

SESSION A:

EARTH MOVING AND TRANSPORTATION MACHINERY

Analysis and calculation of overhead conveyor for metal housings transportation

Spasoje Trifković^{1*}, Nebojša Radić¹, Miroslav Milutinović¹, Srđan Samardžić¹

¹ University of East Sarajevo, Faculty of Mechanical Engineering, Sarajevo, Bosnia and Herzegovina

ARTICLE INFO

* Correspondence: spasoje.trifkovic@ues.rs.ba

DOI: <https://doi.org/10.46793/ET26.A10T>

PAGES: A79 – A84

ABSTRACT

Overhead conveyors are used to increase productivity in manufacturing processes and warehouse centers. These are continuous transport devices that operate above or over the head of both workers and other equipment. Their advantage is that they can transfer the load in any direction in space. Steel ropes and chains are used as pulling elements. The pulling element is connected to the trolley where the carriers are attached. The loads from the cargo are transferred via the wheels to the carrier conveyor track. The carrier track is most often connected to the construction of the hall. In this paper, the analysis and calculation of the overhead chain conveyor for the transportation of metal housings was performed.

KEYWORDS

Transport devices, Continuous transport systems, Overhead conveyors.

1. INTRODUCTION

Conveyors are used for the continuous transport of piece and bulk materials, along a route with horizontal, inclined and vertical sections. The routes are closed, usually flat (for example, vertical or horizontal). When transporting piece goods, overhead conveyor routes can also be spatial, where they are an integral part of a production process [1]. There are also systems based on rails that are installed according to the desired transport paths and in which the vehicles can be maneuvered individually [2]. Most of the work in this area studies overhead conveyors [3]. Various constructions of overhead conveyors were considered in the papers [4,5,6]. Papers [7,8,9] show the advantages and disadvantages of Power & Free Conveyor and their systems. More recent work [10,...,13] focuses on special vehicle designs and other systems or performance enhancements. In this work, the calculation of the basic elements of overhead conveyors used in serial production, especially in the automotive industry was performed [14].

2. OVERHEAD CONVEYORS

The Overhead conveyors, are typically used in manufacturing facilities to move parts from one location to another. They take advantage of the generally unused vertical space above the work area. According to the method of material transportation, they can be [1]:

- conveyors that transport load by carrying (Figure 1.a)
- conveyors that transport load by pushing (Figure 2.b)
- conveyors that transport load by pulling (Figure 3.c)

Common components of an overhead conveyor system include a chain or cable drive, either enclosed or open track, a drive unit, a take-up unit, trolleys, carriers, and supports. These components are specifically engineered to cater to the unique requirements of different applications and operations [15].

Overhead conveyor chains come in various designs, each tailored to handle unit loads or bulk materials. Choosing the appropriate chain for an overhead conveyor depends on the specific application requirements, as well as the chain's durability and reliability. Overhead conveyor chains are available in various shapes, sizes, and designs, each tailored to address the specific requirements of a transport application. The drive system in an overhead conveyor connects to the chain,

propelling it along the conveyor's track. There are two primary drive types: caterpillar and sprocket. The type of drive affects both the chain and trolley speed and the rate at which materials are delivered to their destination [15].

