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SAFETY AND AUTOMATIZATION OF MACHINING LINE

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Abstract: the paper deals with problematic of machining lines of machine components for the automotive industry. There is a current issue of increasing labor productivity and economic efficiency of production with full safety of production and environmental protection. Therefore, for a specific practical assignment, the replacement of existing machinery using manual workpiece handling is performed by a fully automated safety-accessible one. For this purpose, an analysis of the technical and operating parameters of the proposed NC machines has been prepared. Attention is paid to optimization of material flow and arrangement of individual workplaces of production machines including handling and transfer of material between individual workplaces. Particular attention is paid to the safety of workers and improves the environmental conditions of the production plant. Finally, the overall efficiency of the proposed solution is evaluated in detail compared to the current solution.
Keywords: automatization, machining, safety

1. INTRODUCTION

At present, the trend of increasing machine production volumes is clear and it is therefore necessary to focus on increasing production efficiency in the given segment. In order to increase labor productivity, stereotyped human activity is gradually being replaced by activities of fully automated machines (Favi et al., 2017; Fiaidhi et al., 2018; Klimecka-Tatar and Shinde, 2019; Lasi et al., 2014; Ulewicz and Mazur, 2019). Nevertheless, the new machinery also increases the safety requirements for possible temporary manual operation, maintenance as well as bystanders who may accidentally reach the machine's working area.

1.1. Automatic line

The use of an automatic line consists in limiting human work ideally until it is completely eliminated using automation technology - electronically controlled robots (Roldán et al., 2019). The robotized line usually works with higher productivity, lower operating costs and more time utilization. Its advantages include operation on public holidays and weekends (Knop et al., 2019; Lee at al., 2019). On the contrary, it is more demanding on computer technology, considerable initial investment and there is also a risk of hacking.

1.2. Automatic line

Workpiece handling, as one of the important aspects in line design, is a major contributor to reducing production time (Klimecka-Tatar and Shinde, 2019). The automatic line is manipulated by an industrial robot having greater accuracy and speed than the operator. Unlike the operator, however, he is not able to react to unpredictable situations - fall of the workpiece to the ground, non-seating in the correct position in the machining center, incorrectly placed piece in the handling box, etc.

2. ACTUAL CONDITION OF PRODUCING LINE

At present, Aisan Industry Czech uses production lines with the subject arrangement with manual manipulation of the piece by the operator. As an example, the ML14 line was selected using 4 MoriSeiki Ultimill V3000 machining centers, 1 washing machine for final cleaning of the workpiece from process liquid and any remainder of the machining products (chips), compressed air drying and visual inspection by another operator. Each machine on the line is lowered by a manual switch and the presence of, for example, the operator's arm is not monitored between the machining center doors (Aisan, 2017).

