The efficiency of the formatting and milling module of the technological line for door frames production

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Abstract: *By introducing a new technological line for formatting and milling mass-customized door frames for wooden doors, PORTA KMI Poland with an industrial plant located in Ełk, Poland, conducted appropriate performance tests of the line to determine the production capacity during technological acceptance in order to check whether the assumed capacity was met before its technical acceptance takes place. The work describes how the processing time changes for frames with changed beam lengths from the reference length of 2028 mm to 2600 mm and for frames whose width has been increased from 127 and 147 mm to 500 mm. On this basis, an average time of 25.53 s was calculated for door frames with beams 2600 mm long and 28.1 s for door frames with a width of 500 mm. Efficiency was also calculated, which is 2.35 for frames with a changed beam length of 2.14.*

Keywords: efficiency, PortaFRAME, technological line, rebated door frame,

INTRODUCTION

According to B. Joseph Pine II, mass customization is a type of business model where firms may offer a wide range of products at competitive rates thanks to highly adaptable and quick procedures that support a continuous flow of goods and services. Every product is distinct from the one before it because it is special and created to meet a specific customer's wants (Pine, 1993). Mass customization is an idea that was developed by Stanley M. Davies. In his book "Future Perfect," Davis (Davis, S.M., 1987) described it as dealing with many clients, as in the general market, while also treating them individually, as is the situation in individualized markets. To achieve and sustain strategic flexibility, mass customization in conjunction with the company's overall competitive stance can be a powerful and effective method. The company may have an impact on the competitive landscape of an industry if it is applied successfully (Kotha, 1995). Today, more business owners employ the concept of mass product customization to persuade clients to purchase the goods being supplied. The production of doors in the furniture industry is one of them.

For the company to benefit from mass production, the technological process of the products must be profitable. The entire efficiency of a production is one indicator of its profitability.

Efficiency assesses how well a company performs in comparison to best practices, or the maximum amount of output that can be produced with a given level of input and certain production technology (Yu, 2016). According to Schmidt and Finnigan (Schmidt and Finnigan, 1992), efficiency is defined as the production of required output at a perceived minimum cost, measured by the ratio of the number of resources expended to the plan. Efficiency is more specifically a measure of operational excellence in the resource utilization process and is primarily concerned with minimizing costs and dealing with the distribution of resources among various applications. It is not a measure of market success (Achabal et al., 1984).

If a production can't improve any of its inputs or outputs without degrading any of its other inputs or outputs, it is efficient. Efficiency can be raised by either minimizing inputs while maintaining a constant output, maximizing output while maintaining a constant input, or by combining the two (Radam et al., 2010).

To be successful on the market, the company must combine high technical and economic indicators and mass production with customer expectations regarding the customization of products. That is why PORTA KMI Poland carried out tests and calculations to check the efficiency of technological lines for the mass-customized production of door frames.

MATERIALS AND METHOD

The production capacity of automated technological line PortaFRAME (Figure 1) for formatting wooden door frames at PORTA KMI Poland during their technological acceptance was examined to calculate efficiency (Fig. 1). The work completed resulted in the generation of fundamental statistical data characterizing the processing of these products based on the processing times observed during industrial research. It was checked how changing the dimensions, height, or width of the frame beam affected the efficiency of the production line.

The PortaFRAME pilot **technological** line, in accordance with the assumptions, consists of five modules: a pressure module, a module for formatting frames (cross-cutting), drilling holes for hinges, milling sockets for locks and other fittings, and the application of gaskets. In the first, pressing module, the material is manually loaded onto the picking conveyor, from which it is transported to the pressing station. The most important processing operations are carried out on modules 2 (formatting frames), 3 (drilling holes for hinges) and 4 (milling sockets for locks). For typical frames, these modules use the following tools:

- cross-cutting saw with diameter 305 mm, z= 100, n= rpm 5000,
- drilling holes for hinges: typical drill diameter 10 mm, total length 85 mm, working part length 45mm,n= rpm: 6000 ,
- milling sockets for locks: shank cutter with shank diameter= 16 mm, total length= 110 mm, working part length= 55 mm and diameters depending on the type of the lock:11, 14, 16, 18, n= rpm:18 000.

