SERVING TIMES OF DISCONTINUOUS MATERIALS HANDLING MACHINES

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Abstract: The performance of production systems highly depend on the effectiveness of the serving process, which consist of different materials handling operations depend on the applied machines. During the design process of serving systems there are key role of the characterisations of the handling equipment: they determine the applicability of the given machines. In my paper, I analyse the serving operations of discontinuous materials handling machines and define the time requirements of them. After the theoretical analysis I will show an example to compare the serving time requirements of bridge cranes and forklifts. This analysis is very important for the device preselection task of integrated materials handling design processes, because the serving time is a principal machine characterisation.
Keywords: materials handling, serving process, discontinuous operation, cranes, forklifts

1. Introduction

Productivity of advanced manufacturing systems highly depend on the effectiveness of the serving processes, especially at often changing production processes, because in these cases the serving process has to be also modified. The magnitude and the procedure of the modification are based on the parameters of the serving machines.

During the design process of serving systems there are key role of the characterisations of the handling equipment: they determine the applicability of the given machines. Serving processes consist of different materials handling operations which depend on the applied machines.

In this paper, I analyse the serving operations of discontinuous materials handling machines and define the time requirements of them. After the theoretical analysis I will show an example to compare the serving time requirements of bridge cranes and forklifts.

2. Characterisations of serving processes

During the selection process the optimal solution is searched along a given objective function with the comparison of parameters of the materials handling device and the required task. There are many proven methods for the selection of the different equipment (analytic, knowledge-based, integrated methods, etc.), but all of the methods are based on the serving parameters of the machines. [1, 2, 3].

The most generally usable method is the integrated design, which contains a device-preselection step to increase the effectiveness and applicability of the design process. In this case the device selection is actualised in two independent steps (preliminary determination of the equipment type and dimensioning of the given device), which makes the design process simpler and quicker [4].

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The aim of the preselection is to select the suitable materials handling equipment type using an analytical process. In the aspect of the design, materials handling parameters can be grouped into three different categories [5]:

- exclusion-type parameters (they can exclude the application of certain equipment types),
- limitation-type parameters (they can narrow the practical application field of the machines),
- numerical parameters (they are the basis of the analytic design process).

Parameters of the materials handling systems can be related directly to the material flow tasks (task parameters), the environmental conditions (restrictions) or the serving machines (device parameters) [6]. To evaluate the applicability of the different machines for a given task we have to know the characterisations of the materials handling systems, which are

- installation parameters (costs and times),
- serving parameters (cycle times, relations, etc.),
- operation parameters (costs, human resources, maintenance, etc.).

During the design process the installation and operation parameters can be previously calculated based on the data from the manufacturers, but to determine the serving parameters lots of information about the devices and the technology process is required. Basic possibility to get the required information is to analyse the serving process and the characterisations of the work cycle of the different machines.

Because of the operation characteristics of the equipment there is a significant difference between continuous and discontinuous operation. Machines with discontinuous operation work only during the actual task and waits between the work phases. Continuous machines are always operating independently of the task, they transport goods between a source and a destination point [7].

In this paper I am dealing with only the work cycle of the discontinuous materials handling machines.

3. Discontinuous serving cycle

The operation process of materials handling machines consists of different, well definable elements which are actualised step by step. The operation elements serve different purposes which can be:

- handling operations,
- moving phases,
- waiting phases, etc.

Handling operations are simple, or complex activities serve for actualisation of the materials handling tasks. These operations can be grouped into different categories in the aspect of their complexity and role in the process [8]:

- basic operations,
- additional operations,
- complex operations,
- sub-operations.