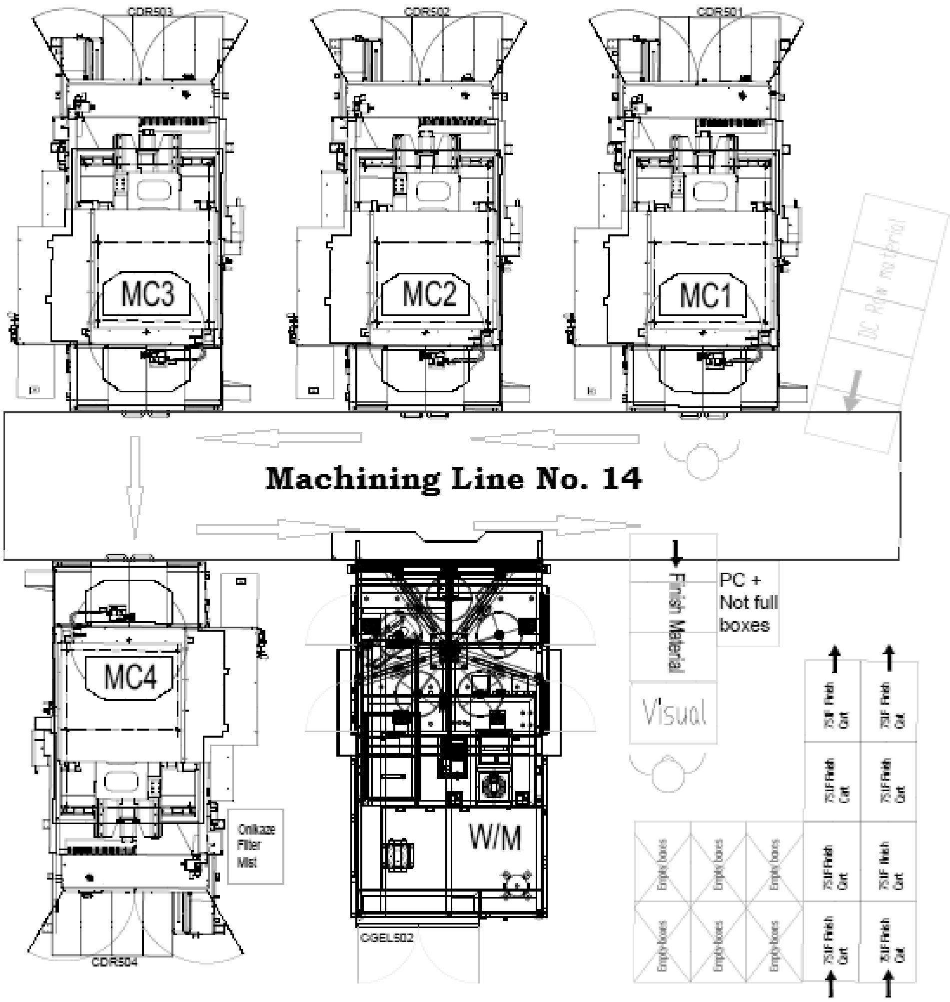

Fig. 1. ML 14 Actual layout with material flow

2.1. Comparison NC manipulation robots

The selection of the robot is based on the values given in Table 1 below, in which the order from 1 to 4 was assigned in each criterion compared and points awarded. These were determined as follows: 1st place = 4 points, 2nd place = 3 points, 3rd place = 2 points, 4th place = 1 point. First of all, it was still necessary to determine which criteria had the greatest weight. In this case, the biggest role was played by the purchase costs and the speed of the robot movement due to faster machine operation. The points for these criteria were therefore multiplied by 2.

Table 1
Comparison of manípulation robots

Producer of robot	Cost [EUR]	Load capacity [kg]	Range [mm]	Number of axes [-]	Power input [kW]	Repeatability [mm]	Ø arm speed[°/s]	Points
ABB	27500	10	1550	6	0.67	±0.06	270.0	24
FANUC	25500	7	1101	6	1.00	±0.08	402.5	27
KUKA	27600	10	1420	6	1.20	±0.04	314.0	24
Mitsubishi	27500	12	1094	6	1.10	±0.05	384.3	26

2.1. Automatic line design

Operated by handling robots, the ML 14 shows 36.1% higher productivity than manual handling.

