PRODUCTION ENGINEERING ARCHIVES

ISSN 2353-5156 (print)
ISSN 2353-7779 (online)

Exist since 4th quarter 2013
Available online at https://pea-journal.eu

Concept of an innovative technological line for the processing of linear profiles

Tomasz Gustowski[1], Waldemar Kurek[1], Rafał Grzejda[2*]

[1] AGICO Group, Miła 1, 70-813 Szczecin, Poland; t.gustowski@agico.com.pl (T.G); w.kurek@agico.com.pl (W.K.)
[2] West Pomeranian University of Technology in Szczecin, Faculty of Mechanical Engineering and Mechatronics, 19 Piastów Ave., 70-310 Szczecin, Poland
*Correspondence: rafal.grzejda@zut.edu.pl

Article history
Received 28.07.2022
Accepted 09.01.2023
Available online 20.02.2023

Keywords
Linear profiles
Automated technological line
Plasma arc cutting
Circular saw cutting
Welding robot

Abstract
The paper presents the concept of an innovative technological line intended for the processing of long linear profiles used in engineering steel and aluminium structures, which can be both hollow and open section profiles. The line is set up with seven main sections: profile loading system, input roller conveyor, plasma arc cutting section, circular saw cutting section, robot welding section, output roller conveyor and profile packaging system. The assumptions adopted to create the concept of the technological line were specified. A block diagram of the line and drawings showing the structure of its selected elements were depicted. The features of the technological line documenting its product and process innovativeness were indicated. The proposed technological line is built in the AGICO Group company, but it can also be successfully implemented in other companies dealing with the processing of long linear profiles.

DOI: 10.30657/pea.2023.29.2

1. Introduction

One of the main functions of operational management in an industrial company is production planning (Cheraghalikhani et al., 2019; Wolniak, 2020). The management processes of own means of production lead to the reduction of production costs (Krynke, 2021; Setamanit, 2019). It is possible, inter alia, by combining various distant production stations into one technological line. Then, it is advisable to automate manufacturing processes, which additionally reduces costs and increases the repeatability of the created details (Pérez et al., 2020; Siderska, 2020; Biedermann et al., 2021).

This paper concerns the concept of a technological line, which was created in a company called AGICO Group dealing with the processing of long linear profiles used as load-bearing or supporting elements in steel structures (Biegus, 2015a; Biegus, 2015b; Gosowski et al., 2016). The processing of these profiles on the designed line takes place in the following three main stages: cutting holes with plasma, cutting to size with a circular saw and welding with robots, while usually this is performed on three separate production stations. The combination of the above-mentioned operations into one line is the process innovativeness of the designed technological line (Kozioł et al., 2015). At the same time, the systems for loading and packaging profiles, as well as the plasma arc cutting section, constitute the product innovativeness of the technological line (Szopik-Depczyńska et al., 2020). The concept is being deployed with the use of the European Union funds. In this sense, the paper should be treated as a preliminary note preceding future publications on the results of implementing the technological line in the own business activity of the AGICO Group.

2. Literature review

Currently, profiles are joined into structures by using multi-bolted (Biegus, 2015a; Sheet et. al., 2013) or welded connections (Havula et. al., 2018; Mirghaderi et. al., 2010). Both hollow section (Singh and Singh, 2018) and open section profiles (Zeinoddini and Hosseini, 2013) are used. Various methods can be applied for cutting profiles, which allow to obtain different properties of the surface layer of the cut edges (Maier-Komor et al., 2010; Węglowski and Pfeifer, 2014; Lipiäinen et al., 2021).

In the literature, one-station methods of profile processing are most often described. Kanyilmaz and Castiglioni (2018) presented the entire manufacturing process applied to joints assembled with tubular column and I-beam of various sizes. The process was divided into two separate stages: cutting profiles with the laser cutting technology (LCT) and welding the profiles into a suitable structure. Kanyilmaz (2019) characterised the problematic nature of the production of steel hollow profile connections and indicated LCT as a remedy for the problems arising in this production. Moazed and Fotouhi (2012) investigated the possibility of using LCT for producing welded square hollow-section T-joints, and compared the fatigue strength between T-joints obtained by mechanical cutting and laser cutting. 21 full-scale experiments with cyclic loading showed that the fatigue strength of the laser-cut samples was higher compared to those obtained with mechanical cutting. The authors also concluded that the hollow section profiles can be feasibly cut using LCT for an efficient connection assembly. It is also possible for open section profiles, as proved by Szlendak and Oponowicz (2013).

