

## DESIGN PROBLEMS OF CONVEYORS

*Péter Telek*

PhD., assoc. prof.

*University of Miskolc, Institute of Logistics*

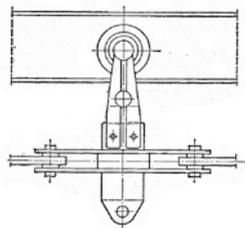
### INTRODUCTION

Continuous handling machines are applied in many parts of the materials handling processes required by the manufacturing process. As the characterisations of these machines differ from the discontinuous ones, the design process is also different. Most of the continuous materials handling equipment use endless towing element to move goods on a certain transport line, so the design of these element are very important for them.

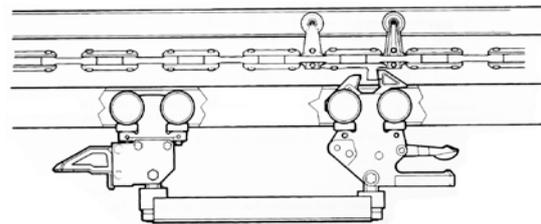
In this paper I summarise the main characteristics of the endless chain drives and their design specifications. The aim of my research to discover the design problems and their solutions of the machines which use endless chain drives.

### 1. DEFINITIONS OF CONVEYORS

In the Hungarian literature [1] the name *conveyor* means in generally a trolley or a cart towed by a continuous chain element (Figure 1). In the English terminology there is a different concept, where the name *conveyor* involves all of the materials handling machines which work in continuous operation [2, 3].



a) *Trolley conveyor* [4]



b) *Tow conveyor* [2]

Figure 1  
Conveyor types in Hungarian literature

I think that in the aspect of the design and operation process of handling machines none of them are suitable, so it is required to change the meaning of this word, because of the similarity of different types of machines.

Conveyors (in both approaching) are one of the most significantly used handling machines, so we have to start our redefinition process from the overview of the continuous handling devices (Figure 2). In the aspect of their operation, these machines have two main groups:

- equipment driven by towing element,
- equipment driven without towing element.

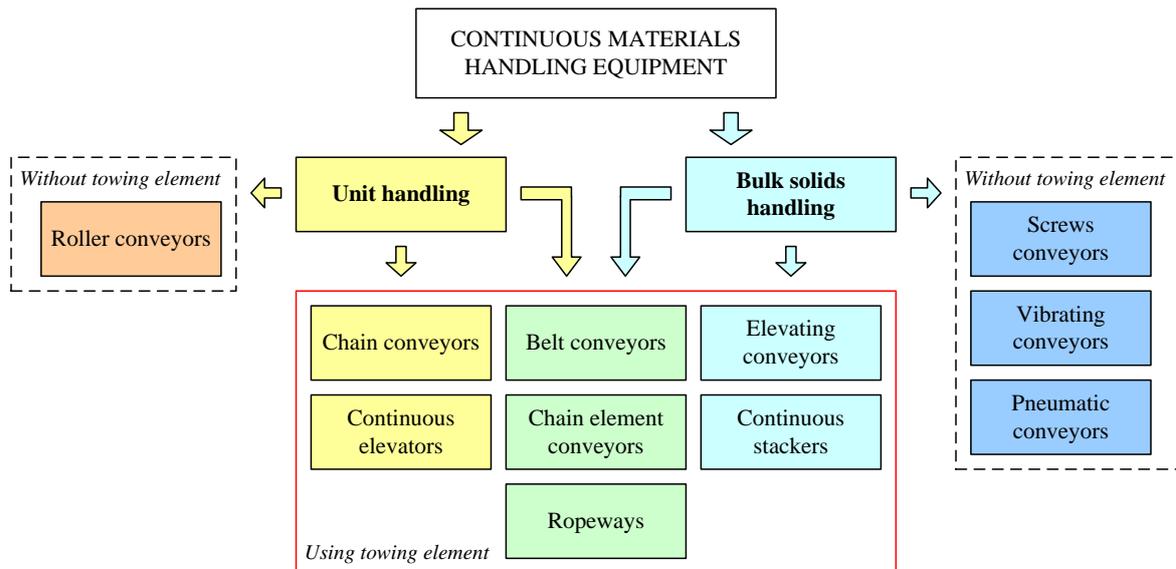


Figure 2  
Variations of continuous handling machines

In the first group, goods are transported by an endless, flexible towing element (belt, chain, rope, etc.) along a given track line.