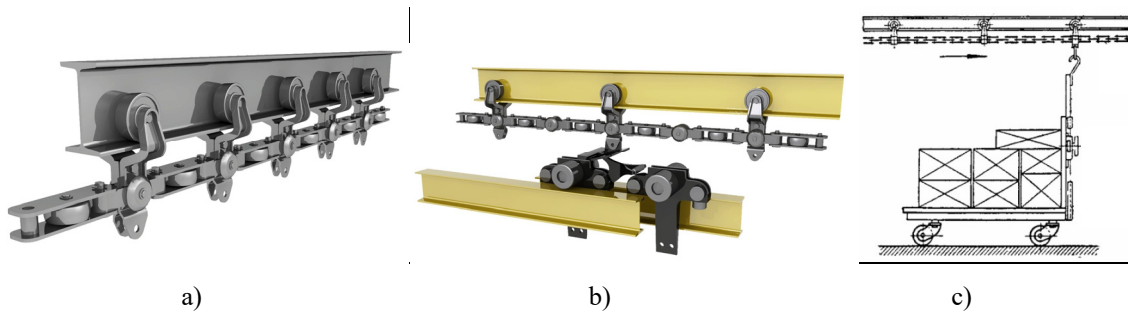


Figure 1: Types of Overhead Conveyors

Overhead conveyor tracks are categorized into I-beam and enclosed types (Figure 2), selected based on the application's requirements and conveyor use. I-beam tracks are popular for their strength and ability to support heavy loads and trolley wheels. Enclosed tracks vary in design, with some featuring a tubular structure and others having a rectangular or square cross-section. Overhead conveyor tracks are constructed from robust steel to endure continuous operation.

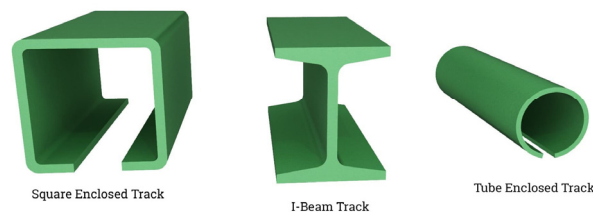


Figure 2: Types of Overhead Conveyor Tracks [15].

Trolleys, connected to a handy chain drive, glide along the track to help move heavy loads with ease. Each trolley comes with a spot to secure different kinds of load carriers. When the chain drive kicks in, it smoothly moves the trolleys along the track, carrying the load from the overhead conveyor. The trolleys' movement is managed by the chain and drive system, making it easy to start and stop whenever necessary. Plus, trolley designs are customized to fit the specific type of track they're linked to, including options for tube enclosed tracks, I-beam tracks, and other enclosed styles.

Take-up units in overhead conveyors are very important for keeping the chain drive nice and taut, which helps everything run smoothly. These handy units come with a roller turn or traction wheel design and tackle any chain stretching that might happen due to temperature changes. Usually found near the drive, often at a low point in the system, take-ups are great at managing how the chain expands and contracts. You can find take-up units in different spots like roller bank turns, traction wheel assemblies, or even within spread track loops.

Pendants in an overhead conveyor system are components that connect to the chain and support the loads being transported. Constructed from durable materials, these pendants are designed to handle the weight and operational stresses of the conveyor system. They attach to load pins on the chain, enabling materials to hang below the chain itself. Pendants are compatible with various tracks, brackets, chains, and other conveyor parts. Spacing between pendants on an overhead conveyor chain differs based on the conveyor model and the type of materials being conveyed. To boost the load capacity, some items are supported by several pendants. Pendants come in various forms, including V-shaped, loading hooks, swivel fixtures, and double loading hooks, each suited for specific load needs [15].

3. CALCULATIONS

It is necessary to calculate an overhead conveyor for the transport of Metal Housings (Figure 3) weighing 40 kg. Other data are:

$$b = 600 \text{ mm} ; h = 1000 \text{ mm}$$

Drive element is welded chain $t_K = 80 \text{ mm}$ or detachable chain $t_K = 100 \text{ mm}$

The conveyor speed is $v = 0.15 \text{ m/s}$, one housing per pendants

The weight of the trolley 5 kg, weight of the pendant 15 kg

Overall mechanical efficiency $\eta_{mech} = 0,65$, total drag chain weight $q_K = 18 \text{ kg/m}$

- 1) What must be the minimum distance between the pendants, that there would be at least 200 mm of space between adjacent housings?
- 2) Which distance between the pendants and which pitch of the chain is obtained?