Simonetto et al. (2021) designed a prototype machine for bending steel hollow profiles with a ratio of the curvature radius to the outer diameter ranging from 0.5 to 8, with high accuracy and repeatability. Keraita and Kim (2007) developed a CNC machine for plasma arc cutting of pipe profiles, capable of producing high-precision parts by simultaneously controlling of two axes. The project of another CNC plasma arc cutting machine was realised by Kudrna et al. (2019). Al-Shamma'a et al. (2002a) and Al-Shamma'a et al. (2002b) presented the concept of a plasma-laser hybrid system for cutting with the use of a special torch.

Stolecki et al. (2015) described the technology of laser welding of finned tubes made of austenitic steel. Sousa et al. (2020) developed an modular equipment to produce T-profiles by continuous laser welding process.

The literature review shows that the combination of all necessary machining operations into one technological line for the production of profile systems is a new idea. The paper presents the concept of such a line for automatic plasma arc cutting, circular saw cutting and welding with use of welding robots. The line is intended for both load-bearing or supporting elements made of hollow or open section profiles.

Waterjet and laser cutting are more precise than plasma (Keraita and Kim, 2007). Nevertheless, high tolerance plasma arc cutting (HTPAC) technology dramatically improves the cutting accuracy possible with plasma technology. Plasma technology, especially at low amperages, has advantages in terms of cost and housekeeping. Improvements in control and extending the consumable life make plasma an even more productive and precise cutting technology. As the systems further improved cut quality, plasma is gradually replacing the more expensive cutting lasers.

The most important parameters in the plasma arc cutting process are: amperage, cutting speed and gas pressure during cutting. The application of dependencies between these parameters in a manufacturing company allows for the minimisation of production losses during the development of the plasma arc cutting process based on the assessment of the significance of controllable process parameters (Feldshtein et al., 2018).

In the designed technological line, plasma arc cutting technology (PACT) was used as an alternative to laser cutting, giving a comparable class of fatigue behavior for steel elements with cut holes (Cicero et al., 2016; Cicero et al., 2017) and causing a similar characteristics of the heat-affected zone (HAZ) during the cutting process (Harničárová et al., 2010). Furthermore, plasma-cut samples exhibit a higher yield point and tensile strength than those made by laser cutting (Andrés et al., 2016), and plasma cut surfaces have a much lower roughness than laser cut surfaces (Farrokhi et al., 2015).

3. Materials and methods

At the stage of creating the technological line design, three variants of its implementation were considered. Optimisation was made on the basis of three criteria: technical, organisational and financial.

In the technical criterion, various variants of the project implementation were analysed in terms of the feasibility of the research and development works. They are listed in Table 1.

Table 1. Design variants in the technical criterion

Variant No.	Specification
I	Performing mainly development works; the ability to reach a solution that is difficult to implement; low innovativeness of the solution.
II	Conducting research and development works on the main components of technology with the use of existing solutions, testing existing solutions; average innovativeness of the solution.
III	Performing research and development works in a wide range; creating a line entirely from scratch; high innovativeness of the solution.

In the organisational criterion, various variants of the project implementation were analysed in terms of the duration time of the project. They are given in Table 2.

Table 2. Design variants in the organisational criterion

Variant No.	Specification
I (12 months)	Impossibility to execute the project up to the TRL IX level; high risk of not achieving the assumed project objectives.
II (24 months)	Possibility to execute the project up to the TRL IX level; average risk of not achieving the assumed project objectives.
III (36 months)	Possibility to execute the project up to the TRL IX level; low risk of not achieving the assumed project objectives; extended duration time of the project, increasing the project implementation costs and associated with the risk of introducing a similar solution to the market by competitors.

In the financial criterion, various variants of the project implementation were analysed in terms of expenditure on the project. They are given in Table 3. In order to be able to carry out an efficient assessment of project variants, the Benefits to Costs ratio (B/C ratio) has been established. Calculations were made for the five-year period after the completion of the project. The calculation results are presented in Table 4 (in Appendix A).

Table 3. Design variants in the financial criterion

Variant No.	Specification
I	The adopted budget is associated with the risk of underestimating in relation to the assumed research works and revenues that can be obtained at a later date.
II	The adopted budget is appropriate to the assumed research work and revenues that can be obtained at a later date.
III	The adopted budget is associated with the risk of overestimation in relation to the assumed research works and revenues that can be obtained at a later date.