At the other machines, goods are moved by a linear moving element, a rotating element (e. g. rollers), or a flowing fluid (e. g. air).

The main difference between the two groups, that all of equipment driven by a towing element can be designed in similar way, but the others have individual design methods.

Equipment driven by a towing element can be grouped in further categories, in the aspect of the driving method:

- friction drive (belt, ropes, etc.),
- chain drive (chains, linked elements, etc.).

Because of the similarities of the design processes and calculation methods, all materials handling machines with chain drive can be designed and operated in similar way, so **these machines can be taken as “conveyors” into consideration.**

Handling machines with friction drive have also similarity in the design and operation processes, but there are some special characterizations (significant pretension, slip, etc.) which make them different and they require individual methods.

## 2. VARIATIONS OF CONTINUOUS MATERIALS HANDLING MACHINES DRIVEN BY CHAIN

The group of continuous materials handling machines driven by chain contains much different equipment. To describe their structures and operation characteristics, it is expedient to group them into further subcategories.

In the aspect of moving direction we can speak about horizontally (e. g. pan conveyor) and vertically circulating (e. g. elevating conveyor) conveyors (Figure 3).

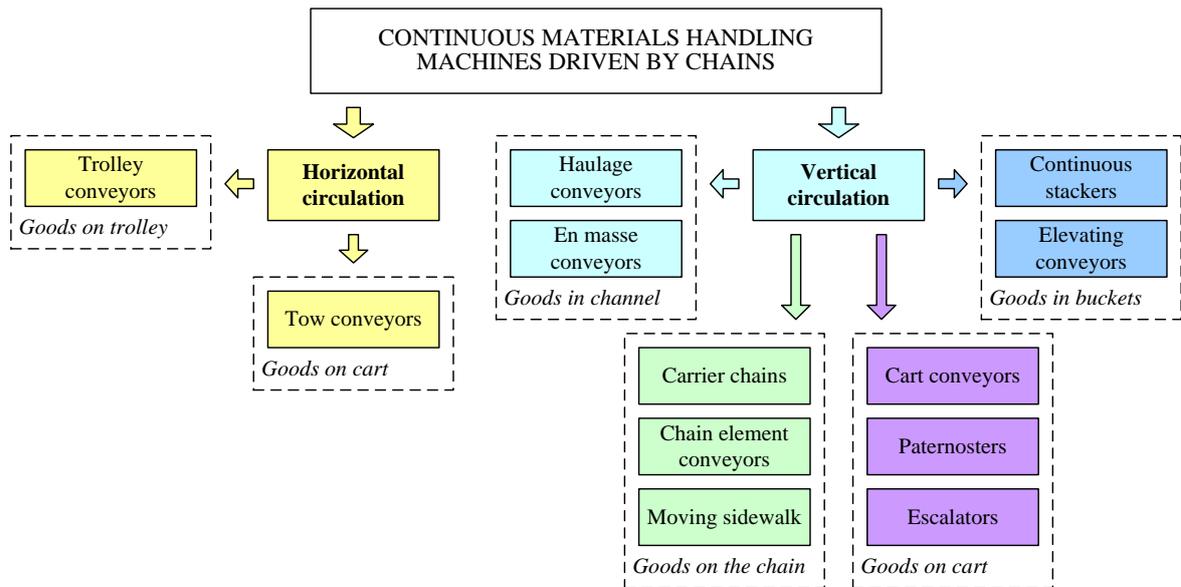


Figure 3

### Variations of continuous materials handling machines driven by chains

The towing element can be a real chain (different types) or a chain of linked elements.

