PRODUCTION LINE AUTOMATION PROJECT BASED OF FMEA METOD

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The main goal of this paper is to analyse production line LITROBA and propose improvements for this line. The paper is divided into three main sections. First section consists of two smaller parts, which treat about method FMEA and about selected product, which is throttle valve. Second section is about branches of production line LITROBA and is concentred on the manual workstations and in this section is used FMEA method as the basic part for the third section. Third section deals with the proposal of robot utilization in the selected production line and there are calculated benefits that will arise from this proposal.

KEYWORDS

FMEA, production line, throttle valve, ESD floor, automation, 3D model

1 INTRODUCTION

Nowadays, every production company is trying to achieve the best results and deliver the highest quality products to its customers. Of course, the higher the quality of the product, the greater the number of pieces produced is requested by the customer. To achieve this, the company needs a team of skilled people and well-established processes in production lines. Because everything goes ahead and technology is not the exception. Thus, in some cases, an automatic robot replaces human work. The main objective will be to specify and propose process improvements of the selected production line in the company so that it will be able to compete with other production lines and other plants involved in the production of throttle valves. The analysis will be carried out on a semi-automatic line called LITROBA, which deals with the production of throttle valves.

2 DESCRIPTION OF THE FMEA PROCESS AND INTRODUCTION OF THE PRODUCED PRODUCT

Failure Mode and Effects Analysis (FMEA) is a systemic approach to detecting potential failures or errors that may arise in the design of a product or process [Pantazopoulos 2005]. FMEA is a method, by which it is possible to prevent or minimize the risks that arise during the construction of the management system, the product development and its construction, in the preparation of new technologies, the process development, respectively preparation of production itself [Altunatas 2019].

The “LITROBA” line produces an electronic throttle valves. The throttle valve is a very important part of the engine that serves to regulate the operation of the engine by opening and closing and reducing or increasing the power of the input gases. The throttle valve is located in the engine's intake tract and is usually controlled by pressing the accelerator pedal. It is used by carburettor engines, but also by fuel injection engines. The composition of the throttle valve is shown in Fig. 1.

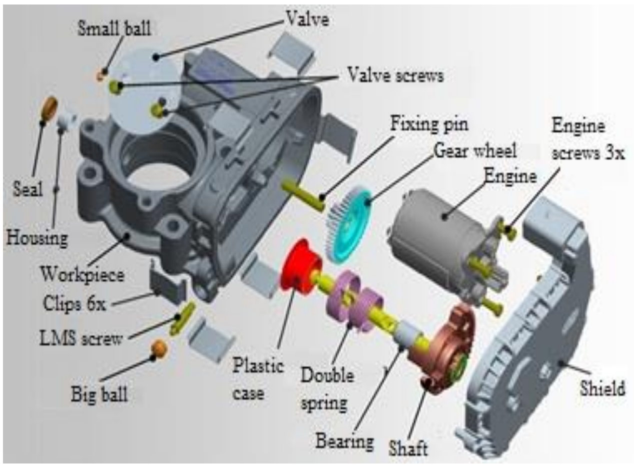


Figure 1: The composition of the throttle valve

3 INTRODUCTION OF THE PRODUCTION LINE LITROBA

The production line LITROBA is located in a production automotive company. This line is semi-automatic and its main product are throttle valves [Banduka 2016]. On this production line, there are three operators and they load components into the production line. The entire production line is built on the ESD floor, due to the possible generation of antistatic energy in the product. The operator entering the production line must pass the ESD tourniquet and wear ESD shoes. In Fig. 2 shows a 3D model of a production line.

The whole production process consists of getting machined pieces to the production line. It all starts from the machining itself, where the castings are inserted into the machine tools and parts are machined and then into these parts are subsequently inserted the components. After the machine tool, the work pieces go to the washing machine, where they are washed in hot emulsion, so that they are free of dirt and aluminium clasps that arise during machining and can thus affect the throttle valve function. In addition, another major part of the throttle valve is the TPS covers, which are produced in the ESD zone and are supplied as components to the production line [Cibulka 2018]. TPS abbreviation means "Throttle Position Sensor" which in translation is a sensor that controls the entire throttle valve. This sensor is programmed on each flap separately to control the timing of opening and closing the throttle valve. The non-contact type of TPS works on the principle of the Hell effect or inductive sensors, in general the magnet or inductive loop is a dynamic part, which is mounted on the throttle valve of shaft transmission and the circuit board to processing sensors and signals and is mounted in the ETC transmission housing. ETC is stationary [Piechowski

2018]. The 2D model of the production line shows three operators in four working positions. The production line is divided into 3 branches, from which empty pallets are returned to the operator station.

