Science paper
Artykuł naukowy

Available online at / Dostępny na stronie
www.biuletyn.online

Biuletyn Informacyjny OB-RPPD 1-2 (2023) xx-xx
https://doi.org/10.32086/biuletyn.2023.02

www.obrppd.com.pl

Processing time of an automated production line for wooden door frames

Czasy operacji zautomatyzowanej linii produkcyjnej ościeżnic drzwi drewnianych

Zdzisław Kwidziński[a,b], *ORCID: 0000-0002-8522-9650*
Barbara Prałat[b],
Adam Wilczyński[a],
Tomasz Rogoziński[b,*], *ORCID: 0000-0003-4957-1042*

[a]*Porta KMI Poland S.A., 54 Szkolna St., 84-239 Bolszewo, Poland*

[b]*Department of Furniture Design, Faculty of Wood Technology, Poznań University of Life Sciences, 38/42 Wojska Polskiego St., 60-627 Poznań, Poland*

[*]*Corresponding author: tomasz.rogozinski@up.poznan.pl*

Abstract

The concept of mass customization of wooden door production implemented in PORTA KMI Poland is associated with investment activities in the form of launching new, automated technological lines. The production capacity of these lines during their technological acceptance is tested to determine the possibility of achieving the designed capacity. The paper describes the results of the technological test relating to the processing times and their statistical comparative analysis in relation to standard door frames with two different beam widths of 127 and 147 mm. It was found that the average processing time for a 127 mm wide frame is 20.42 s, while for a 147 mm wide frame, it is 19.94 s. However, this difference is statistically insignificant. This allows to obtain the maximum capacity of the line of 3 pcs of standard door frames per min. This is the basis for further research into the efficiency of the PortaFRAME line already in the conditions of mass customization.

Streszczenie

Wdrażana w przedsiębiorstwie PORTA KMI Poland koncepcja masowej kastomizacji produkcji drzwi drewnianych wiąże się z działalnością inwestycyjną w postaci uruchamiania nowych, zautomatyzowanych linii technologicznych. Zdolności produkcyjne tych linii w czasie ich odbioru technologicznego są testowane w celu określenia możliwości osiągania projektowanych wydajności. W pracy opisano wyniki testu technologicznego, odnosząc się do czasów obróbki i ich statystycznej analizy porównawczej w odniesieniu do ościeżnic standardowych o dwóch różnych szerokościach belki 127 i 147 mm. Stwierdzono, że średni czas obróbki ościeżnicy o szerokości 127 mm wynosi 20,42 s, natomiast ościeżnicy o szerokości 147 mm wynosi 19,94 s. Różnica ta jest jednak statystycznie nieistotna. Pozwala to na uzyskiwanie maksymalnej wydajności linii, wynosząca 3 sztuki ościeżnic standardowych na min. Jest to podstawą do dalszych badań wydajności linii PortaFRAME już w warunkach masowej kastomizacji.

Keywords: efficiency, door frame, mass customization, PortaFRAME

Słowa kluczowe: wydajność, ościeżnica, masowa kastomizacja, PortaFRAME

Introduction

B. Joseph Pine II explains mass customization as a business model where companies can attain both low prices and high variety because of very flexible and responsive processes that enable a dynamic flow of goods and services. Every product is unique and tailored to the needs of a certain customer, making it different from the previous one (Pine II, 1993). Stanley M. Davies created the concept of mass customization. In his book “Future Perfect” described it as dealing with a lot of customers, like in the case of the general market while, at the same time, treating them uniquely, as is the case in individualized markets (Davis, 1987). Mass customization connected with the company’s overall competitive positioning can offer a potent and successful way to achieve and sustain strategic flexibility. If it will be implemented effectively, the company can have an influence on industries competitive landscape (Kotha, 1995).

Offering products that can be mass-customized can be done in two ways. First, products can be modified by the seller based on the features that have been listed by the customer. Modification is done by using modules of the product that are on offer. The other way is to allow the customer to create the product from previously prepared alternative product parts (Sabioni et al., 2022).