- 3) What are the parts and mass capacity?
- 4) What tractive force is needed (approximate and exact calculation)?
- 5) What is the maximum drive load?
- 6) What must be the tension force, so that the minimum force in the chain is $F_{K\min} = 0,80 \text{ kN}$

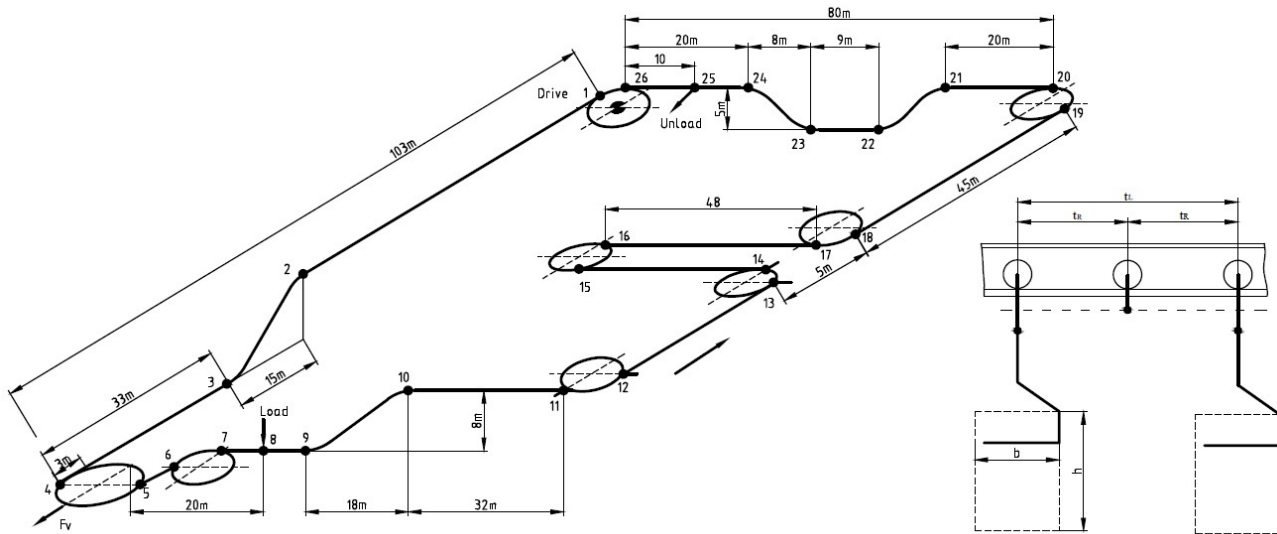


Figure 3: Overhead Conveyor for Metal Housings

Solution:

- 1) In order for the required condition to be met, the highest rise of the conveyor must be observed. It is between points 23 and 24 (Figure 4):

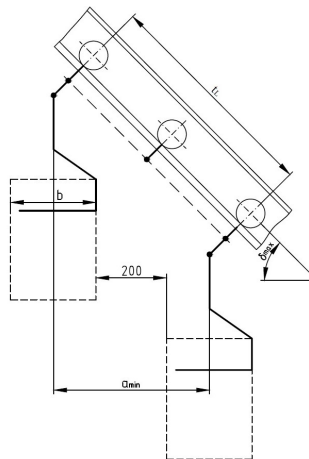


Figure 4: Determination of the minimum distance

$$\tan \delta_{\max} = \frac{5}{8} \Rightarrow \delta_{\max} = 32^\circ \quad (1)$$

$$t_{L\min} = \frac{a_{\min}}{\cos \delta_{\max}} = \frac{b + 200}{\cos 32^\circ} \quad (2)$$

$$t_{L\min} = \frac{600 + 200}{0,848} = 943 \text{ mm} \quad (3)$$

- 2) Considering that: $t_L = 2 \cdot t_R$ and $t_R = (2, 4, 6, \dots) \cdot t_K$ follows:

$$\text{for } t_K = 100 \text{ mm} \Rightarrow 6 \cdot t_K = t_R \quad (4)$$

$$t_R = 600 \text{ mm} \Rightarrow t_L = 1200 \text{ mm} \quad (5)$$

$$\text{for } t_K = 80 \text{ mm} \Rightarrow 6 \cdot t_K = t_R \quad (6)$$

$$t_R = 480 \text{ mm} \Rightarrow t_L = 960 \text{ mm} \quad (7)$$

$$t_L = 960 ; t_K = 80 \text{ mm} \quad (\text{assumed}) \quad (8)$$

$$3) \quad Q_{St} = 3600 \cdot \frac{v}{t_L} \cdot z_1 = 3600 \cdot \frac{0,15}{0,96} \cdot 1 = 562 \text{ kom} / h \quad (9)$$