There can be also differences in the relation of the flexible towing element and the goods (Figure 3):

- goods placed directly onto the towing element,
- goods transported on hangers or in buckets,
- goods transported by a cart moved by the endless towing element.

### 3. DIMENSIONING OF ENDLESS CHAIN DRIVES

During the design process of continuous materials handling machines driven by chains we have to realize the next steps:

- determination of the types of the loading,
- determination of the capacity requirement,
- determination of the loading of the chain,
- determination of the line structure,
- determination of the driving power needs, etc.

#### 3.1. Determination of the type of the loading and the capacity requirement

There are two main parameters which have important role in the determination of the type of the loading character:

- the serving concept and
- the transport method.

The serving concept is influenced by the operation character of the handling machine, which can be transportation between two points (one source and one destination), or among more than one source and destination points (Figure 4).

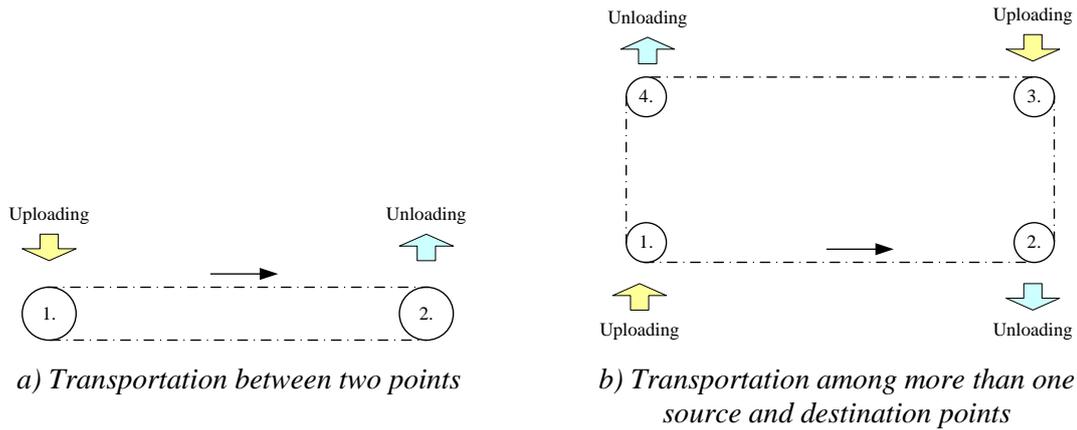


Figure 4  
Variations of the serving concept

At the first case (Figure 4a) the transportation is realised between the two end-point of a transport line. The starting point means the uploading and the end-point means the unloading of the goods. At these machines, the performance needs of the transport can be calculated easily and it is equal to the capacity requirement.

At machines which can transport goods among more than one source and destination points (Figure 4b), we can realize more than one transport task at the same time. The different transport relations have different loading levels, so the calculation of the total loading is very complex task. The dimensioning of these machines involves the analysis of the line segments and the calculation of a significant loading value which determines the capacity requirement [5]:

$$q_M = \max_i q_{i(i+1)} \quad i = 1 \dots (n-1) \quad [\text{N}], \quad (1)$$

where

- $q_{i(i+1)}$  – loading value of the line segment between point  $i$  and  $i+1$  [N],
- $n$  – number of the line segments.

In the aspect of the transport method there are also two different variations for the drive chains:

- continuous material flow and
- discontinuous transport.

Transportation in continuous material flow is possible at machines working between two points. In this case goods move directly on the towing element or in a transport channel (e. g. at en masse conveyor). Real continuous material flow can be realized from bulk solids, but at units we can speak about quasi-continuous flow, if the distance between the following units is very small and there is no break in the transportation process. In this case the capacity requirement is [5]

$$q_v = A_0 \cdot v \quad [\text{m}^3/\text{s}], \quad (2)$$

where

- $A_0$  – cross section area of the goods flow [ $\text{m}^2$ ],
- $v$  – velocity of the transport [m/s].