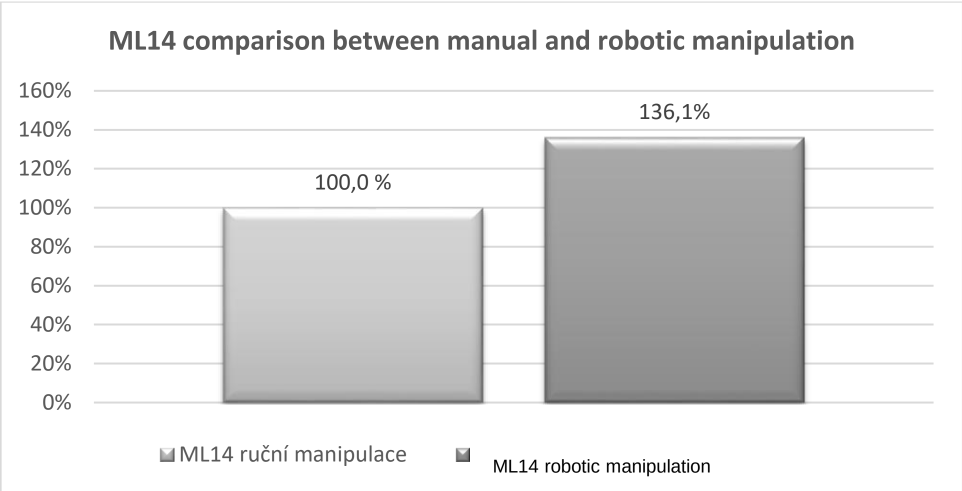

Fig. 2. Comparison between manual and robotic manipulation

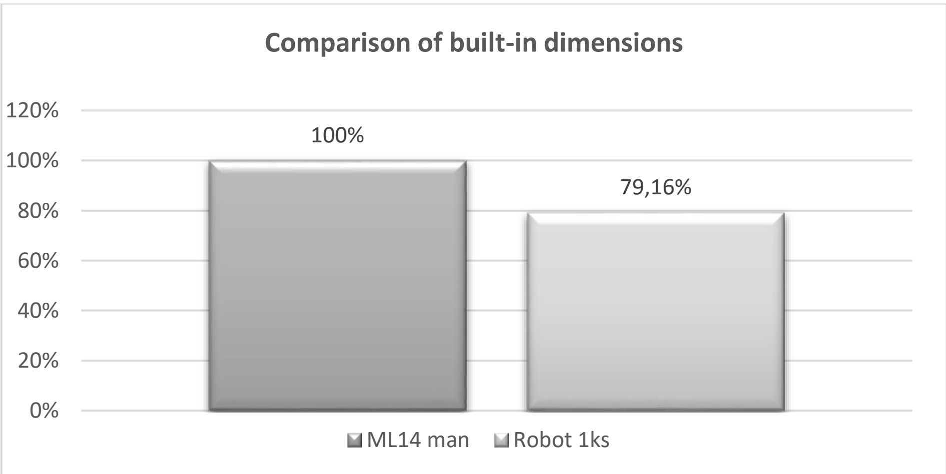

Fig. 3. Comparison of built-in dimensions

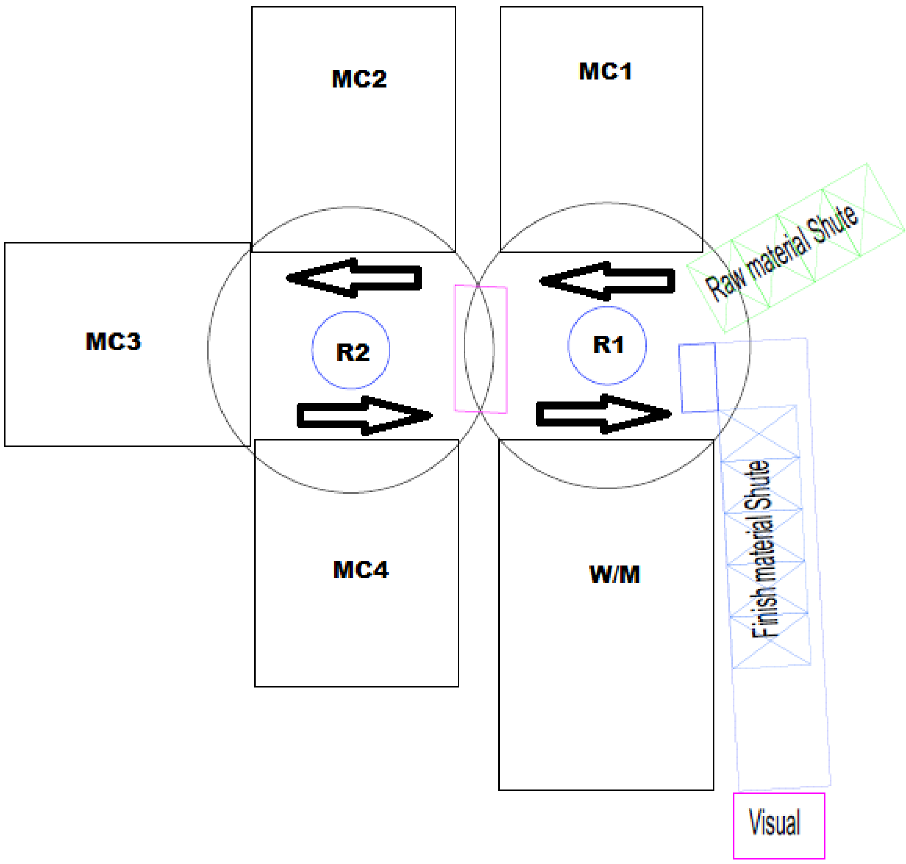

Fig. 4. Machine line new layout

3. SAFETY

Because collaborative robots have lower speeds, their installation is out of the question. It is therefore necessary to install devices to prevent people from entering the machine's work area to ensure production safety. There is a possibility to install safety barriers between individual machines, but due to the high purchase price and the need to increase service capacity is in this respect more economical use of wire mesh around the entire production line with only one input secured by limit switch.In case of opening the line will automatically stop (Hietikko et al.,, 2011; Kielesińska and Pristavka, 2019). A safety barrier with a resolution of 30mm will be installed at the site intended for the transfer of finished workpieces for visual inspection to reduce the risk of robot-human contact. According to the manufacturer, this distinction is fully sufficient to detect the hand of a worker. With a protected height of 246mm, the entire transfer point area will be fully protected. (FANUC, 2016)
Compared to the current situation, the risk of hand gripping into the machining center door is completely eliminated and there is no risk of the worker being affected by the cutting emulsion.