Considering the serving cycle, mainly the basic and sub-operation have great magnitude to the serving process (Figure 1.).
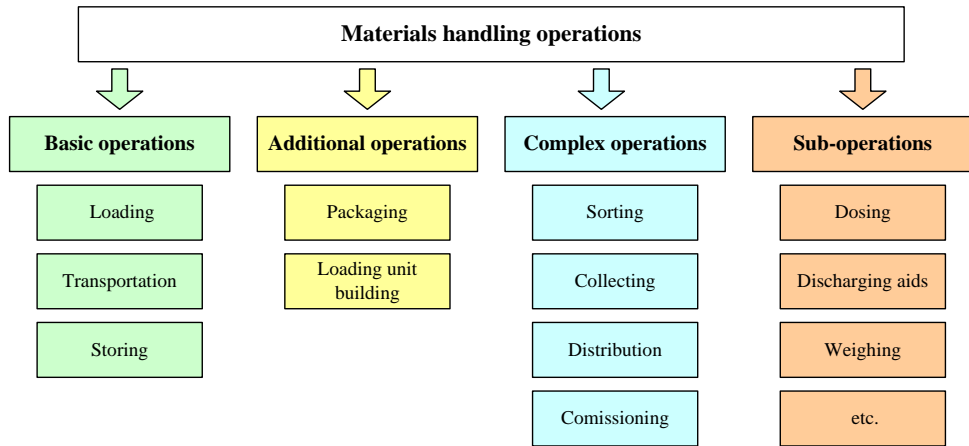
Materials handling operations			
Basic operations	**Additional operations**	**Complex operations**	**Sub-operations**
Loading	Packaging	Sorting	Dosing
Transportation	Loading unit building	Collecting	Discharging aids
Storing		Distribution	Weighing
		Comissioning	etc.

Figure 1. Handling operation categories

Operations during the moving phases are not related to the serving process directly, but have effect to the operation of the devices. These operations can be:
- positioning,
- starting and stopping caused by the traffic,
- changing of the transport ways, etc.

Waiting between the active process elements do not contain really activities, but they have important effect to the total serving time. Main causes of the waiting elements of the serving processes:
- traffic,
- waiting lines,
- parking,
- waiting at the technology objects, etc.

3.1. General serving cycle. Discontinuous handling devices are operating in work cycles (Figure 2.) which can be divided into four different phase:
- a) collecting of the goods,
- b) serving of the technology process,
- c) returning to the parking place,
- d) waiting at the parking place.

Phases a), b) and c) have no direct effect to the serving activities, they can modify only the starting moment of the serving process. There is one similarity related to the three phases: there are no goods on the equipment during the operation. Any of the above mentioned three phases can miss from the serving process or they can replace each other in certain cases.

Main variants of the serving cycle:
- continuous serving (return phase is the same as the next collecting phase),
- related serving (there are no return and collecting),
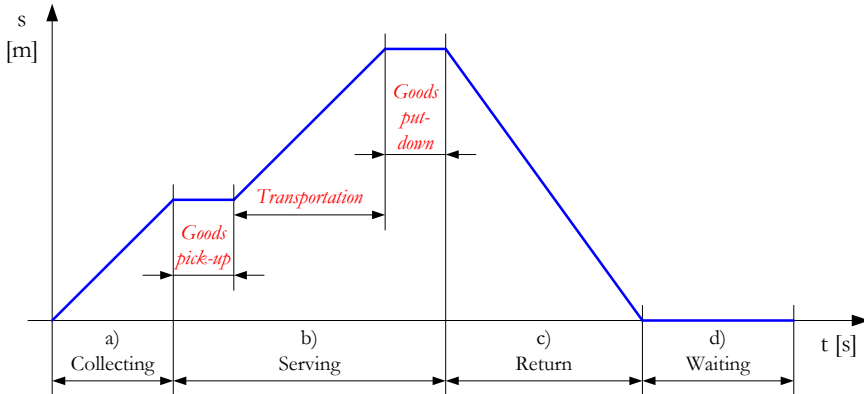- complex serving (for example distribution systems), etc.

Figure 2. General work cycle of discontinuous operation

The most important part of the operation process is the serving phase which can be divided into three further parts (Figure 2.):
- pick-up of the goods,
- transportation,
- putting down of the goods.

Time of general work cycle (t_{wc}) of discontinuous materials handling equipment can be calculated:

$$t_{wc} = t_c + t_s + t_r + t_w \tag{1}$$

where

t_c – collecting time [s],
t_s – serving time [s],
t_r – returning time [s],
t_w – waiting time [s].

3.2. Collecting time. As the collecting phase has no direct relation to the serving activities, so the collecting time also does not depend on the time elements of the serving process. Main factors that affect the collecting time [7]:
- traffic parameters:
  - stopping,
  - starting,
  - waiting, etc.
- waiting lines,
- changing of the transport ways, etc.

As the effects of the above mentioned factors appear in a stochastic way, so they can be taken as an approximation into consideration. Theoretical expression for the determination of the collecting time is the following:

$$t_c = \frac{s_c}{\overline{v}_c} \tag{2}$$

where
  s_c – collecting length [m],
  $\overline{v}_c$ – average collecting velocity [m/s].

The different stochastic events of the real process are taken in the average collecting velocity into account.