Nowadays, more entrepreneurs use the idea of mass customization of products to encourage customers to buy the offered products. One of them is the furniture industry, particularly door manufacturing. When compared to conventional methods of customizing individual products, the introduction of the mass customization concept will meet the needs and requirements of customers to a greater extent than manufacturing a custom product in a traditional way. The cost will also be relatively cheaper. Mass customization will become more relevant in the door industry because of rising consumer expectations and shifting demand heterogeneity, as long as project implementation durations are kept short and product differences from those in the standard offer are minimal (Pędzik et al., 2020). The concept of mass customization seems to be something that should be implemented almost everywhere across industries, nevertheless, it’s being taken into consideration only when profits can be gained from this implementation or there is no loss for the company.

Production line indicators can significantly contribute to introducing or rejecting mass-customized production. A collection of consecutive procedures developed on an industrial shop floor is known as a production line. Transforming components or raw materials into completed products is referred to as a production or manufacturing process. Procurement, fabrication, assembly, testing, packaging, and distribution are the steps in a production process. There are three different types of production or manufacturing lines in different industries: automated production lines, semi-automated production lines, and manual production lines.

The complexity of the manufacturing components, the volume of production, the sensitivity of the product, and the cost all affect how a production line is designed. According to specific production requirements, industry management plans and sets up production lines (Subramaniam et al., 2008). The efficiency of the technological process is one of the most important indicators when it comes to production and production tasks. Efficiency nature is closely connected to the technology and production prosses which are essential and necessary operations of every production company's operations. Taking it into consideration, it's possible to draw the conclusion that technological efficiency depends on a series of technological parameters, as well as the technological process itself, along with its individual stages (Krupińska et al., 2007).

When, through the implementation of mass customization, the obtained results regarding the efficiency of the technological process and economic and technological indicators of the production line are satisfactory, the company can introduce a new product to the market without incurring losses. This is why extensive performance testing should be carried out before a new production line is commissioned.

Aim and scope of study

The aim of the research was to record the processing times of standard wooden door frames with the use of the mass customized technological line PortaFRAME (G. Kraft Maschunenbau GmbH, Rietberg-Mastholte, Germany), and then to compare these times for door frames with two different beam widths. The PortaFRAME line was built based on the technical and technological solutions of Kraft Group. All data on the functioning of the line modules are available on the company's website (Kraft Group, 2023). Based on the processing times recorded during industrial research, the work carried out led to the calculation of basic statistical data characterizing the processing of these products. The obtained values of statistical parameters will constitute in further implementation studies the necessary input data to determine the computational and actual efficiency of the technological line.

Materials and Methods

The research work consisted of two stages. The first stage was to obtain time data regarding processing during the test of the initial production of rebated door frames combined with the technological acceptance of the latest mass customized PortaFRAME technological line at the production plant of PORTA KMI Poland in Ełk. This line consists of 5 production modules, a pressing module, a frame formatting module, milling, and drilling holes for hinges, milling and drilling slots for locks and other fittings, and gasket application (Fig. 1). The test was carried out from November 22, 2022 to January 31, 2023. Data collected during the test in *.csv file format. saved automatically by the line control system.

The second stage of the research was the analysis of the data collected during the test. MS Excel was used to analyse the data. The analysis focused on a standard rebated door frame with a height of 2080 mm and two widths: 147 mm and 127 mm to determine the possible impact of the width of the door frame beam on processing times and, ultimately, on the line efficiency (Fig. 2). It was established that the data on the left beam to determine the processing times necessary to calculate the efficiency of the technological process. To calculate the processing time for the entire frame, consisting of 3 elements, the left vertical beam of the frame was chosen as the starting element to produce the next product.