Figure 2: 3D model of production line

The first branch of the production line ends at station 80, the second branch ends at station 130, and the third branch ends with packaging of the finished product (Fig. 3).

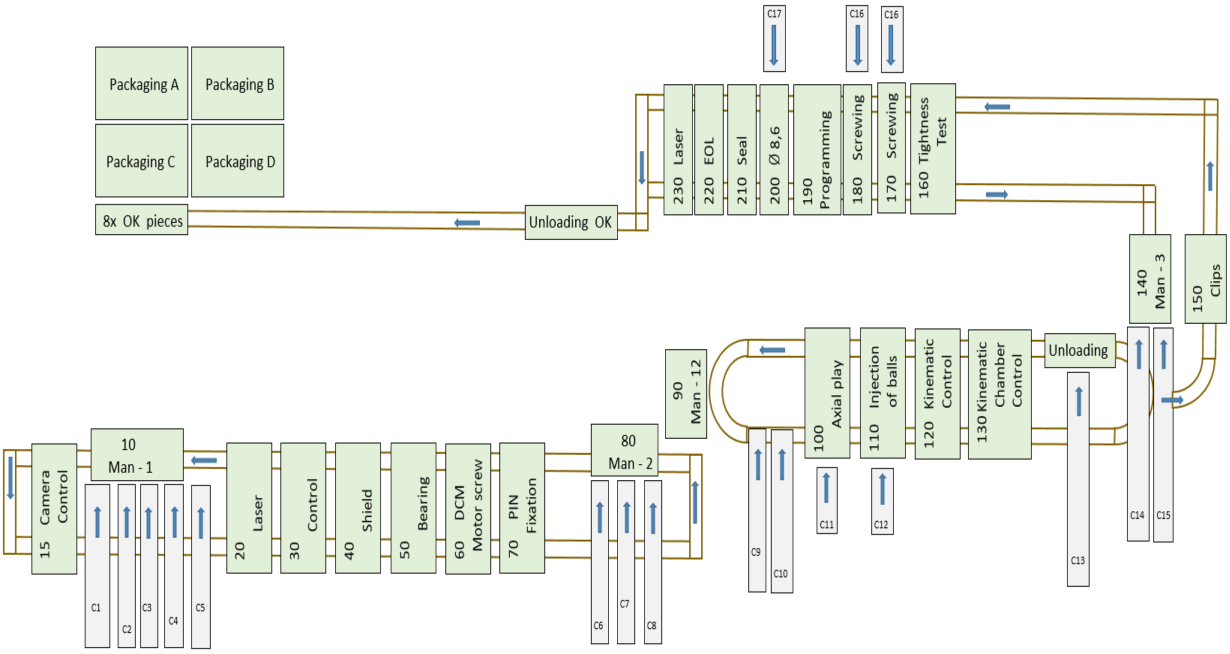


Figure 3: Model of production line with three operators

3.1 DESCRIPTION OF THE FIRST BRANCH OF THE PRODUCTION LINE IN TERMS OF MANUAL WORK

Manual Operator Station 1 (component loading, station 10) includes a linear conveyor, safety light barriers, all necessary components, an LCD monitor, a stop button Bosh Rexroth and a Datametrix code reader [Chin 2009], [Cibulka 2018]. Within the operator station 1, a plastic case is also loaded into the work piece, as shown in Fig. 4.

Operator station 2 (or station 80) has a second operator, which inserts the manual components into the station, and at the same time ends the first branch of the line and after loading all components passes to branch no. 2.