$$Q_G = \frac{Q_{St} \cdot G_{St}}{1000} = \frac{562 \cdot 40}{1000} = 22,5 \text{ t} / h \quad (10)$$

$$T = \frac{t_L}{z_1 \cdot v} = \frac{0,96}{1 \cdot 0,15} = 6,4 \text{ s} \quad (11)$$

$$4) \quad f_{uk} \approx f \cdot \left(1 + f_F \cdot f_S^x \cdot f_{WK}^y \cdot f_{wR}^z \right) \quad (12)$$

Since most of the climbs are in the area $25^\circ < \delta < 35^\circ$, chosen $f_S = 1,02$.

$$f_{uk} \approx 0,025 \cdot \left(1 + 0,4 \cdot 1,02^8 \cdot 1,025^7 \cdot 1,03^3 \right) \approx 0,4 \quad (13)$$

$$q = q_K + \frac{G_{Lw}}{t_R} + \frac{G_T}{t_L}$$

$$q = 18 + \frac{5}{0,48} + \frac{15}{0,96} = 44 \text{ kg} / m \quad (14)$$

$$G_G = \frac{G_{St} \cdot z_1}{t_L} = \frac{40 \cdot 1}{0,96} = 41,7 \text{ kg} / m \quad (15)$$

$$L = 2 \cdot 80 + 2 \cdot 100 + 2 \cdot 3 + 2 \cdot 48 = 462 \text{ m} \quad (16)$$

$$L_T = L - (10 + 103 + 6 + 20) = 323 \text{ m} \quad (18)$$

$$F_u = f_{uk} (L \cdot q + L_T \cdot G_G) \cdot g + G_G \cdot g (H_2 - H_1) \quad (19)$$

$$F_u = 0,04 \cdot (462 \cdot 44 + 323 \cdot 41,7) \cdot g + 41,7 \cdot g \cdot 8 = 16,90 \text{ N} \quad (20)$$

$$P_E = \frac{F_u \cdot v}{\eta_u} = \frac{16,90 \cdot 0,15}{0,65} = 3,82 \text{ kW} \quad (21)$$

The minimum force is at point 1 or 3:

$$f \cdot L_{1/3} = 0,025 \cdot 55 = 1,37 \text{ m}, H_{1/3} = 8 \text{ m} \quad (22)$$

$$f \cdot L_{1/3} < H_{1/3} \Rightarrow F_{K3} = F_{K \min} \quad (23)$$

$$F_{K3} = F_{K \min} = 0,80 \text{ kN} \quad (24)$$

$$F_{K4} = F_{K3} + q \cdot g \cdot f \cdot L_{3/4}$$

$$F_{K4} = 0,80 + 44 \cdot g \cdot 0,025 \cdot 33 = 1,164 \text{ kN} \quad (25)$$

$$F_{K5} = F_{K4} + f_{WK} = 1,164 \cdot 1,03 = 1,20 \text{ kN} \quad (26)$$

$$F_{K6} = F_{K5} + q \cdot g \cdot f \cdot L_{5/6}$$

$$F_{K6} = 1,20 + 44 \cdot g \cdot 0,025 \cdot 3 = 1,233 \text{ kN} \quad (27)$$

$$F_{K7} = F_{K6} + f_{WK} = 1,233 \cdot 1,025 = 1,265 \text{ kN} \quad (28)$$

$$F_{K8} = F_{K7} + q \cdot g \cdot f \cdot L_{7/8}$$

$$F_{K8} = 1,265 + 44 \cdot g \cdot 0,025 \cdot 20 = 1,485 \text{ kN} \quad (29)$$

$$F_{K9} = F_{K8} + (q + G_G) \cdot g \cdot f \cdot L_{8/9}$$

$$F_{K9} = 1,485 + 85,7 \cdot g \cdot 0,025 \cdot 10 = 1,70 \text{ kN} \quad (30)$$

$$F_{K10} = [F_{K9} \cdot f_S + (q + G_G) \cdot g \cdot f \cdot L_{9/10} + (q + G_G) \cdot g \cdot H_{9/10}] \cdot f_S$$