The beam is glued to the architraves of technical door frames for typical profiles of adjustable door frames with dimensions and lengths up to 2500 mm and a width of 500 mm. In the next module, the elements are formatted. Trimming elements at an angle of 45° and 90° with the expected tolerance on the length of the formatted element +/-0.5mm, tolerance of the cut angle 0.1°. Trimming of bands with a width of 100 to 500 mm. Holes are drilled in the milling module for the hinges. Milling is used for sockets for striker plates and hook brackets, sockets for connectors in wide bands, sockets for decorative elements, switches, intelligent elements in bands, expansion in the groove beam for a movable angle at the mounting height of the steel panel, for the LED strip. An automatic control of the correctness of the cutters is also carried out. The last module is the fitting module, where the seal is inserted into the prepared channel in the beam, fittings, catches, and hinge sockets are installed. Decorative elements (premises number), switches (bells) and intelligent elements (control panel, sensors, displays) are mounted in bands. Gluing fluorescent inlays and mounting LED strips.

Figure 1. Technological line PortaFRAME

	FrameId	Part	Nok	StartTime	EndTime	PosNoOutfeed	State	ArcWidth	BoardWidth	PartLength	Colour
2	12434	UR	0	23-01-31 13:21	23-01-31 13:48	0	-1	120	476	2620	
3	13433	UL	0	23-01-31 13:06	23-01-31 13:21	8000	0	80,5	147	2028	
4	13433	UR	0	23-01-31 13:06	23-01-31 13:21	8000	0	80,5	147	2028	
5	13433	CP	0	23-01-31 13:19	23-01-31 13:21	8000	0	80,5	147	826	
6	13433	Rest	0	23-01-31 13:19	23-01-31 13:20	4025	0	80,5	147	1050	
7	14433	UR	0	23-01-31 13:20	23-01-31 13:20	0	-1	80,5	147	2100	
8	19433	CP	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
9	19433	UR	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
10	19433	UL	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
11	18433	CP	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
12	18433	UR	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
13	18433	UL	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
14	17433	CP	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
15	17433	UR	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
16	17433	UL	0	2023-01-31 13:19:57.077	2023-01-31 13:19:57.077	0	-1	80,5	147	2100	
17	16433	CP	0	2023-01-31 13:19:57.027	2023-01-31 13:19:57.027	0	-1	80,5	147	2100	
18	16433	UR	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
19	16433	UL	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
20	15433	CP	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
21	15433	UR	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
22	15433	UL	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
23	14433	CP	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
24	14433	UL	0	23-01-31 13:19	23-01-31 13:19	0	-1	80,5	147	2100	
25	12433	UL	0	23-01-31 13:05	23-01-31 13:10	8000	0	80,5	147	2028	
26	12433	UR	0	23-01-31 13:05	23-01-31 13:09	8000	0	80,5	147	2028	
27	12433	CP	0	23-01-31 13:05	23-01-31 13:09	8000	0	80,5	147	826	
28	12433	Rest	0	2023-01-31 13:08:06.013	23-01-31 13:08	4025	0	80,5	147	1050	
29	12434	UR	0	23-01-31 12:50	23-01-31 12:50	0	-1	120	470	2620	
30	19434	CP	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
31	19434	UR	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
32	19434	UL	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
33	18434	CP	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
34	18434	UR	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
35	18434	UL	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
36	17434	CP	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
37	17434	UR	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
38	17434	UL	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
39	16434	CP	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
40	16434	UR	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
41	16434	UL	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
42	15434	CP	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	
43	15434	UR	0	2023-01-31 12:49:55.047	2023-01-31 12:49:55.047	0	-1	120	470	2620	
44	15434	UL	0	2023-01-31 12:49:55.003	2023-01-31 12:49:55.003	0	-1	120	470	2620	
45	14434	CP	0	23-01-31 12:49	23-01-31 12:49	0	-1	120	470	2620	

Figure 2. Sample of obtained raw data from processing line

The data file was obtained from the factory's computer system. The file was then processed in MS Excel. The most important parameters considered were BoardWidth means width of elements (column J), ParthLength means total length of elements (column K), Part means particular part taken to the test (UL- left beam, UR- right beam, CP-upper beam) (column C) and EndTime means recorded by IT system processing end time(column F)

(Figure 2.). The processing time was calculated based on the EndTime of the door frame elements. The left "UL" beams of the door frame were taken for calculations, calculating the time difference between the output of one "UL" beam and the previous one.

