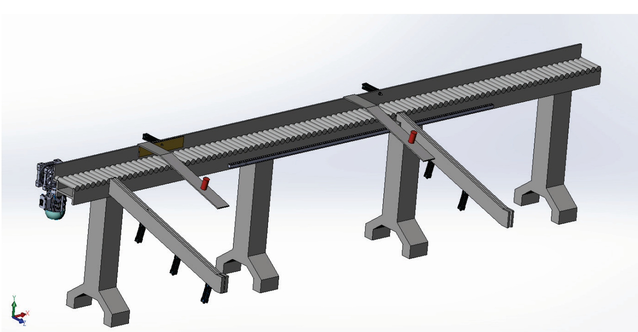

Figure 4 Longitudinal and cross conveyor

The Fig. 3 presents the concept of the upgrading of the profile packaging section. This concept was fully manufactured and installed in the investor plant.

The Fig. 4 presents the longitudinal and cross conveyor, including gravitation forces controller and positioners.

The gravitation forces have to be controlled because of the different range of the weight of the profiles in kg/m. Two stopping stations on each side of the sliders were planned (Fig. 5).

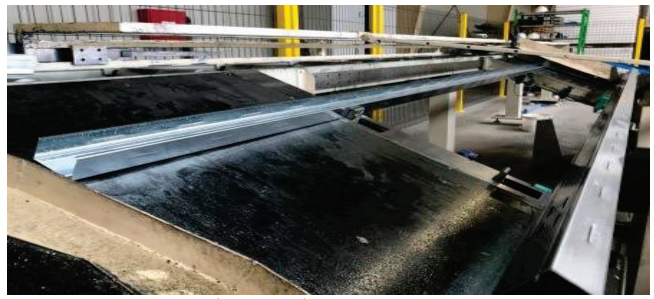

Figure 5 Gravitation forces controllers – stoppers

The stoppers are controlled through PLC and they can be adjusted by controlling the opening time (Fig. 6). In addition, the length of the profiles could be adjusted.

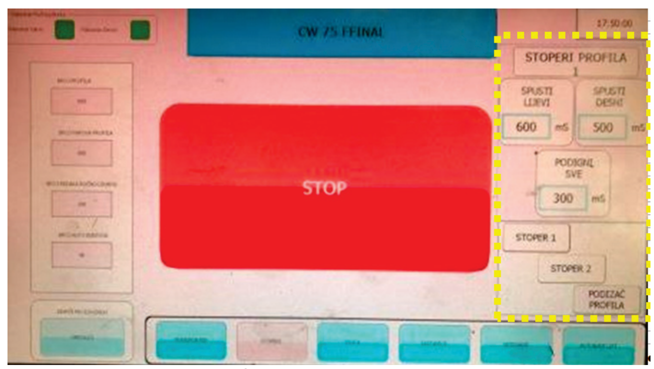

Figure 6 Stoppers control and adjustment

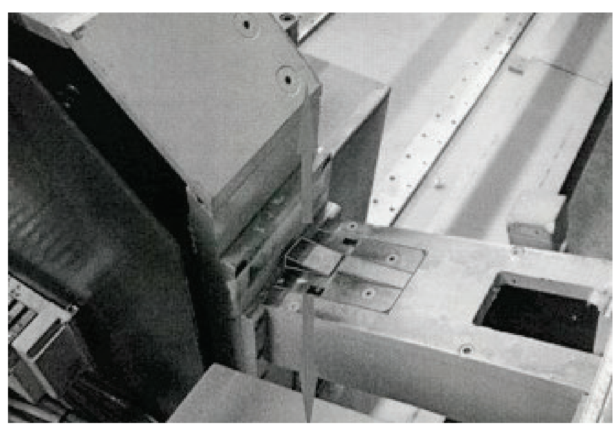

Figure 7 Profile positioner - fixed

The positioning of the first profile is very important for further function of the machine. If the first profile is not on the requested position, the turner will not succeed to pair it with the second piece. One aggravating circumstance is the different geometry of the profiles, as well as their dimensions and specific weight. The problem was solved with designing different positioners for each type of profile (Fig. 7 and Fig. 8).

For UD profile which has the smallest dimensions and which is lighter, the special magnetized holder which rotates in one point through a pneumatic actuator was designed (Fig. 8).

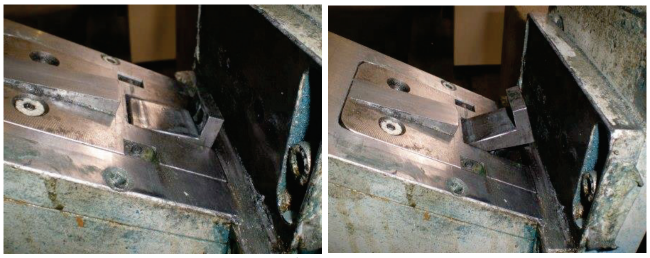

Figure 8 Profile positioner - rotary

The matching of two profiles was reached by the profile matching and turner machine. The drive elements move the carriers on X and Z axes, which provides lifting of the matched profiles and positioning them for the next step – preparation of small bundle. The carriers have different design, depending on the type of the profile and various dimensions.