$$\delta_{9/10} = 24^\circ \Rightarrow f_S = 1,015 \quad (31)$$

$$F_{K10} = [1,70 \cdot 1,015 + 85,7 \cdot g \cdot 0,025 \cdot 18 + 85,7 \cdot g \cdot 8] \cdot 1,015 = 9,11 \text{ kN} \quad (32)$$

$$F_{K11} = F_{K10} + (q + G_G) \cdot g \cdot f \cdot L_{10/11}$$

$$F_{K11} = 9,11 + 85,7 \cdot g \cdot 0,025 \cdot 32 = 9,80 \text{ kN} \quad (33)$$

$$F_{K12} = F_{K11} \cdot f_{WK} = 9,80 \cdot 1,025 = 10,05 \text{ kN} \quad (34)$$

$$F_{K13} = F_{K12} + (q + G_G) \cdot g \cdot f \cdot L_{12/13}$$

$$F_{K13} = 10,05 + 85,7 \cdot g \cdot 0,025 \cdot 50 = 11,125 \text{ kN} \quad (35)$$

$$F_{K14} = F_{K13} \cdot f_{WK} = 11,125 \cdot 1,025 = 11,40 \text{ kN} \quad (36)$$

$$F_{K15} = F_{K14} + (q + G_G) \cdot g \cdot f \cdot L_{14/15}$$

$$F_{K15} = 11,40 + 85,7 \cdot g \cdot 0,025 \cdot 48 = 12,43 \text{ kN} \quad (37)$$

$$F_{K16} = F_{K15} \cdot f_{WK}^3 = 12,43 \cdot 1,03^3 = 13,55 \text{ kN} \quad (38)$$

$$F_{K17} = F_{K16} + (q + G_G) \cdot g \cdot f \cdot L_{16/17}$$

$$F_{K17} = 13,55 + 85,7 \cdot g \cdot 0,025 \cdot 48 = 14,58 \text{ kN} \quad (39)$$

$$F_{K18} = F_{K17} \cdot f_{WK} = 14,58 \cdot 1,025 = 14,95 \text{ kN} \quad (40)$$

$$F_{K19} = F_{K18} + (q + G_G) \cdot g \cdot f \cdot L_{18/19}$$

$$F_{K19} = 14,95 + 85,7 \cdot g \cdot 0,025 \cdot 45 = 15,92 \text{ kN} \quad (41)$$

$$F_{K20} = F_{K19} \cdot f_{WK} = 15,92 \cdot 1,025 = 16,32 \text{ kN} \quad (42)$$

$$F_{K21} = F_{K20} + (q + G_G) \cdot g \cdot f \cdot L_{20/21}$$

$$F_{K21} = 16,32 + 85,7 \cdot g \cdot 0,025 \cdot 20 = 16,75 \text{ kN} \quad (43)$$

$$F_{K22} = [F_{K21} \cdot f_S + (q + G_G) \cdot g \cdot f \cdot L_{21/22} - (q + G_G) \cdot g \cdot H_{21/22}] \cdot f_S$$

$$\delta_{21/22} = 29^\circ \Rightarrow f_S = 1.020 \quad (44)$$

$$F_{K22} = [16,75 \cdot 1.02 + 85,7 \cdot g \cdot 0,025 \cdot 9 - 85,7 \cdot g \cdot 5] \cdot 1.02 = 13,24 \text{ kN} \quad (45)$$

$$F_{K23} = F_{K22} + (q + G_G) \cdot g \cdot f \cdot L_{22/23}$$

$$F_{K23} = 13,24 + 85,7 \cdot g \cdot 0,025 \cdot 23 = 13,73 \text{ kN} \quad (46)$$

$$F_{K24} = [F_{K23} \cdot f_S + (q + G_G) \cdot g \cdot f \cdot L_{23/24} - (q + G_G) \cdot g \cdot H_{23/24}] \cdot f_S$$