Ultimately, variant No. II was selected as the optimal variant of the project implementation. Research and development works were assumed in the material and financial schedule of the project. They were planned for 24 months to ensure the feasibility of the project in terms of organisation. From the financial point of view, a variant was chosen which also corresponded to the high probability of the research and development works feasibility, and at the same time obtained the highest value of the B/C ratio.

Design assumptions conditioning the implementation of the project are summarised in Table 5 (in Appendix B).

The block diagram of the technological line for the production of long linear profiles is presented in Fig. 1 (in Appendix C). It consists of three main sections for: plasma arc cutting, circular saw cutting and robotic welding. The line includes an input roller conveyor with a profile loading system and an output roller conveyor with a packaging system for finished products.

To create the concept of the technological line, the following assumptions regarding its functionality were used:

1. The purpose of the line will be the processing of long linear profiles.
2. The line will be fully automated and will be equipped with computer numerical control (CNC). It will also be possible to control online all parameters of the line by an external system (Łyp-Wrońska et al., 2017).
3. The designed technological line will occupy a much smaller area in relation to the line composed of individual machines with the same purpose.
4. The starting material in the form of hollow or open section profiles will be collected automatically from the warehouse at the beginning of the technological line and, after going through the entire line in the automatic cycle, will be stored at the end of the line in the finished product warehouse.
5. The plasma arc cutting section will be equipped with four torches, operating in two independent pairs and in two directions perpendicular to each other.
6. The circular saw cutting section will be equipped with a proprietary solution enabling the profiles to be cut from the bottom.
7. Due to the reduction of the number of servicing employees by non-standard combining of production stations into one technological line, reducing the distance between the stations and automation the line, a significant increase in the production efficiency of linear profiles will be achieved.

As a result of the fulfilment of the above assumptions, a 3D model of the technological line for the production of long linear profiles was developed, shown in Fig. 2 (in Appendix D).

Line performance simulation has been performed based on the AGICO Group company hourly standards. The process of machining of one 6-meter element on separate processing stations is characterised in Table 6. As a result of this process, the machining of one element takes a total of 18 minutes. It is planned that on the newly created line, processing of the same element will take 2 minutes. It will be possible thanks to the performance of several technological treatments at the same time.

Table 6. Processing time of one 6-meter element on separate processing stations

Process name	Daily standard	Number of employees
Saw cutting	120 pieces	1
Plasma arc cutting	140 pieces	2
Drilling	115 pieces	2

4. Results and discussion

The designed technological line is to be located on the area of a rectangle measuring 45.2 m by 10.3 m.

The current status of work on the implementation of the designed sections for laser cutting and sawing is shown in Figs. 3 and 4, respectively.

a) b)

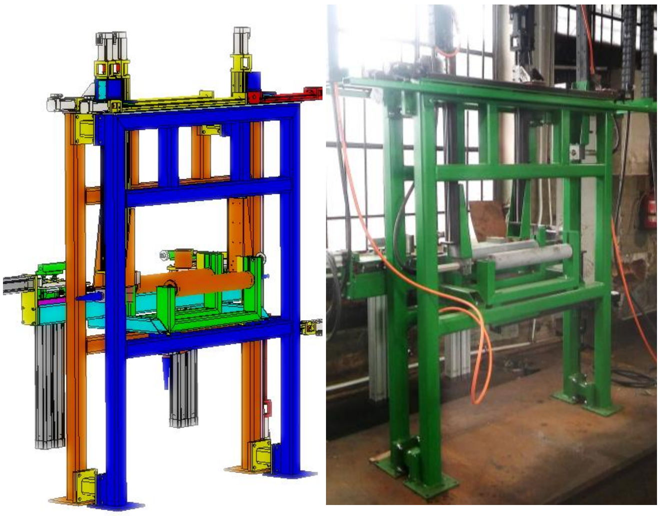

Fig. 3. Plasma arc cutting section: a) model 3D, b) general view

The designed technological line is characterised by the following main features:

1. The plasma arc section allows for cutting hollow sections on four walls in the same setting and for simultaneous cutting of holes of the same shape on opposite walls (Gustowski et al., 2023).