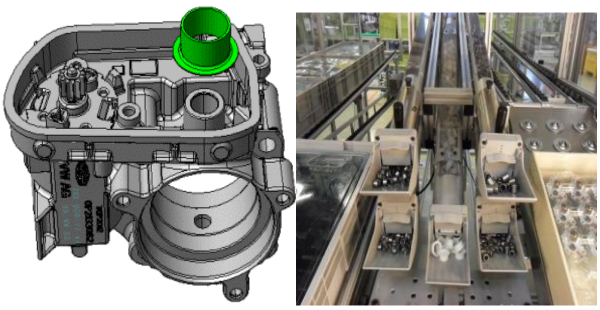


Figure 4: Loading the plastic case into the work piece

3.2 DESCRIPTION OF THE SECOND BRANCH OF THE PRODUCTION LINE IN TERMS OF MANUAL WORK

Within second branch of the production line, the operator takes the loaded components and puts the piece into the operator station no. 3 (Fig. 5). This station is manual and is connected next to the second operator station. Station 90 (throttle valve loading) contains same parts as previous station (station 80) and potentiometer [Shaker 2018].

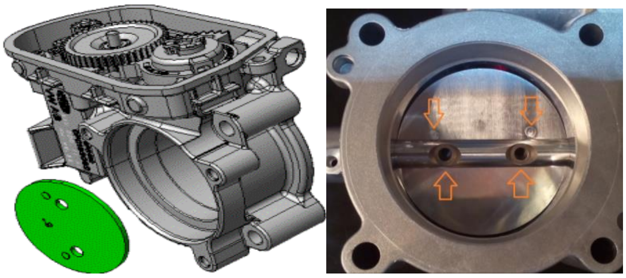


Figure 5: The throttle valve-loading model and displaying its insertion

3.3 DESCRIPTION OF THE THIRD BRANCH OF THE PRODUCTION LINE IN TERMS OF MANUAL WORK

At operator station no. 4, 6 pieces of metal clips are loaded on the work piece to hold the attached TPS cover on the work piece [CKrasaephol 2018]. A linear conveyor is used to feed seals and clips to station 140. The operator station (manually loading of the seal and clips) includes a linear conveyor, a seal presence camera, a clips presence camera, and a stop button Bosch Rexroth. Fig. 6 shows a 3D model of loading metal clips and a system of its pushing [Gawdzinska 2017].

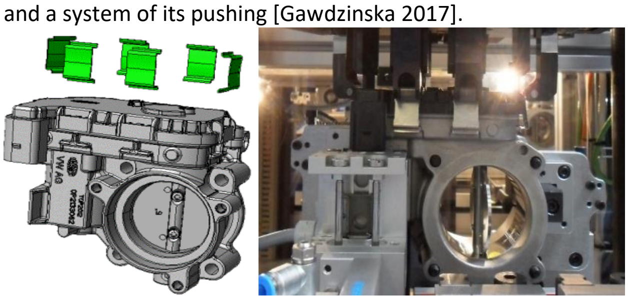


Figure 6: 3D model of metal clips loading and their pressing system

Due to the nature of the paper, we don´t describe the other stations of the production line, because they carry out operations where no human element is required and we focus on human element [Dudek 2017], [Cibulka 2018].

Operator station									
Process description / Functions	Potential possible error	Potential consequence of error	Severity	Potential reason / cause of error	Prevention (preventive measures)	Occurence	Detection (problem detected)	Detection	RPN
Inserting the double spring into the workpiece	Component error	Delay in production	8	Operator failure	Training of operators	3	100% control by camera	2	48
	Component has been reversed	Delay in production	8	Operator failure	Training of operators	3	100% control by camera	2	48
	Placing upside - down	Product`s functionality affected	8	Operator failure	Poka yoke (only one way to insert component)	1	100% control by camera	2	16
	Placing of 2 components	Product`s functionality affected	8	Operator failure	Training of operators	4	100% control by camera	2	64
Inserting the shaft into the workpiece	Component error	Delay in production	8	Operator failure	Training of operators	3	100% control by camera	2	48
	Component not placed correctly	Delay in production	8	Operator failure	Training of operators	3	100% control by camera	2	48
	Placing upside - down	Product`s functionality affected	8	Operator failure	Training of operators	3	100% control by camera	2	48
	Placing of 2 components	Product`s functionality affected	8	Operator failure	Training of operators	4	100% control by camera	2	64
Loading of double wheel	Component error	Delay in production	8	Operator failure	Training of operators	3	100% control by operator	2	48
	Component not placed correctly	Delay in production	8	Operator failure	Training of operators	3	100% control by operator	2	48
	Placing upside - down	Product`s functionality affected	8	Operator failure	Training of operators	3	100% control by operator	2	48
	Inserting 2 components simultaneously	Product functionality not affected	8	Operator failure	Training of operators	4	100% control by operator	2	64

Table 1: Analysis of possible occurrence and impact of errors – FMEA

Tab. 1 shows the FMEA document, which is implemented directly on the production line, because it will help us to identify the causes of errors and their possible impact on the production line LITROBA.