3.3. Serving time. Serving activities are actualised during the serving time, so their length effects directly the technology process. Serving time contains four main time elements:

$$t_s = t_{lu} + t_t + t_{ld} + t_{sw} \tag{3}$$

where
  t_{lu} – pick-up time [s],
  t_t – transport time [s],
  t_{ld} – put-down time [s],
  t_{sw} – waiting times during the serving [s].

3.4. Returning time. Similarly to the collecting time, the returning time also does not depend on the serving activities and their influencing factors are the same (which see in Chapter 3.2.). It can be calculated by a similar form:

$$t_r = \frac{s_r}{\overline{v}_r} \tag{4}$$

where
  s_r – returning length [m],
  $\overline{v}_r$ – average returning velocity [m/s].

3.5. Waiting time. Principally it means only the time of the passive states (not working), but it is worth to include all waiting times occurring during the whole process (for example: waiting before picking-up or putting-down of the goods). In this case it consists of the following elements:

$$t_w = t_{wp} + t_{wb} + t_{wa} \tag{5}$$

where
  t_{wp} – waiting at the parking place [s],
  t_{wb} – waiting before the service activities [s],
  t_{wa} – waiting after the service activities [s].

4. Serving times of bridge-cranes and forklifts

Because the individual materials handling machines require different operation elements, the parameters of the serving process can be very different in operation number and time. If we want to compare the different machines in the design process, we have to know all of the operation elements and their time requirements for every applicable machine. In this paper we cannot analyse all of the handling equipment. As an example we will define the operation elements and their time requirements of two characteristically different discontinuous machines (a forklift and a bridge crane) at a similar handling task.

Analysis of the operation elements of materials handling machines has almost one hundred years history, started with the manual activities and included all of the advanced machines [9]. In the advanced, most applied devices the operation elements can be well settled and automatized, but some manual element is also existed (Table I.).

Table I.

Operation elements of bridge cranes and forklifts

	Operation elements	Forklift	Bridge crane
1.	Collecting	x	x
2.	Positioning (empty)	x	x
3.	Clutching	x	(manual)
4.	Lifting (with goods)	x	x
5.	Transporting	x	(linear)
6.	Positioning (with goods)	x	x
7.	Releasing	x	(manual)
8.	Lifting (empty)	-	x
9.	Returning	x	-
10.	Waiting	x	x

It can be stated from Table I. that there are four main differences between the two machine types:
- clutching and releasing of the goods are generally a manual operation at the cranes,
- transport line of the bridge cranes is linear, against the complex line of a forklift,
- clutching device of cranes have to be lifted in loaded and also in empty state,
- cranes can stay at the finishing position after the serving process, forklifts need to return into the parking place in generally.

One of the most important differences between the cranes and trucks that the stochastic phenomenon is more rear at cranes because of the movement on a high track. The effects of the waiting during the serving process can cause significant increasing of the serving times at ground line equipment (for example at forklifts).

For the analysis of the serving times we use a real materials handling example, in which

frequent serving tasks have to be actualized between two given objects. The parameters of the serving task can be seen in Table II. The data of the machines used in the calculations based on practical information from the literature [10, 11].

Parameters of the serving process [10,11]

	Parameters	**Forklifts**	**Bridge cranes**
1.	Transport length	100 m	50 m
2.	Transport velocity	200 m/min	50 m/min
3.	Lifting velocity	20 m/min	10 m/min
4.	Lifting height	2 m	10 m

At first, we have to compare the times of the operation elements of the two machines. As it can be seen in Figure 3., the general time requirement of the individual operations is significantly different for the distinct devices. At the crane the handling operations requires much time and the full serving time is almost double of the forklift.
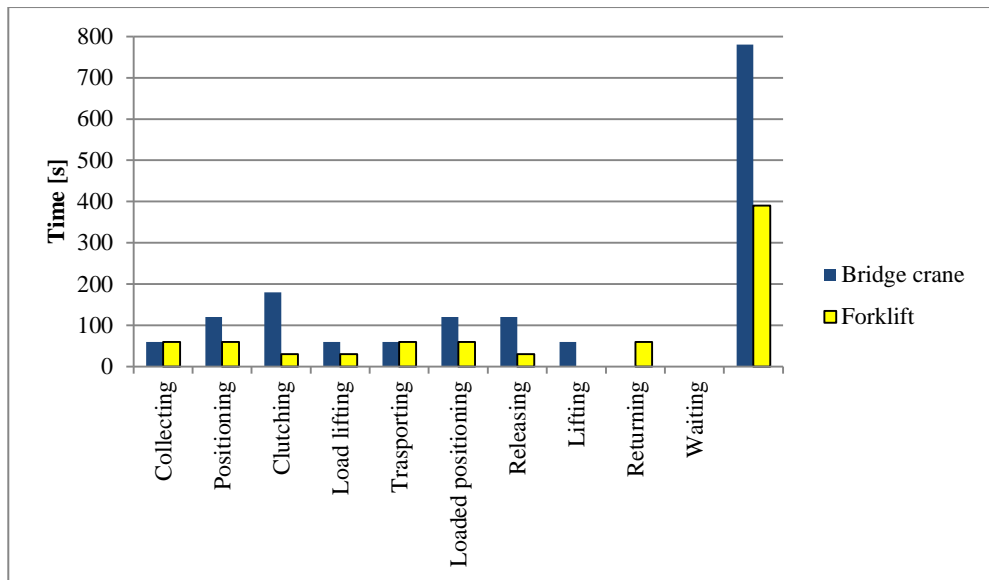

