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INFLUENCE OF SEQUENCE AND TIMING OF OPERATIONS ON THE PRODUCTIVITY OF DOOR ASSEMBLY

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Abstract

The use of production lines in wood industry plants results from the necessity to reduce the labour intensity involved in the technological operations. Production lines are characteristic of mass production, where similar operations are performed on different products. An example is door production. This paper presents an example of the organisation of a door assembly line. Line efficiency was also calculated for two door models based on the assembly programmes prepared as part of the project and the takt times adopted. The paper also describes the possibility of forecasting efficiency depending on changing production tasks.

Key words: *door assembly, production line, productivity*

INTRODUCTION

The mechanisation and automation of production processes in industrial plants is reflected in the creation of production lines. Depending on the character of the technological operations performed, production lines can be used for processing or assembly purposes. A production line comprises workstations set in the order in which particular technological operations are performed. Such production organisation is typical of mass production [1, 2, 3, 4].

Each workstation within a production line should be assigned identical workload and at the same time should be used to its maximum capacity. The operation of those workstations should be synchronised, which means that they should work according to a common *takt*. The takt time of a production line is a measure of its efficiency and refers to the time between the production of two consecutive units. A production line should include no parallel stations or stations performing operations from outside the scope of its work. For these reasons, a production line always constitutes a distinct whole.

Apart from workstations, the correct operation of a production line is affected by the transporting devices used. Their task is to provide efficient transport of elements between particular workstations. Additionally, a production line should make use of manipulators that are to replace completely manual operations related to gathering elements before the performance of an operation, handing elements over to workstations, removing elements in an appropriate manner, and collecting ready units from workstations. Such devices include all types of feeders, which enable the precise separation of individual elements from a large number of objects held in a container.

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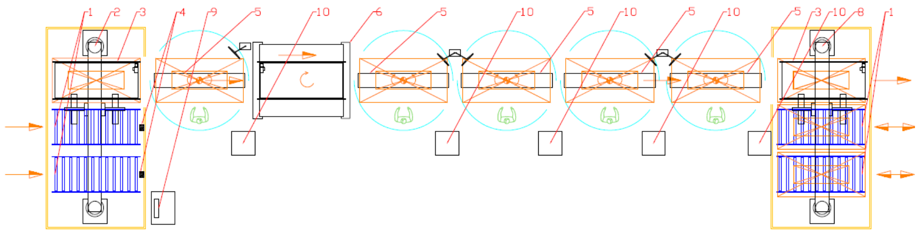
Due to the similar character of accessory mounting operations in different door types and models, the creation of production lines performing such tasks is particularly justified, especially that it enables the elimination of time-consuming manual activities. Thus, a decision was made to design a door fitting assembly line and to perform an initial analysis of its productivity.

DOOR ASSEMBLY LINE ANALYSIS

In order to increase the efficiency of assembly operations on door fittings produced using the principles of mass customisation, such operations on the TechnoPorta line were designed to be performed also in the line system. They will be performed within a newly-designed assembly line. The door fitting assembly line is basically made up of five universal stations — working tables (Fig. 1.). All of them use the same equipment that enables them to perform assembly operations. Up to 10 fitting operations can be performed at each station. Examples of assembly operations on doors:

- mounting of hinges,
- mounting of locks,
- mounting of door closers,
- mounting of bolts,
- mounting of automatic door bottom seals,
- mounting of seals,
- mounting of stainless steel panels,
- mounting of stainless steel strips protecting narrow door surfaces,
- mounting of glazing elements,
- mounting of any other accessories.



Legend:
1. Roller conveyor
2. Double station stacker with transverse vacuum gripping system.
3. Motorized belt conveyor.
4. Automatic barcode scaner/s.
5. Rotary assembly table with double high.
6. Longitudinal turntable
7. Operators monitors.
8. Double station Stacker with transverse vacuum gripping system.
9. Line control computer with manual scaner
10. Label printing system

Fig. 1. Door assembly line setup

Table 1. Timing of assembly operations for door type 1

Operations	Notes	**Door type 1**				
		Station	**Op No.**	**Number of accessories**	**Time/act**	**Time/Station**
Washing	Side 1	1	1	1	0:01:44	0:01:44
	Side 2	2	2	1	0:01:44	0:01:44
3-element hinge		3	3	2	0:00:52	0:01:43
3-element hinge		4	4	1	0:00:52	0:01:50
Security bolt			3	4	0:00:15	
Multipoint lock	8 screws	5	4	1	0:01:12	0:01:34
Mounting of the ID plate			5	1	0:00:22	
					Total:	**0:08:35**
					Takt time:	**0:01:50**
					Total time:	**0:09:09**

Table 2. Timing of assembly operations for door type 2

OPERATIONS	Notes	**Door type 2**				
		Station	**Op No**	**Number of accessories**	**Time/act**	**Time/unit**
Washing	Side 1	1	1	1	0:01:44	0:03:23
Cleaning fire seal grooves	all		2	4	0:00:07	
Fire seal 20×2	bottom		3	1	0:01:12	
Washing	Side 2	2	4	1	0:01:44	0:04:09
Fire seal 20×2	hinge + top		5	2	0:01:12	
Fire seal 10×2	lock	3	6	1	0:00:24	0:02:49
Fire seal 20×2			7	2	0:01:12	
3-element hinge		4	8	3	0:00:52	0:03:33
Security bolt			9	4	0:00:15	
Multipoint lock	8 screws	5	10	1	0:01:12	0:02:58
ID plate — registration in the IFS			11	1	0:01:23	
ID plate — mounting			12	1	0:00:22	
					Total:	**0:16:51**
					Takt time:	**0:04:09**
					Total time:	**0:20:43**

The purpose of the analysis is to determine the potential efficiency capacities of the assembly line for different types of produced doors. Using the proposed calculation method, it will be possible to predict the target efficiency of the production line depending on the quantitative proportions of doors subjected to fitting on the line. However, at first, it is necessary to develop an assembly program based on which particular operations on consecutive working tables will be performed. The assembly programme needs to take into account the equal assignment of those operations due to the logic of the technology and the time burden. Thus, the workload of particular working tables should result in a similar accessory assembly time at each station — the takt time. Examples of assembly programmes for two door models are presented in Tables 1 and 2.
Under line synchronisation conditions, in a specific takt time, the line efficiency can be calculated using the formula:

$$N = F \times k/T$$

Where:
F — nominal line work time fund,
k — line workstation use coefficient,
T – takt time.

For the takt times determined for door type 1: 1,83 min/unit and for door type 2: 4.15min/unit and the adopted value of the use coefficient: k = 0.85, with a nominal two-shift work time fund of F = 4000h/y, the following annual efficiency was calculated: N_1 = 111475 units and N_2 = 57831 units.

SUMMARY AND CONCLUSION

The analysis performed above shows that the assembly line takt time determined on a project basis affects significantly the final efficiency of the line. Thus, the correct determination of accessory assembly programmes for different door models is very important. Such correctness should be characterised by the shortest possible takt time. An accessory assembly programme should also take into account the technological order of particular activities, which is a limiting factor for takt time optimisation.
With projected or known quantitative tasks for particular door types or models and for takt times determined on a project or chronometric basis, it is possible to predict the efficiency of an assembly line and thus of the entire process.

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