2. The presented concept of the plasma system gives extended possibilities in relation to other concepts of prototype CNC plasma cutting machines (Oysu, 2007; Kudrna et al., 2019).
3. In order to meet the design assumptions for the maximum external dimensions of the profile being processed, and at the same time to limit the external size of the circular saw blade, the circular saw cutting section is adapted to cut profiles from the bottom (Gustowski et al., 2022).
4. The welding section consist of two welding robots and two manipulators. Manipulators are used to feed the prefabricated elements, and robots to weld them according to a predefined program to the main element.
5. The line replaces the work of five highly qualified employees and, according to an internal analysis carried out by the AGICO Group, it allows for a five-fold increase in efficiency compared to the traditional methods of producing linear elements used so far. A final estimate of the line's efficiency will be possible after the line is completed and tested.

a) b)

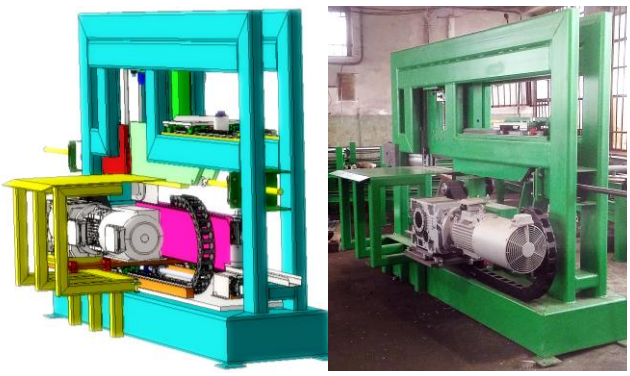

Fig. 4. Circular saw cutting section: a) model 3D, b) general view

Economic profits from the implementation of the designed technological line in the AGICO Group's own business result directly from:

- high performance and efficiency of the line,
- versatility of the technological line, which enables the production of elements of various assortments, both from hollow and open section profiles, made of various weldable and non-weldable steels, alloyed steels or aluminium,
- saving time, fuel and electricity used so far for transporting materials with forklifts or overhead cranes between stations,
- improvement of quality and the elimination of defects,
- significantly reduced usable area of the hall,
- possibility of on-line central control of all operating parameters of the technological line.

The implementation of a process based on the technological line will allow for an increase in production capacity, and thus an increase in revenues from the AGICO Group's own business activities.

5. Conclusions and outlook

Modern production capabilities enable the design of automated devices to perform several machining operations in one cycle, reducing manufacturing costs and improving its efficiency. An example of such a procedure is the planning of a technological line grouping stations for plasma arc cutting, circular saw cutting and welding of long linear profiles, the concept of which was presented in the paper. The designed line obeys to all the established pre-requisites and enables the production of structural elements made of hollow or open section profiles of various sizes.

The technological line is distinguished by the complexity of its specific components with a very wide versatility and the performance of many operations at the same time, or in coordinated sequences of execution, feeding and integration in order to make the vast majority of line profiles. The combination of three operations (plasma arc cutting, circular saw cutting and welding) into one line is the process innovativeness of the designed technological line. However, the systems for loading and packaging profiles and the plasma arc cutting section are the product innovativeness of the technological line.

The line will be implemented in the own business of the AGICO Group, which will enable the expansion of the company's business profile. The results of testing the prototype of the technological line under operating conditions will be published in a separate paper.

Acknowledgements

The research leading to these results received funding from the European Union from the European Regional Development Fund under the Regional Operational Program of the West Pomeranian Voivodeship 2014-2020 under Grant Agreement No RPZP.01.01.00-32-0010/18-00.

Fundusze Europejskie Program Regionalny | Rzeczpospolita Polska | Pomorze Zachodnie | Unia Europejska Europejskie Fundusze Strukturalne i Inwestycyjne

References

Al-Shamma'a, A.I., Wylie, S.R., Lucas, J., Stuart, R.A., 2002a. Microwave plasma jet for material processing at 2.45 GHz. Journal of Materials Processing Technology, 121(1), 143-147, DOI: 10.1016/S0924-0136(01)01231-6.

Al-Shamma'a, A.I., Wylie, S.R., Lucas, J., Yan, J.D., 2002b. Atmospheric microwave plasma jet for material processing. IEEE Transactions on Plasma Science, 30(5), 1863-1871, DOI: 10.1109/TPS.2002.805371.

Andrés, D., García, T., Cicero, S., Lacalle, R., Álvarez, J.A., Martín-Meizoso, A., Aldazabal, J., Bannister, A., Klimpel, A., 2016. Characterization of heat affected zones produced by thermal cutting processes by means of Small Punch tests. Materials Characterization, 119, 55-64, DOI: 10.1016/j.matchar.2016.07.017.