Figure 3. Serving times of the operation elements

It is worth to examine the ratio of the handling and the transporting elements, because it gives information about the effects of the stochastic phenomenon. Figure 4. shows the ratios of the serving elements to the full serving time at the different machines. At forklifts the summarized time of the transport operation elements (collecting, transporting and returning) is about 45 % of the total time requirement, but at bridge cranes it is only about 16 %.
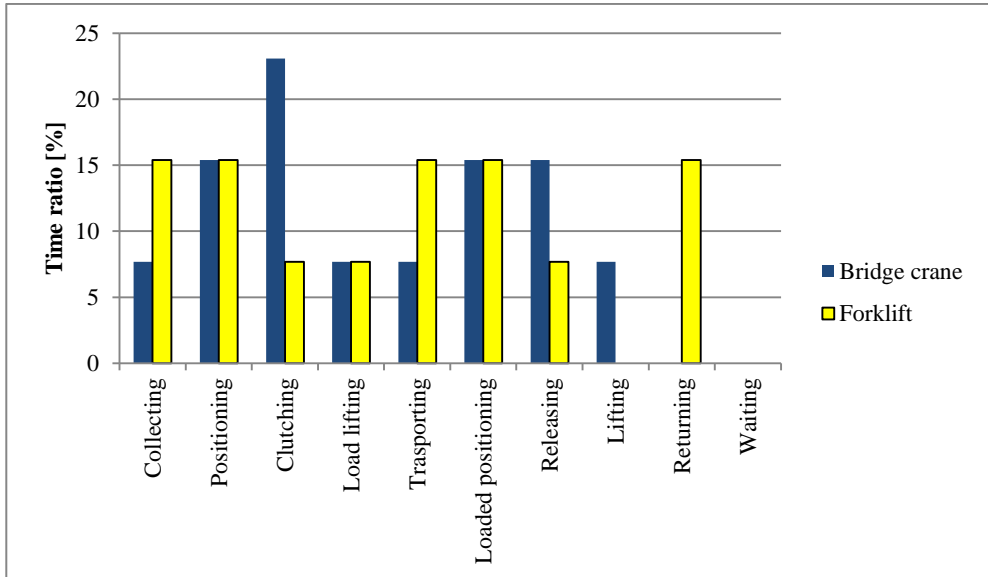
Figure 4. Serving ratios of the operation elements

The above ratios will be even more visible, if we increase the transport length of the given task. Figure 5. contains the effects of the transport length increasing to the total serving time. It is obvious that the serving time of the bridge crane will be ever closer to the forklift's if the transport length is increasing. The difference in the total serving time is only 18% at 200 m, against the 50% at 50 m transport length.
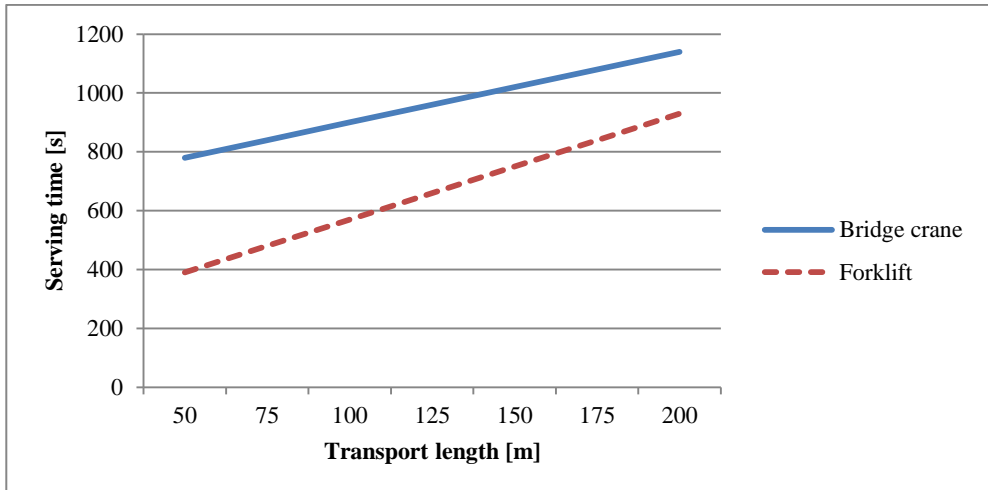