For efficiency calculations reference door frames have been selected with a standard-length of 2028 mm and a width of 127 mm and 147 mm, 10 rebated door frames with a non-standard height of 2600 mm and 127 or 147 widths (Figure 3.) and 10 rebated door frames with a width of 500 mm and 2028 height (Figure 4.) were randomly selected from the data obtained during the test, column "Time" were added to the data set witch contains the results of calculations of processing time.

Their processing time was measured and based on the data collected, the arithmetic mean "AVERAGE.A(BY:BY)", standard deviation "STDEV.POPUL(BYx:BYy)" and efficiency were calculated in MS Excel software. To calculate efficiency (A), working time (T) which was 60 s, and the arithmetic average was taken as the processing time (t_w). The formula was used:

$$A = \frac{T}{t_w}$$

Id	FrameId	Part	Nok	StartTime	EndTime	PosNoOut	State	ArcWidth	BoardWid	PartLength	Colour	Time
31859	1,31E+08	UL	0	23-01-31 11:18	23-01-31 11:23	8000	1	60,5	147	2600	RAS	25,00
31850	1,31E+08	UL	0	23-01-31 11:16	23-01-31 11:22	8000	1	60,5	147	2600	RAM	25,00
31847	1,31E+08	UL	0	23-01-31 11:16	23-01-31 11:22	8000	1	60,5	147	2600	RAM	25,00
31844	1,31E+08	UL	0	23-01-31 11:15	23-01-31 11:21	8000	1	60,5	147	2600	RAM	26,00
31841	1,31E+08	UL	0	23-01-31 11:13	23-01-31 11:21	8000	1	60,5	147	2600	RAM	25,00
30884	1,31E+08	UL	0	23-01-30 13:30	23-01-30 13:33	8000	1	80,5	147	2600	SCM	26,00
30878	1,31E+08	UL	0	23-01-30 13:29	23-01-30 13:33	8000	1	80,5	147	2600	SCM	26,00
30875	1,31E+08	UL	0	23-01-30 13:29	23-01-30 13:32	8000	1	80,5	147	2600	SCM	25,00
30868	1,31E+08	UL	0	23-01-30 13:29	23-01-30 13:31	8000	1	80,5	147	2600	SCM	27,00
30808	1,31E+08	UL	0	23-01-30 13:21	23-01-30 13:24	8000	1	80,5	127	2600	PSM	25,00
30805	1,31E+08	UL	0	23-01-30 13:20	23-01-30 13:23	8000	1	80,5	127	2600	PSM	26,00
30790	1,31E+08	UL	0	23-01-30 13:09	23-01-30 13:21	8000	1	80,5	127	2600	PDL	27,00
30781	1,31E+08	UL	0	23-01-30 13:08	23-01-30 13:20	8000	1	80,5	127	2600	PDL	25,00
30778	1,31E+08	UL	0	23-01-30 13:07	23-01-30 13:19	8000	1	80,5	127	2600	PDL	25,00
30775	1,31E+08	UL	0	23-01-30 13:06	23-01-30 13:19	8000	1	80,5	127	2600	PDL	26,00
30771	1,31E+08	UL	0	23-01-30 13:06	23-01-30 13:19	8000	1	80,5	127	2600	PDL	25,00
30768	1,31E+08	UL	0	23-01-30 13:06	23-01-30 13:18	8000	1	80,5	127	2600	PDL	26,00
30765	1,31E+08	UL	0	23-01-30 13:05	23-01-30 13:18	8000	1	80,5	127	2600	PDL	25,00
30762	1,31E+08	UL	0	23-01-30 13:05	23-01-30 13:18	8000	1	80,5	127	2600	PDL	25,00

Figure 3. Selected processing times of door frames with 2600 mm hight in Ms Excel