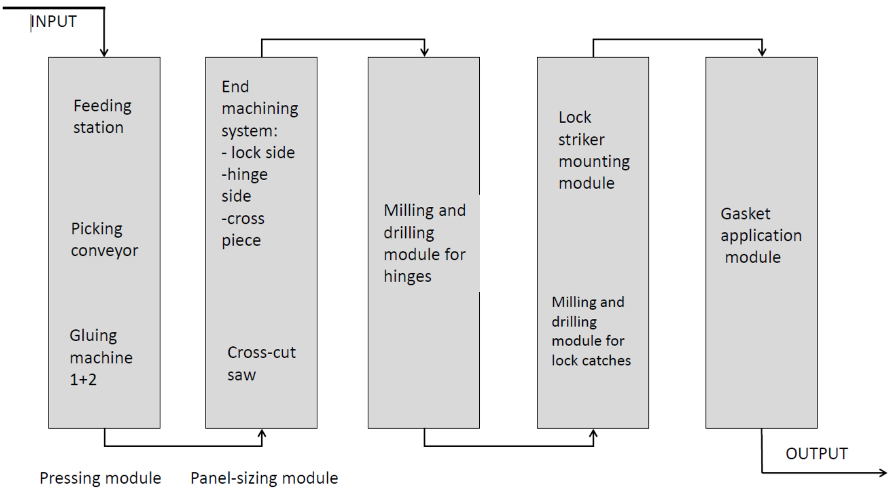

Fig. 1. Schematic diagram of the PortaFRAME line
Rys. 1. Schemat operacyjny linii PortaFRAME

The first step of the analysis in the MS Excel program (Fig. 3) was to extract the lines regarding the left "UL" beams of the frame by the "filter" command. The criteria for the filter were the length of the standard door frame 2028 mm "PartLength", the width 147 mm and 127 mm of the "BoardWidth" beam and the frame identifier "FrameId", the range of which started with the number ≥13*10^7. Then, considering the "EndTime" column, using the "SUM(Fn-Fn+1)" function, by subtracting from the time of completion of technological operations of the current element, the time of completion of technological operations of the previous element, the time in which successive left beams of the frames passed through the technological line, from loading the workpiece in the feeding station, to the completion of technological operations. Then, with the “filter” command beams with a width of 147 mm and 127 mm were separated into separate sheets and processing times in the range of 12 s to 25 s were extracted, which were used for statistical calculations. This time interval is considered when considering breaks for testing activities other than standard frame processing. Each row in column “TIME” (Fig. 3) shows this time intervals and contains information about processing time of individual rebated door frame in relation to the line, it is not possible in the IT system to extract processing times on individual modules of the line.