Biedermann, M., Beutler, P., Meboldt, M., 2021. Automated design of additive manufactured flow components with consideration of overhang constraint. Additive Manufacturing, 46, 102119, DOI: 10.1016/j.addma.2021.102119.

Biegus, A., 2015a. Causes of imminent failure damage and repair of steel building purlins. Archives of Civil and Mechanical Engineering, 15(2), 509-515, DOI: 10.1016/j.acme.2014.05.014.

Biegus, A., 2015b. Trapezoidal sheet as a bracing preventing flat trusses from out-of-plane buckling. Archives of Civil and Mechanical Engineering, 15(3), 735-741, DOI: 10.1016/j.acme.2014.08.007.

Cheraghalikhani, A., Khoshalhan, F., Mokhtari, H., 2019. Aggregate production planning: A literature review and future research directions. International Journal of Industrial Engineering Computations, 10(2), 309-330, DOI: 10.5267/j.ijiec.2018.6.002.

Cicero, S., García, T., Álvarez, J.A., Klimpel, A., Bannister, A., Martín-Meizoso, A., 2017. Fatigue behaviour and BS7608 fatigue classes of steels with thermally cut holes. Journal of Constructional Steel Research, 128, 74-83, DOI: 10.1016/j.jcsr.2016.08.012.

Cicero, S., García, T., Álvarez, J.A., Martín-Meizoso, A., Aldazabal, J., Bannister, A., Klimpel, A., 2016. Definition and validation of Eurocode 3 FAT classes for structural steels containing oxy-fuel, plasma and laser cut holes. International Journal of Fatigue, 87, 50-58, DOI: 10.1016/j.ijfatigue.2016.01.012.

Farrokhi, F., Nielsen, S.E., Schmidt, R.H., Pedersen, S.S., Kristiansen, M., 2015. Effect of cut quality on hybrid laser arc welding of thick section steels. Physics Procedia, 78, 65-73, DOI: 10.1016/j.phpro.2015.11.018.

Feldshtein, E., Patalas-Maliszewska, J., Kłos, S., Kałasznikow, A., Andrzejewski, K., 2018. The use of Plackett-Burman plans and the analysis of expert opinions, in order to assess the significance of controllable parameters of the plasma cutting process. Eksploatacja i Niezawodnosc – Maintenance and Reliability, 20(3), 443-449, DOI: 10.17531/ein.2018.3.13.

Gosowski, B., Lorkowski, P., Redecki, M., 2016. Analysis of longitudinal skylights structure made of rectangular tubes in industrial hall. Thin-Walled Structures, 108, 234-244, DOI: 10.1016/j.tws.2016.08.015.

Gustowski, T., Kurek, W., Samsonik, K., Grzejda R., 2022. Prototype of the cutter with a circular saw blade fixed from the bottom of the workpiece (in Polish). Systemy Wspomagania w Inżynierii Produkcji, 11(2), 57-65.

Gustowski, T., Kurek, W., Samsonik, K., Grzejda R., 2023. Concept of an innovative plasma system for hole-cutting in linear profiles. Manufacturing Letters, under review.

Harničárová, M., Zajac, J., Stoić, A., 2010. Comparison of different material cutting technologies in terms of their impact on the cutting quality of structural steel. Technical Gazette, 17(3), 371-376.

Havula, J., Garifullin, M., Heinisuo, M., Mela, K., Pajunen, S., 2018. Moment-rotation behavior of welded tubular high strength steel T joint. Engineering Structures, 172, 523-537, DOI: 10.1016/j.engstruct.2018.06.029.

Kanyilmaz, A., 2019. The problematic nature of steel hollow section joint fabrication, and a remedy using laser cutting technology: A review of research, applications, opportunities. Engineering Structures, 183, 1027-1048, DOI: 10.1016/j.engstruct.2018.12.080.

Kanyilmaz, A., Castiglioni, C.A., 2018. Fabrication of laser cut I-beam-to-CHS-column steel joints with minimized welding. Journal of Constructional Steel Research, 146, 16-32, DOI: 10.1016/j.jcsr.2018.02.039.

Keraita, J.N., Kim, K.-H., 2007. PC-based low-cost CNC automation of plasma profile cutting of pipes. ARPN Journal of Engineering and Applied Sciences, 2(5), 1-7.

Kozioł, L., Kozioł, W., Wojtowicz, A., Pyrek, R., 2015. Diagnosis of innovation enterprises - study theoretical and empirical results. Procedia - Social and Behavioral Sciences, 175, 137-145, DOI: 10.1016/j.sbspro.2015.01.1184.