4 PROPOSAL FOR PROCESSES IMPROVEMENT ON THE LITROBA PRODUCTION LINE

As the FMEA analysis indicated several problems related to manual work, we propose to introduce full automation of the LITROBA production line [Geramian 2018]. Instead of manual insertion of the shaft into the work piece, we propose to implement the IRB 6700 robot (Fig. 7) from ABB in the production station 80 and the gripper from SCHUNK. SHUNK will supply this robot with a gripper that is managed by a control panel and a program designed for the robot. Grippers with four fingers have an advantage over conventional centric grippers, for example, when rolled work pieces are stored in tablets. The gripper processes the work pieces by controlled and reliable process (despite disturbing contours) [Yazdi 2019].
Gripper will be programmed to insert the shaft into the work piece accurately [Feng 2018]. This reduces the cycle time of the production line by almost 10 seconds and avoids the errors most commonly occurred on a production line. There, the operator has to insert the shaft with rotational movement and sometimes this is a problem as the shaft is inserted through the double metal spring and the operator still doesn´t insert the shaft properly. With the operator, the shaft insertion cycle time was 35 seconds, and when the robot will be load, a shaft insertion time will be 27 seconds, which is 8 seconds faster than in the current state. Using the automatic robot for shaft insertion not only speeds up cycle time, but it also increases production line production and eliminates errors after incorrect shaft insertion.

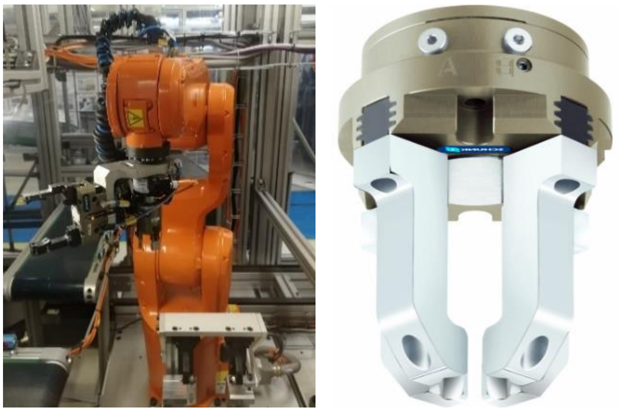
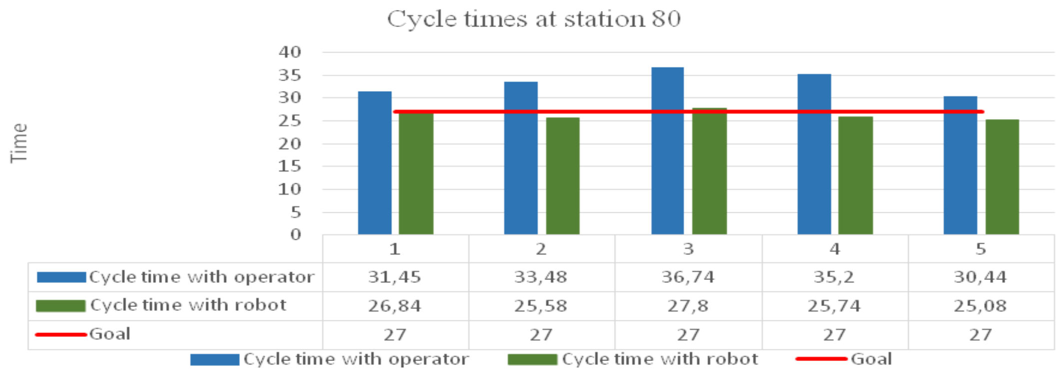


Figure 7: Automatic robot IRB 6700 and gripper

Fig. 8 shows the cycle times before and after the introduction of the robot. Production line cycle time is set to 27 second tact. The station 80 has a high cycle time due to the operator. After the robot introduction, the cycle times will reduce by 10%, which makes smoother production [Hidayat 2018], [Lo 2018].
Tab. 2 shows activities that are carried out on the production line. For example, there are AM activities that include cleaning the machine, cleaning the station, feeding "master" samples into the machine, and controlling the machine.