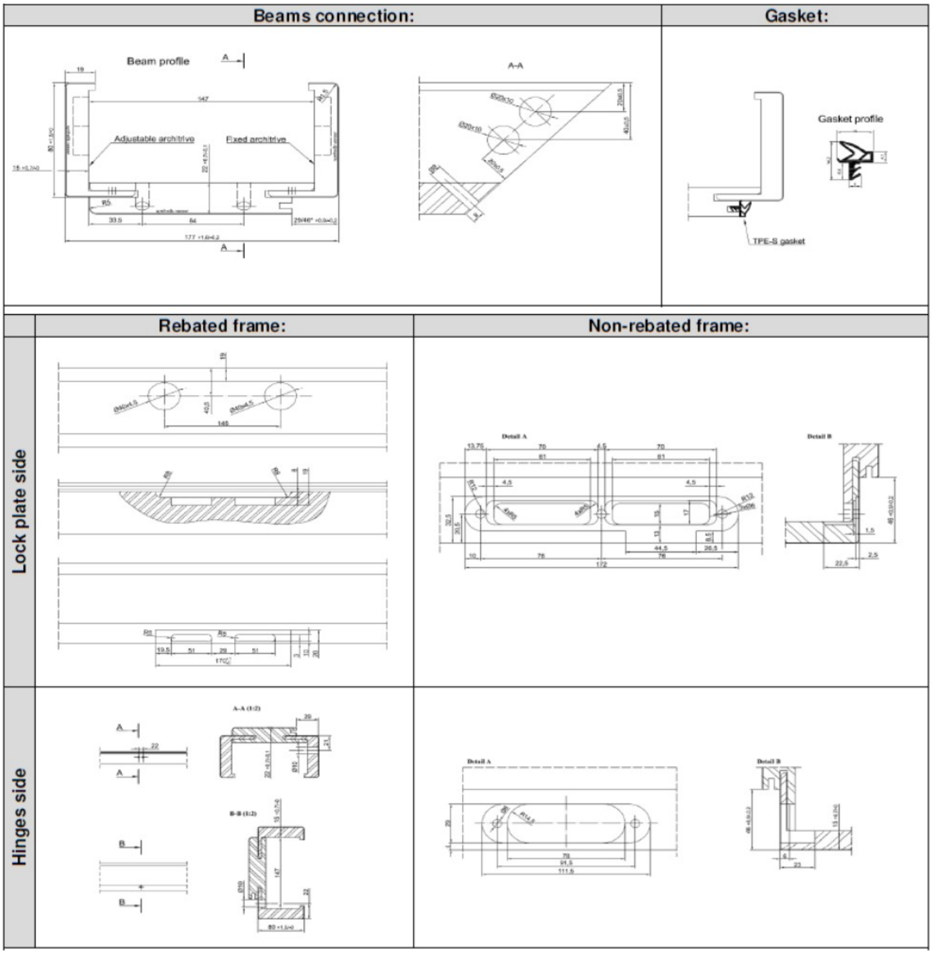

Fig. 2. Door frame construction
Rys. 2. Konstrukcja ościeżnicy

Using the “COUNTIF(Ax:Ay;AQ12)” function, it was calculated how many times a given time was repeated during the test for the left beam with a width of 147 mm and the “COUNTIF(Bx:By;CA13))” function for the left beam set with a width of 127 mm wide. For further calculations, they were formatted in a separate column in numerical format. For each sheet with the function "COUNT(Xx:Xy)" the total number of door frames used in the test and the number of left beams whose processing time was within the range of 12-25 s was calculated. For this range, the median was also calculated for both door frame widths function "MEDIAN(BY:BY)", the arithmetic mean "AVERAGE.A(BY:BY) and the time that occurred most often "MOST(BY:BY)". The standard deviation of the sample with the function "STDEV.A(BYx:BYy)" and the population "STDEV.POPUL(BYx:BYy) were also calculated. The significance of the difference in average processing times for both frame widths was assessed using the Student's t-test. Data analysis in excel is crucial to achieving the set goal, i.e. calculating average times.