Krynke, M., 2021. Management optimizing the costs and duration time of the process in the production system. Production Engineering Archives, 27(3), 163-170, DOI: 10.30657/pea.2021.27.21.

Kudrna, L., Fries, J., Merta, M., 2019. Influences on plasma cutting quality on CNC machine. Multidisciplinary Aspects of Production Engineering, 2(1), 108-117, DOI: 10.2478/mape-2019-0011.

Lipiäinen, K., Ahola, A., Skriko, T., Björk, T., 2021. Fatigue strength characterization of high and ultra-high-strength steel cut edges. Engineering Structures, 228, 111544, DOI: 10.1016/j.engstruct.2020.111544.

Łyp-Wrońska, K., Wzorek, Ł., Jamróz, K., 2017. Methods of improving production processes in the metal industry (in Polish). Mechanik, 90(1), 70-71, DOI: 10.17814/mechanik.2017.1.17.

Maier-Komor, P., Hoffmann, H., Ostermair, M., 2010. Cutting of hollow profiles using electromagnetic fields. International Journal of Material Forming, 3, Suppl. 1, 503-506, DOI: 10.1007/s12289-010-0817-x.

Mirghaderi, S.R., Torabian, S., Keshavarzi, F., 2010. I-beam to box-column connection by a vertical plate passing through the column. Engineering Structures, 32(8), 2034-2048, DOI: 10.1016/j.engstruct.2010.03.002.

Moazed, R., Fotouhi, R., 2012. The influence of mechanical and laser cutting on the fatigue strengths of square hollow-section welded T-joints. Journal of Offshore Mechanics and Arctic Engineering, 134(3), 031401, DOI: 10.1115/1.4005186.

Oysu, C., 2007. Automation of welding face shaping process for tubular structures. Industrial Robot, 34(1), 32-8. DOI: 10.1108/01439910710718423.

Pérez, L., Rodríguez-Jiménez, S., Rodríguez, N., Usamentiaga, R., García D.F., Wang, L., 2020. Symbiotic human–robot collaborative approach for increased productivity and enhanced safety in the aerospace manufacturing industry. The International Journal of Advanced Manufacturing Technology, 106(3-4), 851-863, DOI: 10.1007/s00170-019-04638-6.

Setamanit, S., 2019. Improving transportation contract management using simulation. Polish Journal of Management Studies, 20(2), 466-477, DOI: 10.17512/pjms.2019.20.2.39.

Sheet, I.S., Gunasekaran, U., MacRae, G.A., 2013. Experimental investigation of CFT column to steel beam connections under cyclic loading. Journal of Constructional Steel Research, 86, 167-182, DOI: 10.1016/j.jcsr.2013.03.021.

Siderska, J., 2020. Robotic Process Automation – a driver of digital transformation? Engineering Management in Production and Services, 12(2), 21-31, DOI: 10.2478/emj-2020-0009.

Simonetto, E., Ghiotti, A., Bruschi, S., 2021. High accuracy direct hot bending of hollow profiles. Manufacturing Letters, 27, 63-66, DOI: 10.1016/j.mfglet.2020.12.005.

Singh, T.G., Singh, K.D., 2018. Experimental investigation on performance of perforated cold–formed steel tubular stub columns. Thin-Walled Structures, 131, 107-121, DOI: 10.1016/j.tws.2018.06.042.

Sousa, V., Silva, F.J.G., Fecheira, J.S., Campilho, R.D.S.G., Vandermeulen, V., 2020. A novel modular design of an equipment to produce "T"-profiles by laser welding. Procedia Manufacturing, 51, 446-453, DOI: 10.1016/j.promfg.2020.10.063.

Stolecki, M., Bijok, H., Kowal, Ł., Adamiec, J., 2015. Laser welding of finned tubes made of austenitic steels. Archives of Metallurgy and Materials, 60(3), 1807-1811, DOI: 10.1515/amm-2015-0309.

Szlendak, J.K., Oponowicz, P.L., 2013. Experimental tests and numerical models of double side non-welded T RHS truss joints. Procedia Engineering, 57, 1109-1120, DOI: 10.1016/j.proeng.2013.04.140.

Szopik-Depczyńska, K., Cheba, K., Wiśniewska, J., 2020. Innovation, R&D and user-driven innovation activity in R&D departments in Poland. The multi-criteria analysis. Procedia Computer Science, 176, 2705-2713, DOI: 10.1016/j.procs.2020.09.290.