Figure 5. Total serving times

Results of the presented analysis do not contain the effects of the stochastic

phenomenon. If we assume that the time of the random waiting elements (which is the most important consequence of the stochastic phenomenon) is near proportional to the times of the transporting operation elements, than we can determine the actual waiting times based on the transport elements. Figure 6. shows the length of the waiting times for the two equipment as a function of the transport operation elements. As we can see on the diagrams, the waiting times of the forklifts have more significant effect to the serving processes.
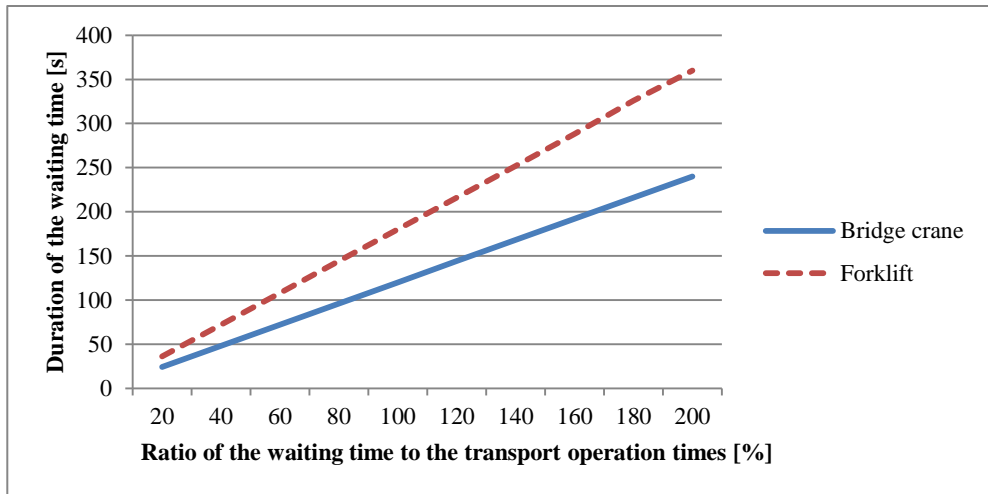

Figure 6. Effect of disturbances to the total serving time

As the above mentioned results show, there are two main differences between the serving processes of bridge cranes and forklifts:

- ratio of the transport operations to the handling operations is higher at forklifts than at cranes,
- the effects of stochastic phenomenon are more significant at forklifts.

It means that it is possible to determine applicability limits for the examined devices in the aspect of the transport length. However, it can be taken into consideration, that the transport length is also limited by the structure and the real construction environment.

Another important fact is the stochastic phenomenon, which makes the application of forklifts hard in complex serving systems, because the complexity of a serving process increases the appearing of the random waiting phases.

As our analysis was realized for manual serving machines, so the results cannot be generalized. To get generally usable results there is obvious, that the analysis have to be widened for more device types included automatic machines.

5. Summary

Productivity of manufacturing systems highly depends on the effectiveness of the serving processes, which consist of different materials handling operations depend on the applied machines. During the design process of serving systems there are key role of the

characterisations of the handling equipment: they determine the applicability of the given machines.

In this paper, I analysed the serving operations of discontinuous materials handling machines and defined the time requirements of them. After the theoretical analysis I made a practical example to compare the serving time requirements of bridge cranes and forklifts.

As a result of my research I can say, that it is possible to determine applicability limits for the examined devices in the aspect of the transport length. Another important result is that the stochastic phenomenon makes the application of forklifts hard in complex serving systems. Because the analysis dealt with only manual serving machines, to get generally usable results we have to widen the research for more device types included automatic machines.

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