4. ENVIRONMENTAL ASPECTS

Machining lines using a mixture of water and cutting emulsion as a process liquid produce a fine aerosol of the mixture. Due to its adverse effects on human health and last but not least on the cleanliness of the working environment, machine tools are equipped with FILTERMIST centrifugal oil mist separators. Collected cutting emulsion effluents are discharged away from the machines into a common container to reduce the risk of cutting emulsion contamination in the machines.

Conventional oil mist or emulsion aerosol, which is produced during machining on machine tools, is usually composed of particles with a size of 0.5 - 10 microns. According to world expert studies, about 93% of all particles exceed 1 μm, about 5% of the particles range from 0.6 to 1 μm and only the remaining 2% of the particles are less than 0.6 μm (Wemac, 2016).
The efficiency of FILTERMIST centrifugal units in filtering such composite air massages is extraordinary. In principle, particles of one micron size are captured with almost 100% efficiency. Independent tests carried out by the British Government Defense Evaluation and Research Agency (DERA) on the FX5000 showed the following efficiency in filtering conventional oil mist:

Table 2
Efficiency of FILTERMIST (Wemac 2019)

Particle size	**μm**	**0.09**	**0.25**	**0.50**	**0.80**	**1.25**	**2.50**
Efficeiency of filtration	%	~ 60	~ 86	~ 98	~ 99	~ 100	~ 100

However, in order to properly compare efficacy, it is necessary to evaluate efficacy in the long term (Shen, 2015). The chracteristic of production efficacy in the long term is presented in Fig.4.

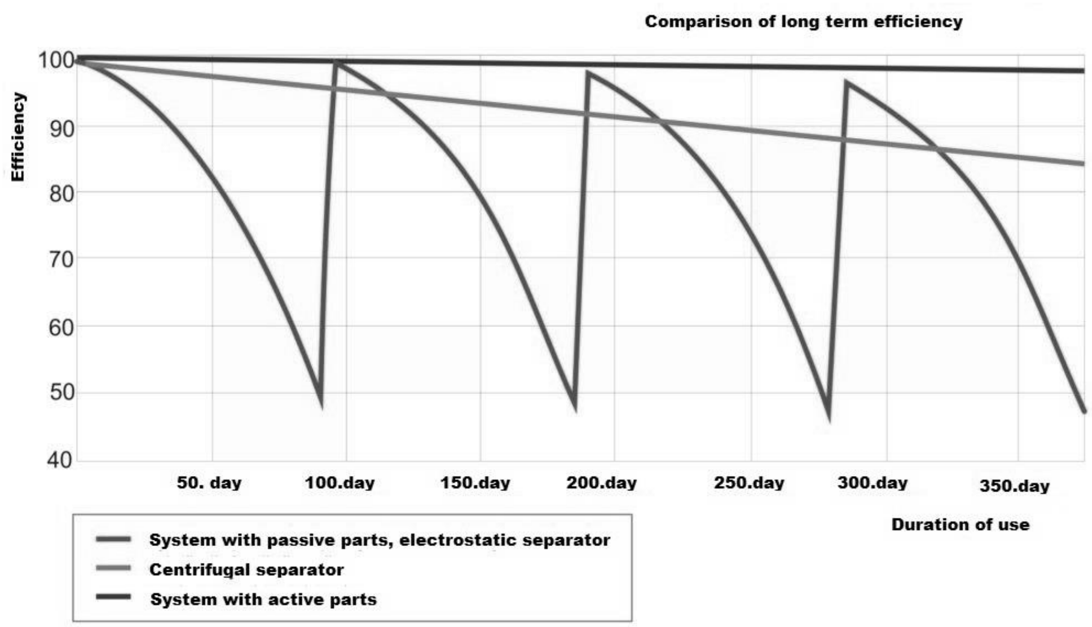

Fig. 4. Comparison of long term efficiency (Wemac, 2019)

The operating costs included the costs of electricity consumed by handling robots, machining centers and dishwashers of machined pieces, the purchase of machine tools, the replacement and disposal of process fluids and, last but not least, the operator's work.
The difference in cost per piece produced by a manually operated line is up to 42% higher compared to an automatic line.