Węglowski, M.S., Pfeifer, T., 2014. Influence of cutting technology on properties of the cut edges. Advances in Manufacturing Science and Technology, 38(2), 63-73, DOI:10.2478/amst-2014-0011.

Wolniak, R., 2020. Main functions of operation management. Production Engineering Archives, 26(1), 11-14, DOI: 10.30657/pea.2020.26.03.

Zeinoddini, M., Hosseini, S.A., 2013. Fire response of externally stiffened steel I-beam-to-CHS welded connections: A numerical modelling. Journal of Constructional Steel Research, 89, 42-51, DOI: 10.1016/j.jcsr.2013.05.024.

Appendix A

Table 4. B/C ratio calculation results

	Variant No. I	Variant No. II	Variant No. III
Project duration time	12 months	24 months	36 months
Expenditure on project implementation, PLN	2,499,400	4,999,400	7,499,100
Operational costs, PLN	9,733,500	32,445,000	32,445,000
Revenue from the implementation, PLN	12,600,000	42,000,000	42,000,000
B/C ratio	1.03	1.12	1.05

Appendix B

Table 5. Design assumptions for the implementation of the project

No.	Description
	Resource assumptions
1.	All necessary materials and equipment will be acquired and made available for use during the project implementation.
2.	The technological line will be located in a newly built technological hall.
3.	The people involved in the project will be mainly employees of the project contractor. Part of the work will be commissioned by a science and research university.
4.	All the resources (equipment, tools, or materials) will be kept in good condition for use throughout the project life-cycle.
5.	Project team members will have access to the tools they need to carry out their respective tasks on schedule, including advanced hardware and software, and electricity during working time.
	Cost assumptions
1.	The cost of purchasing and maintaining resources will stay within the planned budget of the project.
2.	The remuneration costs of people working on the project will be included in the planned budget of the project.
3.	Wages of any subcontractors and indirect costs will be within the planned budget of the project.
4.	The total project budget will not be exceeded.
	Schedule-based assumptions
1.	All the equipment or materials are available as needed according to the planned schedule.
2.	Project finances are within the budget for the specified period of time planned for the project.
3.	All the staff members and employees can efficiently carry out their tasks in accordance with the planned schedule.
4.	The suppliers will deliver consumables on time.
5.	The expected project schedule can be met and the project will be completed within the expected time.
	Quality/specification assumptions
1.	The quality of all equipment and materials will be in good condition throughout the project life-cycle.
2.	The scope and specifications of the project will not change during the project implementation, unless there are cases where they need to be altered to cater to the requirements and needs of the project.
3.	All the goods provided by suppliers will be in the best condition and of the preferable quality.
4.	All the staff members and employees possess good qualities of the skills required for the project.
	Technology assumptions
1.	The line design software development process will be able to meet the needs of stakeholders and customers.
2.	The IT support of the project will be able to cope with technical difficulties such as system errors, network congestion, connection problems, and technical errors.
3.	The data in the data inventory will be automatically updated and all the information in the data inventory will be synchronised.
4.	All the physical devices will be in good working order for project use.
5.	The project system will be compatible, it will run correctly and stably to make the project run smoothly.
	Location/environments assumptions
1.	There will be minimal network congestion and strong internet connection in the location where the project will be implemented.
2.	The location of the project will be constant throughout its life-cycle and will not change as the project progresses.
3.	During the winter or rainy season, the project will continue to operate normally and will not be affected by changes in weather.