A	B	C	D	E	F	G	H	I	J	K	L	M
Id	FrameId	Part	Nok	StartTime	EndTime	PosNoOut	State	ArcWidth	BoardWid	PartLengtl	Colour	TIME
31905	130728599	UL	0	23-01-31 11:23	23-01-31 11:28	8000	1	60,5	127	2028	DOR	0:00:28
31901	130756628	UL	0	23-01-31 11:23	23-01-31 11:27	8000	1	60,5	127	2028	DO2	0:01:40
31886	130756611	UL	0	23-01-31 11:21	23-01-31 11:26	8000	1	60,5	127	2028	DDT	0:00:26
31882	130728572	UL	0	23-01-31 11:21	23-01-31 11:25	8000	1	60,5	127	2028	DDT	0:01:52
31865	130728999	UL	0	23-01-31 11:18	23-01-31 11:23	8000	1	60,5	147	2028	RDS	0:00:40
31859	130728979	UL	0	23-01-31 11:18	23-01-31 11:23	8000	1	60,5	147	2028	RAS	0:00:19
31856	130728978	UL	0	23-01-31 11:17	23-01-31 11:23	8000	1	60,5	147	2028	RAS	0:00:39
31850	130756856	UL	0	23-01-31 11:16	23-01-31 11:22	8000	1	60,5	147	2028	RAM	0:00:19
31847	130756855	UL	0	23-01-31 11:16	23-01-31 11:22	8000	1	60,5	147	2028	RAM	0:00:19
31844	130756854	UL	0	23-01-31 11:15	23-01-31 11:21	8000	1	60,5	147	2028	RAM	0:00:20
31841	130756853	UL	0	23-01-31 11:13	23-01-31 11:21	8000	1	60,5	147	2028	RAM	0:00:19
31838	130756852	UL	0	23-01-31 11:13	23-01-31 11:21	8000	1	60,5	147	2028	RAM	0:00:41
31834	130728974	UL	0	23-01-31 11:13	23-01-31 11:20	8000	1	60,5	147	2028	RAM	21:45:41
30894	130704051	UL	0	23-01-30 13:31	23-01-30 13:34	8000	1	80,5	147	2028	SCM	0:00:26
30890	130704050	UL	0	23-01-30 13:31	23-01-30 13:34	8000	1	80,5	147	2028	SCM	0:00:14
30888	130704049	UL	0	23-01-30 13:31	23-01-30 13:34	8000	1	80,5	147	2028	SCM	0:00:26
30884	130704045	UL	0	23-01-30 13:30	23-01-30 13:33	8000	1	80,5	147	2028	SCM	0:00:20
30881	130704048	UL	0	23-01-30 13:29	23-01-30 13:33	8000	1	80,5	147	2028	SCM	0:00:13
30878	130677481	UL	0	23-01-30 13:29	23-01-30 13:33	8000	1	80,5	147	2028	SCM	0:00:20
30875	130677479	UL	0	23-01-30 13:29	23-01-30 13:32	8000	1	80,5	147	2028	SCM	0:00:19
30872	130677478	UL	0	23-01-30 13:29	23-01-30 13:32	8000	1	80,5	147	2028	SCM	0:00:27
30868	130677477	UL	0	23-01-30 13:29	23-01-30 13:31	8000	1	80,5	147	2028	SCM	0:00:21
30865	130677476	UL	0	23-01-30 13:28	23-01-30 13:31	8000	1	80,5	127	2028	SCM	0:00:22
30862	130677475	UL	0	23-01-30 13:27	23-01-30 13:31	8000	1	80,5	127	2028	SCM	0:00:16
30860	130677473	UL	0	23-01-30 13:27	23-01-30 13:30	8000	1	80,5	127	2028	SCM	0:00:22
30857	130677474	UL	0	23-01-30 13:27	23-01-30 13:30	8000	1	80,5	127	2028	SCM	0:00:22
30854	130677472	UL	0	23-01-30 13:26	23-01-30 13:30	8000	1	80,5	127	2028	SCM	0:04:31
30817	130704235	UL	0	23-01-30 13:22	23-01-30 13:25	8000	1	80,5	127	2028	IDQ	0:00:22
30814	130677683	UL	0	23-01-30 13:22	23-01-30 13:25	8000	1	80,5	127	2028	IDQ	0:00:23
30811	130676861	UL	0	23-01-30 13:21	23-01-30 13:24	8000	1	80,5	127	2028	PUA	0:00:44
30808	130703387	UL	0	23-01-30 13:21	23-01-30 13:24	8000	1	80,5	127	2028	PSM	0:00:19
30805	130703386	UL	0	23-01-30 13:20	23-01-30 13:23	8000	1	80,5	127	2028	PSM	0:00:20
30802	130676843	UL	0	23-01-30 13:20	23-01-30 13:23	8000	1	80,5	127	2028	PSM	0:01:39
30796	130703244	UL	0	23-01-30 13:13	23-01-30 13:21	8000	1	80,5	127	2028	PDL	0:00:22
30793	130703243	UL	0	23-01-30 13:10	23-01-30 13:21	8000	1	80,5	127	2028	PDL	0:00:23
30790	130703242	UL	0	23-01-30 13:09	23-01-30 13:21	8000	1	80,5	127	2028	PDL	0:00:21
30787	130703241	UL	0	23-01-30 13:09	23-01-30 13:20	8000	1	80,5	127	2028	PDL	0:00:23

Fig. 3. Sample data on processing times in Ms Excel
Rys. 3. Przykładowe dane dotyczące czasów obróbki w programie Ms Excel

Results

The results of the calculation of the average processing time for door frames using the PortaFRAME line are shown in Fig. 4. Other statistical data on the course of the technological test are presented in Table 1. The average processing time for 127 mm wide frames is nearly 20 s, while the processing time for 147 mm wide frames is approx. 0.5 s longer and is almost 20.5 s. As demonstrated by the Student's t-test, this difference is statistically insignificant. Nevertheless, frames with a width of 147 mm appear in production more than ten times more often than frames with a width of 127 mm, which, when determining the theoretical, computational efficiency of the PortaFRAME line, will make this efficiency close to 3 pcs/min.