Profi-bus communication protocol is widely used in pneumatic and electric drives. It is common to apply one profi-bus among many field-buses in the controller in order to provide multi-axis position control via high speed serial-bus. This allows communication of a far higher density of information to and from the controller, and also enables the realization of multivariable sensors and integrated sensing, control and actuation in a single system.

In both pneumatic and electric drives, this capability opens an opportunity to automate processes, covering larger range of parameters, such as position, pressure, speed, flow, etc. In addition, communication with external devices and systems is also possible, without additional cablings, which further enhances the implementation of a fieldbus-based controller [33-35].

The Fig. 9 presents the profile matching and turner.

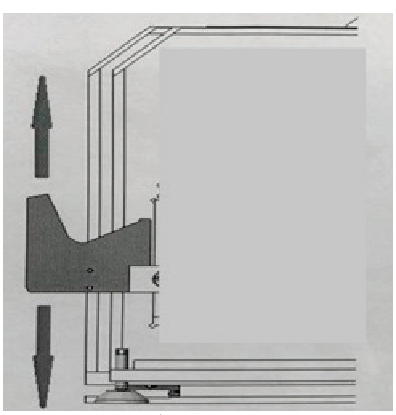

Figure 9 Profile matching and turner

Apart from the design, for the success of this operation, the speed of movement of the carrier is essential. The carriers are powered by three different speeds. The speeds are adjustable (Fig. 10) and they vary depending on the type of the profile.

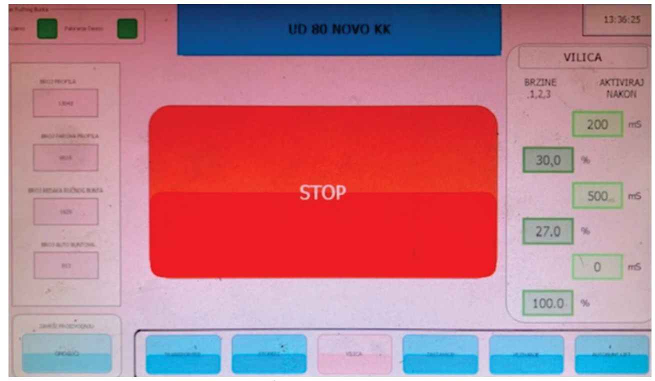

Figure 10 Profile turner – speed adjustment

The small bundle stacking station (Fig. 11) is composed of a single stopper, a lifting device that allows the stacking of multi-row profiles and a push button which using pneumatic actuator transmits a small cable to the binding station.

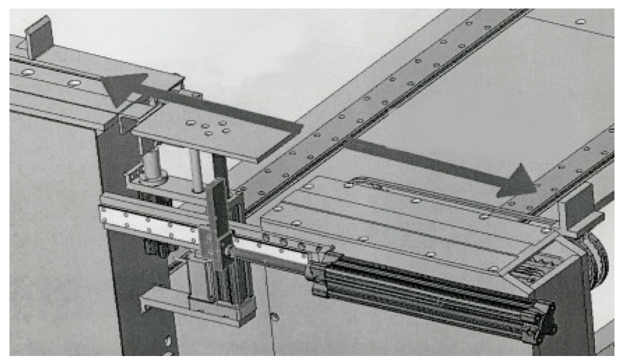

Figure 11 Small bundle stacking and lifting machine

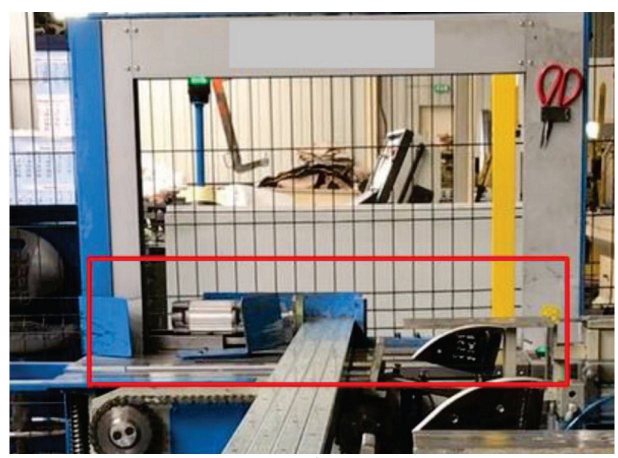

Figure 12 Strapping station

The main role of the strapping station (Fig. 12) is to tie a small bundle. The strapping station consists of strapping machines which are moved longitudinally. In strapping station there is an embedded system for handling the bundle before strapping. The longitudinally movement is enabled by pneumatic actuators.