Appendix C

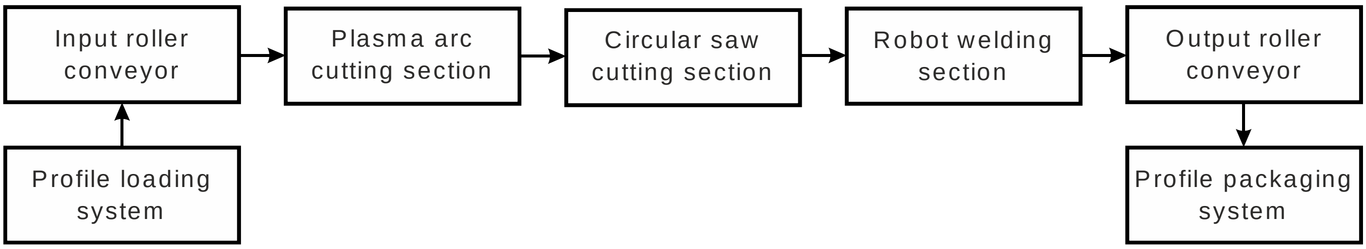

Fig. 1. Block diagram of the designed technological line

Appendix D

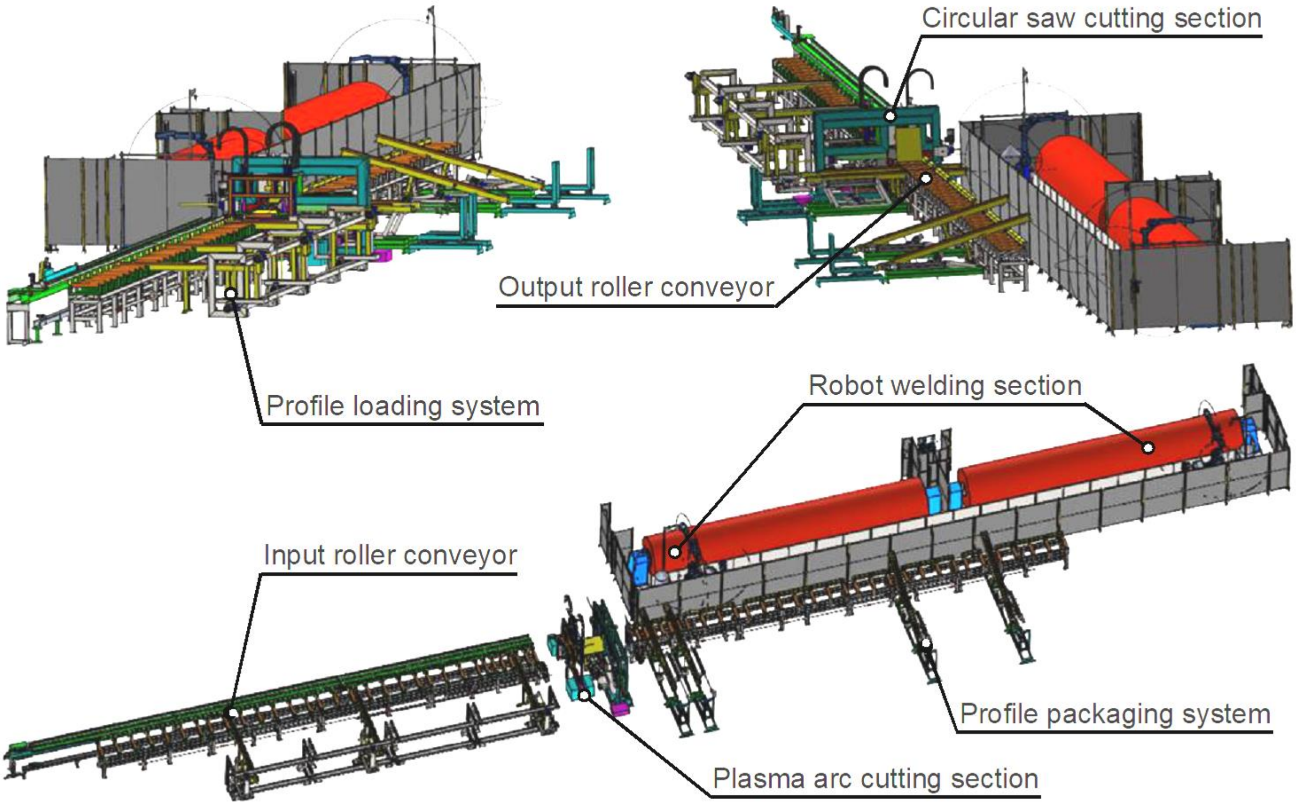

Fig. 2. 3D model of the designed technological line

用于加工线性型材的创新技术线的概念

關鍵詞
线性轮廓
自动化工艺线
等离子弧切割
圆锯切割
焊接机器人

摘要
本文介绍了一条创新技术线的概念，旨在加工工程钢和铝结构中使用的长线性型材，这些型材可以是空心截面型材，也可以是开放截面型材。 该线设置有七个主要部分：型材装载系统、输入辊道输送机、等离子弧切割部分、圆锯切割部分、机器人焊接部分、输出辊道输送机和型材包装系统。 详细说明了创建技术路线概念所采用的假设。 描绘了显示其所选元素结构的线路框图和图纸。 指出了记录其产品和工艺创新的技术线的特征。 拟议的技术线建在 AGICO 集团公司，但也可以在处理长直线型材加工的其他公司中成功实施。