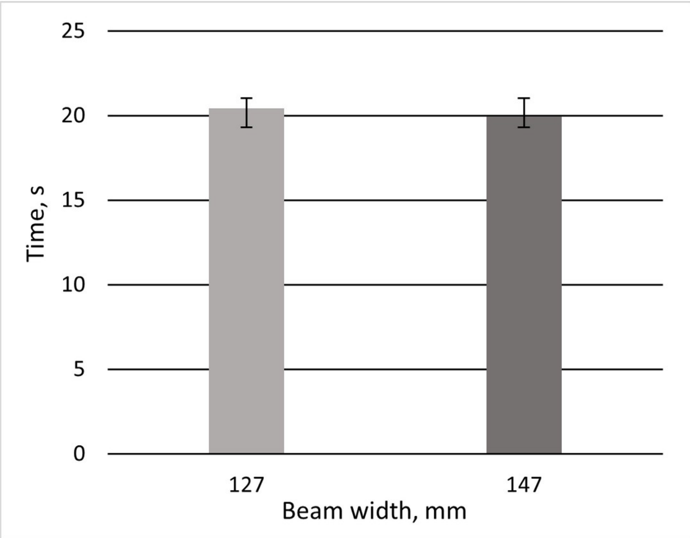

Fig. 4. Processing time
Rys. 4. Czas obróbki

Table 1. Test statistical parameters
Tabela 1. Parametry statystyczne testu

	Beam width, mm	
	127	147
Median, s	21	20
The most common, s	23	20
Amount of all times	223	2691
Number of frames in the time range 12-25 s	135	1771
Student's t-test	0.005	

The significance level of the Student's t-test has been checked. There is no reason to reject the null hypothesis "H_0: Processing times of the two frame widths do not differ" in favor of the alternative hypothesis "H_1: Processing times of the two frame widths differ significantly".

Conclusion

In the technological test of the line for the automated processing of wooden door frames, processing times for frames with a beam width of 127 and 147 mm were recorded, analysed and compared. It was found that the average processing time for a 127 mm wide frame is 20.42 s, while for a 147 mm wide frame it is 19.94 s. Such a pace of line operation allows to achieve the maximum efficiency of the PortaFRAME line at the level of 3 pcs/min. This is a preliminary result for standard products. However, it is the basis for further tests and determination of line performance in conditions of mass customization of products.

References

Davis, S.M., 1987. Future Perfect. Addison-Wesley Publishing: Reading, MA, USA.

Kraft Group, 2023. [WWW Document]. URL https://www.kraft-group.com/loesungen/maschinen (accessed 7.3.2023).

Krupińska, B., Szewiczek, D., Dobrzanski, L., 2007. Improvement of technological processes by the use of technological efficiency analysis. Archives of Materials Science and Engineering 28, 751-756.

Pędzik, M., Bednarz, J., Kwidziński, Z., Rogoziński, T., Smardzewski, J., 2020. The Idea of Mass Customization in the Door Industry Using the Example of the Company Porta KMI Poland. Sustainability 12, 3788. DOI: https://doi.org/10.3390/su12093788

Pine II, B.J., 1993. Making mass customization happen: Strategies for the new competitive realities. Planning Review 21, 23-24. DOI: https://doi.org/10.1108/eb054435

Sabioni, R.C., Daaboul, J., Le Duigou, J., 2022. Joint optimization of product configuration and process planning in Reconfigurable Manufacturing Systems. International Journal of Industrial Engineering and Management 13, 58-75. DOI: https://doi.org/10.24867/IJIEM-2022-1-301

Subramaniam, S., Husin, S., Yusop, Y., Hamidon, A., 2008. Machine efficiency and man power utilization on production lines. Proceedings of the 8th WSEAS Int. Conf. on Electronics, Hardware, Wireless and Optical Communications, 70-75. ISSN: 1790-511770, ISBN: 978-960-474-053-6

Reviewed paper / Artykuł recenzowany
Submitted / Zgłoszony: 06.05.2023
Published online / Opublikowany online: 07.07.2023