Id	FrameId	Part	Nok	StartTime	EndTime	PosNoOut	State	ArcWidth	BoardWid	PartLength	Colour	time
30662	1,31E+08	UL	0	23-01-30 12:51	23-01-30 12:57	8000	1	80,5	500	2028	PDA	28,30
30659	1,31E+08	UL	0	23-01-30 12:51	23-01-30 12:57	8000	1	80,5	500	2028	PDA	27,30
30656	1,31E+08	UL	0	23-01-30 12:51	23-01-30 12:57	8000	1	80,5	500	2028	PDA	28,30
30633	1,31E+08	UL	0	23-01-30 12:41	23-01-30 12:48	8000	1	60,5	500	2028	DOR	28,30
30603	1,31E+08	UL	0	23-01-30 12:35	23-01-30 12:41	8000	1	60,5	500	2028	DOB	28,30
30596	1,31E+08	UL	0	23-01-30 12:30	23-01-30 12:41	8000	1	60,5	500	2028	DOB	27,30
30593	1,31E+08	UL	0	23-01-30 12:30	23-01-30 12:40	8000	1	60,5	500	2028	DOB	28,30
30571	1,31E+08	UL	0	23-01-30 12:27	23-01-30 12:36	8000	1	60,5	500	2028	DSA	28,30
30568	1,31E+08	UL	0	23-01-30 12:26	23-01-30 12:36	8000	1	60,5	500	2028	DSA	28,30
30561	1,31E+08	UL	0	23-01-30 12:25	23-01-30 12:35	8000	1	60,5	500	2028	DSA	27,30
22403	1,31E+08	UL	0	23-01-23 9:13	23-01-23 9:25	8000	1	80,5	500	2028	UBI	28,30
22397	1,31E+08	UL	0	23-01-23 9:12	23-01-23 9:24	8000	1	80,5	500	2028	UBI	29,30
22394	1,31E+08	UL	0	23-01-23 9:11	23-01-23 9:23	8000	1	80,5	500	2028	UBI	28,30
22391	1,31E+08	UL	0	23-01-23 9:11	23-01-23 9:23	8000	1	80,5	500	2028	UBI	28,30
22388	1,31E+08	UL	0	2023-01-23 09:1	23-01-23 9:23	8000	1	80,5	500	2028	UBI	28,30
22385	1,31E+08	UL	0	23-01-23 9:10	23-01-23 9:22	8000	1	80,5	500	2028	UBI	29,30
21927	1,31E+08	UL	0	23-01-22 10:28	23-01-22 10:35	8000	1	80,5	500	2028	UBI	27,30
21924	1,31E+08	UL	0	23-01-22 10:28	23-01-22 10:35	8000	1	80,5	500	2028	UBI	28,30
21921	1,31E+08	UL	0	23-01-22 10:28	23-01-22 10:34	8000	1	80,5	500	2028	UBI	28,30
21918	1,31E+08	UL	0	23-01-22 10:27	23-01-22 10:34	8000	1	80,5	500	2028	UBI	27,30

Figure 4. Selected processing times of door frames with 500 mm width in Ms Excel

RESULTS

Figure 5. and Figure 6. display the outcomes of calculations made to determine the typical processing time for door frames utilizing the PortaFRAME line. Table 1 also includes additional statistical information about the technological test's progress, such as the technological line's efficiency. The analysis shows that the processing time (Figure 5) of the rebated door frame with the changed length of the beam to a non-standard dimension of 2600 mm increases on average by 5.59 s compared to the processing time of the reference rebated door frames which is 2028 mm. The processing time of the rebated door frame whose width was changed from 127 mm and 147 mm to 500 mm (Figure 6) also changed, increasing by an average of 8.16 s. With the increase in processing time, the processing efficiency for rebated door frames with a non-standard length of 2600 mm decreased by 0.66, and for rebated door frames with a changed width of 500 mm, by 0.87. Of these 2 overall dimensions, the width is more important than the height for scheduling production in terms of line capacity. The order of entry into the product line is controlled by a computer system that, in order to achieve adequate performance, must obtain data from the production of elements preceding the introduction of changes, so as to adjust the production of subsequent elements in a way that does not threaten the established capacity and production of the line.
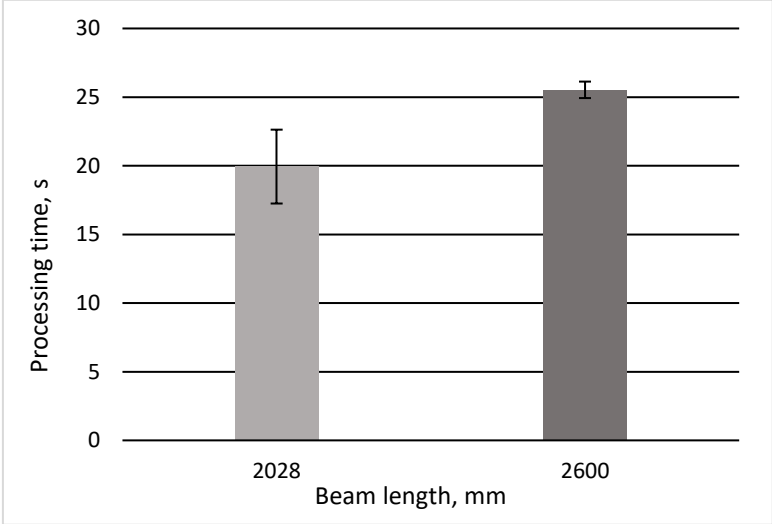