	1	2	3	4	5
Cycle time with operator	31,45	33,48	36,74	35,2	30,44
Cycle time with robot	26,84	25,58	27,8	25,74	25,08
Goal	27	27	27	27	27

Figure 8: Cycle times of station 80 at present and after the introduction of the robot

It is assumed with 2-shift work and this makes a net working time of 22.5 hours per day. The nominal time fund is calculated according to a coefficient (working days per year x hours per day). In Tab. 3 are evaluated costs and revenues, which have to be taken into account, if the company want to buy a new automatic robot IRB 6700. The price of this robot is 85 000 EUR. The installation costs of the robot and the introduction of a robotic gripper, which will cost 2500 EUR, will also have to be taken into account. The total cost of introducing the robot has risen to almost 90 000 EUR.

Usable time fund of the machine	
Nominal time fund - time losses (repairs and breaks)	
Time losses/downtimes in conventional production:	
7% of total hours of work shift	0,84
Workplace preparation and cleaning	
2% of total hours of work shift	0,24
Repairs and maintenance of machine	
TOTAL 9%	1,08
>>> Time loss coefficient	k = 100 – 9 = 91%
Calculation:	F = 5647,5 working hours/year * 0,91
Usable time fund	5139,225
Effective time fund of machine includes also vacations at work for the whole company.	
Workplace preparation and cleaning (AM activities):	
2% of total hours of work shift (12hours)	15 minutes
Repairs and maintenance of machine :	
5% of total hours of work shift (12h)	35 minutes
TOTAL 7%	50 minutes
>>> Time loss coefficient	0,07
Usable time fund (hours per year)	5252,175
Nominal time fund * time loss coefficient	k = 100 – 7 = 93%

Table 2: Time fund of machine utilization

Production line			
Purchasing the robot	85 000 EUR	Production with operator	0 EUR
Direct wages	1 500 EUR	Direct wages	900 EUR
Time of installation * hourly wage	1 500 EUR	Production time * hourly wage	45 EUR
Total production time of the product * hourly wage	0 EUR		
Other	2 903.38 EUR		
Price of the subcontractor for bevels product	2 500 EUR	Costs per operator per month	900 EUR
Transport (number of km * price per km)	400 EUR	Costs per operator per year	11 295 EUR
Machine electric energy consumption	3,38 EUR		
Maintenance and repairs	0 EUR		
DIRECT COSTS (VARIABLE)	86 500 EUR	DIRECT COSTS (VARIABLE)	900 EUR
TOTOAL PRODUCTION COSTS	89 403.38 EUR	TOTOAL PRODUCTION COSTS	12 195 EUR
Revenues			
Production time of 1 product	27 seconds	Production time of 1 product	35 seconds
Price of the 1 finished product	30 EUR	Price of the 1 finished product	30 EUR
Number of pieces produced/hour	134 pieces	Number of pieces produced/hour	103 pieces
Number of pieces produced/day	3 015 pieces	Number of pieces produced/day	2 318 pieces
Number of pieces produced/year	756 765 pieces	Number of pieces produced/year	581 818 pieces
Profit per year	22 702 950 EUR	Profit per year	17 454 540 EUR
Difference: 5 248 410 EUR			

Table 3: Financial evaluation of the robot's contribution

The costs of buying a robot will be justified, as we estimate the payback of this robot is about 1 year and 11 months. This action will prevent scraps and possible production errors on the production line LITROBA. A great benefit is also easing the work for the operator at the station 80, where he doesn´t have to perform unnecessary movements by inserting components. The most important benefits of the proposed solution can be summarized as the reduction of scraps, reduction of cycling time by approximately 23% and increase of production output by 31 pieces per hour (approximately 80 000 pieces per year).

5 CONCLUSIONS

In the first part of the paper, we described the basis of the FMEA method and the produced product – throttle valve. In the second part of the paper, we analyzed in detail, the production processes on the LITROBA production line using manual work, while we investigated and monitored possible improvements at selected stations. By analyzing the production line, we found that it is possible to optimize and improve processes at station 80, where is located the operator. In the third part of the paper, we proposed a change for station 80 by adding a robot and we calculated the economic benefits of this proposal. Next, we evaluated the benefits of implementation of the robot by installing it in station 80. At the beginning, we monitored and measured the operator's output (how it can feed the shaft into the work piece), but after analysis we proved that automation of this workplace is necessary.

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