4. CONCLUSIONS

Given that the line is primarily to be a tool for generating company profits, it is necessary to include in the total payback period also increased profits resulting from increased production and of course the actual savings. Including increased profits, the payback period is 2.05 years.

A significant benefit in the implementation of automation is a significant reduction in the risk of injury or damage to the health of both operators on the line and of all people in the area.

As is clear from the data gathered during the processing of the data necessary for the required analyzes and calculations, the introduction of an automatic line will affect the operation of the whole factory. Production of casting lines and subsequent assembly of components as well as logistics and external suppliers of materials and parts will necessarily have to respond to increasing the productivity of the machining line. If these parameters are not matched, the investment in the automatic line is unnecessary, almost irreversible and the capacity of the automatic line will be unused. Therefore, when implementing automation, it is necessary to take into account the need to invest in previous and subsequent production and non-production operations, as well as the need to employ more employees with higher education and qualifications. Therefore, the return on investment in the new automatic machining line includes mainly increased productivity and partly also savings resulting from the reduction of the number of employees employed. Despite all the above-mentioned advantages and disadvantages, the use of robots in industry is both economically and technologically advantageous and can be recommended.

REFERENCES

ABB Company, 2017. Company documentation.

AISAN Industry Czech, s.r.o,, 2017. Company documentation, Louny.

Bořecký, J., 2012. *Diplom thesis.*

FANUC, 2017. Company documentation.

Favi, C., Germani, M., Marconi, M., 2017. *A 4M Approach for a Comprehensive Analysis and Improvement of Manual Assembly Lines*, Procedia Manufacturing, 11, 1510–1518, DOI:10.1016/j.promfg.2017.07.283

Fiaidhi, J., Mohammed, S., Mohammed, S., 2018. *The Robotization of Extreme Automation: The Balance Between Fear and Courage*, IT Professional, 20(6), 87–93, DOI: 10.1109/MITP.2018.2876979

Hietikko, M., Malm, T., Alanen, J., 2011. *Risk estimation studies in the context of a machine control function,* Reliability Engineering & System Safety, 96(7), 767–774, DOI: 10.1016/j.ress.2011.02.009

Kielesińska, A., Pristavka, M. 2019., *The Machinery Safety Management - Selected Issues,* System Safety: Human - Technical Facility - Environment, 1(1), 45–52, DOI: 10.2478/czoto-2019-0006

Klimecka-Tatar, D., Shinde, V., 2019. *Improvement of Manual Assembly Line Based on Value Stream Mapping (VSM) and Efectiveness Coefficient,* Quality Production Improvement - QPI, 1(1), 537–544, DOI: 10.2478/cqpi-2019-0072

Knop, K., Olejarz, E., Ulewicz, R., 2019. *Evaluating and Improving the Effectiveness of Visual Inspection of Products from the Automotive Industry*, Lecture Notes in Mechanical Engineering, 7, 231–243, DOI: 10.1007/978-3-030-17269-5_17

Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., Hoffmann, M., 2014. *Industry 4.0,* Business & Information Systems Engineering, *6*(4), 239–242, DOI: 10.1007/s12599-014-0334-4

Lee, D.-H., Na, M.-W., Song, J.-B., Park, C.-H., Park, D.-I., 2019. *Assembly process monitoring algorithm using force data and deformation data*, Robotics and Computer-Integrated Manufacturing, *56*, 149–156, DOI: 10.1016/j.rcim.2018.09.008

Mašín, I., Vytlačil, M., 2000. *Nové cesty k vyšší produktivitě: Metody průmyslového inženýrství.* 1. vydání. Liberec.

Rumíšek, P., 2013. *Automatizace (roboty a manipulátory,).*

Roldán, J. J., Crespo, E., Martín-Barrio, A., Peña-Tapia, E., Barrientos, A., 2019. *A training system for Industry 4.0 operators in complex assemblies based on virtual reality and process mining*. Robotics and Computer-Integrated Manufacturing, 59, 305–316, DOI: 10.1016/j.rcim.2019.05.004

Shen, C.-C., 2015. Discussion on key successful factors of TPM in enterprises. Journal of Applied Research and Technology, 13(3), 425–427, DOI: 10.1016/j.jart.2015.05.002

Ulewicz, R. Mazur, M., 2019. *Economic aspects of robotization of production processes by example of a car semi-trailers manufacturer,* Manufacturing Technology, 19(6), 1054–1059, DOI: 10.21062/ujep/408.2019/a/1213-2489/MT/19/6/1054

WEMAC, 2019*. Company documentation*