In the small bundle transportation and stacking section the already strapped small bundle is moved to the lifting station and set one above the other. When the number of small bundles in a column is reached, the lifting machine lifts the column down to the requested position. After that the column will be pushed in cross direction to the roller conveyors – left and right through a pusher (Fig. 13).

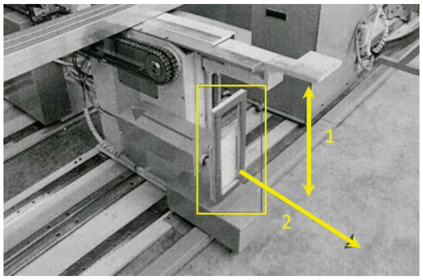

Figure 13 Transportation and stacking station

4 ANALYSIS OF THE RESULTS OBTAINED AFTER THE UPGRADING

On Fig. 14 is presented a new concept of the automated production line.

The Tab. 2 contains data based on the analysis of the results obtained after 8 months after the automation and commissioning of the production line for the metal profiles production. The presented data shows a comparison of productivity and other key performance indicators before and after automation.

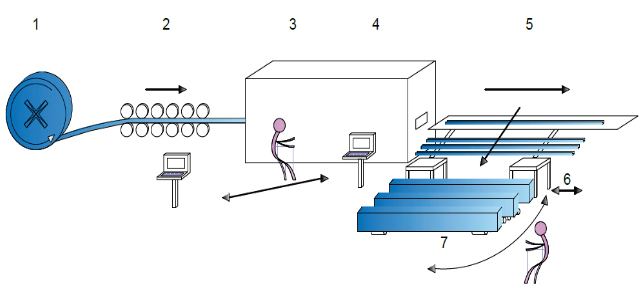

Figure 14 New concept – Automated production line

Table 2 Data for the production process before and after the automation

Topic	Unit	Before	After
Number of staff per shift	person	3	2
Max. achievable production speed	m/min	110	105
Average production speed	m/min	82	85
Shift production amount	m	28.929	30.120
Productivity per employee	m/person	9.643	13.406
Employee costs shear	%	1,04 %	0,75%

All data after automation, exept maximal acivable production speed, have shown better results. The decrease of maximal achivable production speed is less than 5%, but what is more important the average production speed after automation increased about 4 %.

The only one disadvantage, decrease of maximal achivable production speed, should be easily overcome by replacing the pneumatic actuators (Fig. 15) which drive the strapping machines, with servo motors that will enable:

1) Greater speeds of small bonding machines.
2) Easy control of motion, because they will be able to define start and stop cycles.

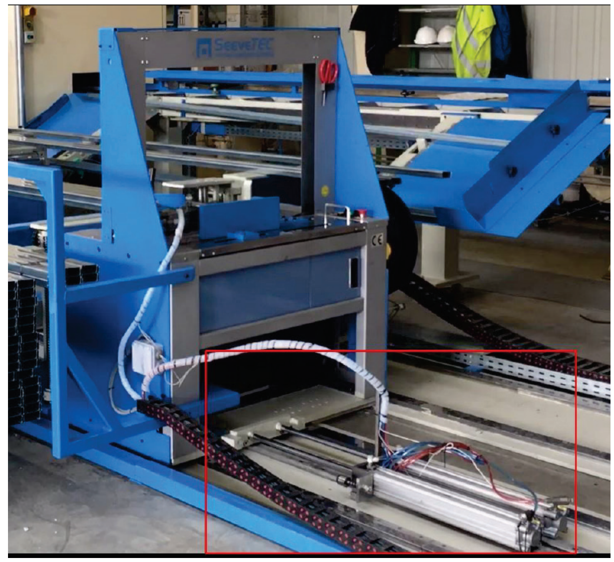

Figure 15 New concept – Automated production line

The health and safety standards in the automated production line were improved through machine guarding.

Machine guarding is one of the most relevant areas of local legal requirements, applied in industrial automation systems. In machine guarding standards, the most significant area in automated systems is guarding the place of processing [37-39].

The automated-system designer should consider the safety aspects of manufacturing systems in the design phase. The hazards of the human/machine interface should be removed before the system is built [37-39].

Following types of guarding were installed in the above-mentioned partly automated production line in order to enable preventive protection of the danger zones on machines:

1) Gates: They close and remain closed during the entire cycle.
2) Presence-Sensing Devices: Infrared systems for sensing objects that penetrate and enter in the danger zone.
3) Interlock mechanisms: Interlock mechanisms preventing a machine to operate, if any part of the machine is in an unsafe mode. The machine will not operate if the door is open.

5 CONCLUSION

This innovation project is an excellent example how automation, even of one section of the production line, influence on the increasing of the productivity accompanied with lower costs per produced product and improvement of health and safety standards in one company.

In addition, due to the very short time of return of investment, the crucial benefit of this innovation automation project is possibility of its implementation in other plants of the company. This will multiply the benefit and provide more competitiveness of the company on the world market, due to the decrease of the production costs.

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