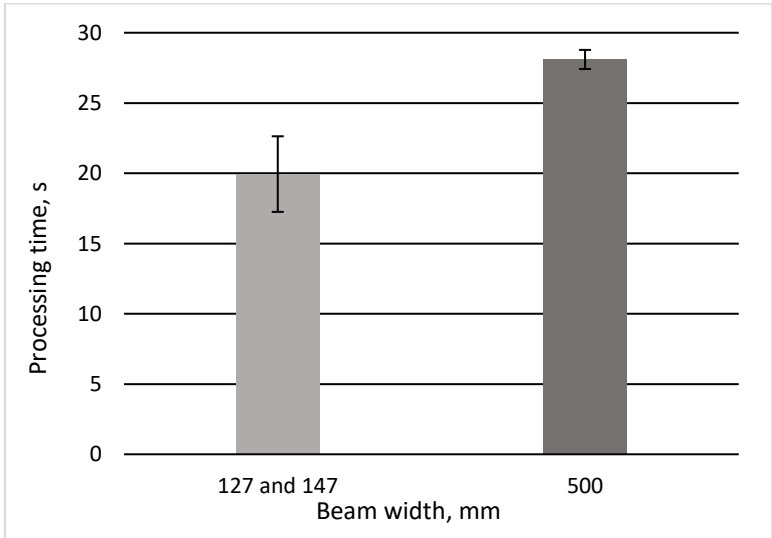**Figure 5.** Processing time of door frames with different height

Figure 6. Processing time of door frames with different width

Table 1. Test statistical parameters

	Length, mm	Width, mm	St. dev., s	Average processing time, s	Processing efficiency, A, pcs./min
Reference	2028	127 and 147	2,69	19,94	3,01
Calculated	2600	128 and 147	0,67	25,53	2,35
Calculated	2028	500	0,68	28,1	2,14

CONCLUSION

The extension of the processing time results from the increase in the beam dimension, which increases the operating time. By increasing the dimension of the frame beam in length, 2 cuts become longer, while with width 3 cuts, hence the greater difference between the average processing times. This directly affects the efficiency of the production line, which is lower than the reference capacity.

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Streszczenie: *Wydajność modułu formatowania i frezowania linii technologicznej do produkcji ościeżnic.* Wprowadzając nową linię technologiczną do formatowania i frezowania masowo kastomizowanych ościeżnic do drzwi drewnianych, firma PORTA KMI Poland z zakładem przemysłowym mieszczącym się w Ełk, Polska przeprowadziła odpowiednie testy wydajnościowe linii, aby określić zdolność produkcyjną w trakcie odbioru technologicznego w celu sprawdzenia, czy założona wydajność została spełniona, zanim nastąpi jej odbiór technologiczny. W pracy opisano, jak zmienia się czas obróbki ościeżnic o zmienionej długości belek z referencyjnej wynoszącej 2028 mm do 2600mm oraz ościeżnic, których szerokość z szerokości 127 i 147 mm zwiększono do 500 mm. Na tej podstawie wyliczono średni czas wynoszący 25,53 s dla ościeżnic o belkach długości 2600 mm oraz 28,1 s dla ościeżnic o szerokości 500 mm. Obliczono również wydajność, która wynosi 2,35 dla ościeżnic o zmienionej długości belki wynoszącej 2,14.

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