At discontinuous transportation the goods moves on hangers or trolleys (at units) or in buckets (at bulk solids). In this case the capacity requirement is [5]

$$q_v = \frac{m_{db}}{e} \cdot v \quad [\text{kg/s}], \quad (3)$$

where

- $m_{db}$  – mass of the units or bulks [N],
- $e$  – distance between the following units [m].

### 3.2. Determination of the loading of the chain element

The loading of the chain element is different at continuous material flow and at discontinuous transport.

At continuous material flow the transport is realized generally along a linear line and can be calculated easily based on the capacity needs of the machine and the length of the transport line.

At discontinuous transport the loading is appearing in discrete points of the machine (in buckets or on hangers), so we have to calculate an average loading value for the dimensioning [6]:

$$\bar{q} = \frac{q_z \cdot n_z + q_t \cdot n_t}{n_z + n_t} \quad [\text{N}], \quad (4)$$

where

- $q_z$  – loading of the empty hangers/buckets [N],
- $n_z$  – number of the empty hangers/buckets,
- $q_t$  – loading of the loaded hangers/buckets [N],
- $n_t$  – number of the loaded hangers/buckets.

Dimensioning of the chain element means the determination of the towing forces in the chain on the different line segments [6]:

$$T_{i+1} = T_i + q_i \cdot h_i + \mu_i \cdot q_i \cdot l_i + \mu_i \cdot p_i \cdot s_i \quad (5)$$

where

- $T_i$  – towing force at the start-point of line segment i [N],
- $T_{i+1}$  – towing force at the end-point of line segment i [N],
- $q_i$  – loading of the chain element on line segment i [N/m],
- $\mu_i$  – loss coefficient of the chain element on line segment i,
- $p_i$  – pretension force of the chain element on line segment i [N],
- $s_i$  – length of line segment i [m],
- $h_i$  – fall/lift of line segment i [m],
- $l_i$  – horizontal distance between the end-points of line segment i [m].

There is a possibility to demonstrate the towing forces along the transport line in a diagram, in order to gain information for the design of the equipment (Figure 4).

The most important parameters which can be calculated on the towing forces [6]:

- driving force requirement:

$$F_k = T_{fel} - T_{le} \quad [\text{N}], \quad (6)$$

where

$T_{fel}$  – towing force at the arriving point on the driving sheave [N],

$T_{le}$  – towing force at the leaving point on the driving sheave [N],

- maximal force in the chain:

$$F_{\max} = T_{\max} \quad [\text{N}], \quad (7)$$

- pretension force requirement:

$$F_e = T_{\min} \quad [\text{N}], \quad (8)$$

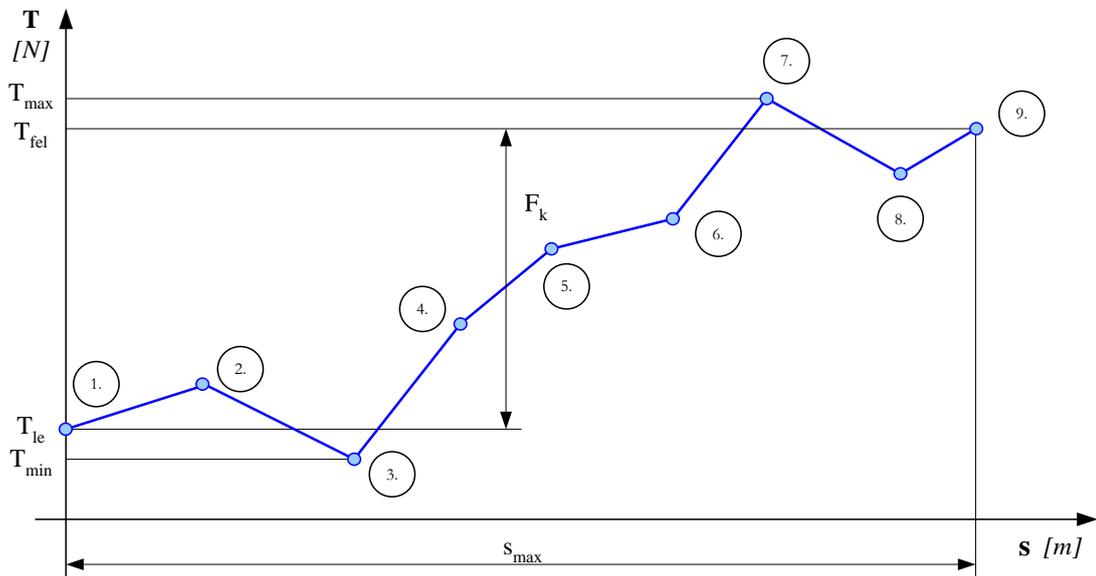


Figure 4

Example for a towing force diagram and the significant forces in the chain

#### 4. DESIGN PROBLEMS OF ENDLESS CHAIN DRIVES

Using the above mentioned design method and calculation formulas we can design an endless chain drive in generally, but there are some parameters which cannot be calculated exactly and cause problems during the operation. The most important questions are the effects of the load-changing in time, the effects of the location of the driving sheave and the effects of the location and size of the pretension solution, etc.

##### 4.1. Load-changing

One of the most important problems of the endless chain drives is the changing of the loads along the transport line. Causes of the changing:

- depend on the number and location of the source and destination points, different loading segments have to be taken into account along the transport line,
- loading property can change within the individual line segments,
- loading values can change in time, etc.

The above described design scheme is based on a dominant, constant loading level. Because of this approaching, which uses in generally the maximal values as dominant, this dimensioning method results smaller or larger oversizing of some segments of the equipment.

The oversizing in generally does not cause operation problems, but increases the installation and operation costs of the handling system. Costs can be reduced by the application of additional handling machines (e. g. transport trucks) at the high loaded segments to reduce the oversizing of the other segments.

Another possibility to reduce the oversizing is the using of divided transport lines with more than one endless chain drives. The costs of it are not lower, but it gives a more efficient, harmonized operation. Unfortunately only certain kind of equipment can be used in this concept (e. g. tow conveyors), because of the transfer needs between the chain lines.

The determination of the dominant loading of the individual line segments can also cause problems during the design process, because in certain situations the actual loading level can be highly different from the average value, for example in case of local loading peaks. To avoid this problems the more accurate analysis of the loading on the individual line segments and using of other loading values (e. g. maximal values) as dominant is required.

The most problematic element of the design process of endless chain drives is the load-changing in time. One of the most often used solutions to handle this problem is also the oversizing, but its effect is bigger. Suitable method can be the discontinuous operation (switch off the machine in certain periods) of the equipment to reduce the cost-consequence of the oversizing, but it cannot be applied for all of the machines.

#### *4.2. Location of the driving sheave*

The driving sheave can be theoretically located in any point of the transport line, but it is expedient to build into a reversing point to fulfil the requirement of the effective driving. Theoretically, the driving force requirement is the same in all points of the line, but in the practice the local losses can modify the value [7]. The optimal location for the driving sheave is at the minimal towing force, and it has effect to the location of the pretension device.

Selection methods can be found in the literature [7] are suitable for the determination of the location of the driving sheave, but only at discrete line points. In many cases, some of the line-points are not suitable for the driving sheave, because of their conditions. The selection process will be much more complex, if we want to take the load-changing in time into consideration, and to gain results we need special, complex optimisation methods [8].

## 5. SUMMARY

The characterisations of the continuous handling machines differ from the discontinuous equipment, so the design process is also different. Most of the continuous materials handling equipment use endless towing element to move goods on a certain transport line.

In this paper I have shown the main characters of the endless chain drives and the machines which use them for transportation. After the details of the dimensioning process I discovered the main problems during the design, which are the effects of the changing loads in time, the effects of the location of the driving sheave, the effects of the location and size of the pretension solution, etc.

The aim of my research is to describe the design problems and to look for solution methods to avoid them. After the definition of the problems, the next step will be the analysis of the influencing parameters and their main effects for the design processes.

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