$$\delta_{23/24} = 32^\circ \Rightarrow f_S = 1.020 \quad (47)$$

$$F_{K24} = [13,73 \cdot 1.02 + 85,7 \cdot g \cdot 0,025 \cdot 8 + 85,7 \cdot g \cdot 5] \cdot 1.02 = 18,84 \text{ kN} \quad (48)$$

$$F_{K25} = F_{K24} + (q + G_G) \cdot g \cdot f \cdot L_{24/25}$$

$$F_{K25} = 18,84 + 85,7 \cdot g \cdot 0,025 \cdot 10 = 19,06 \text{ kN} \quad (48)$$

$$F_{K26} = F_{K25} + q \cdot g \cdot f \cdot L_{25/26}$$

$$F_{K26} = 19,06 + 44 \cdot g \cdot 0,025 \cdot 10 = 19,17 \text{ kN} \quad (50)$$

$$F_{K2} = \left(F_{K3} \cdot \frac{1}{f_S} - q \cdot g \cdot f \cdot L_{2/3} + q \cdot g \cdot H_{2/3} \right) \cdot \frac{1}{f_S}$$

$$\delta_{2/3} = 28^\circ \Rightarrow f_S = 1.020 \quad (51)$$

$$F_{K2} = \left(\frac{0,80}{1.02} - 44 \cdot g \cdot 0,025 \cdot 15 + 44 \cdot g \cdot 8 \right) \cdot \frac{1}{1.02} = 4,07 \text{ kN} \quad (52)$$

$$F_{K1} = F_{K2} - q \cdot g \cdot f \cdot L_{1/2}$$

$$F_{K1} = 4,07 - 44 \cdot g \cdot 0,025 \cdot 55 = 3,46 \text{ kN} \quad (53)$$

$$F_{WA} = 0,04 (F_{K1} + F_{K26}) = 0,04 (3,46 + 19,17) = 0,90 \text{ kN} \quad (54)$$

$$F_O = F_{K26} - F_{K1} + F_{WA} = 19,17 - 3,46 + 0,90 = 16,61 \text{ kN} \quad (55)$$

$$P_E = \frac{F_O \cdot v}{\eta_u} = \frac{16.61 \cdot 0.15}{0.65} = 3.76 \text{ kW} \quad (56)$$

- 5) The maximum drive load occurs when the upper take-up unit passes under load. In this case the upper take-up unit is from 23 to 24. Since almost maximum chain pull occurs here, the load will be set to 100% of the allowed value. Thus, according to equation [1], a required radius of curvature of $R = 5 \text{ m}$.

$$F_{L_{\max}} = G_E \cdot g + G_L \cdot g + F_{K24} \cdot \frac{t_R}{R}$$

$$F_{L_{\max}} = (5 + 15) \cdot g + 40 \cdot g + 18.84 \cdot \frac{0.48}{5} \approx 2.50 \text{ kN} \quad (57)$$

6) $F_P = F_{K4} + F_{K5} = 1.164 + 1.20 \approx 2.37 \text{ kN} \quad (58)$

4. CONCLUSION

This paper aims to illustrate the necessary calculations for overhead conveyor systems used for piece goods. In this case, the system is designed for metal housings. For the given conveyor parameters, the minimum distance between the carriers and the capacity were determined. The calculation of the traction force is performed by an approximate and exact method (the contour method). The difference between these forces is less than 2%, which means that the approximate method gave quite good results. Based on the results obtained, we can continue the further calculation of the conveyor and choose its elements.

REFERENCES

- [1] M. Gašić, "Transportni uređaji, neprekidni transport", Faculty of Mechanical Engineering Kraljevo, Kraljevo (Serbia), (2010)
- [2] L. Schlerholz, "Elektrohängebahn. System 624 / 634", TU Dortmund University Logistics Department, Louis Schierholz GmbH, (2014)
- [3] VDI 3643, "Elektrohängebahn; Anforderungsprofil an ein kompatibles System", VDI-Verlag, Düsseldorf, Germany, (1998)
- [4] M. Broggi, "Sonderheft Lagertechnik: Fahrerlos vom Lager bis in die Produktion", Fördermittel Journal, pp. 80-85, (1987)
- [5] D. Pfeifer, "Flexible Automatisierung im Automobilbau, Beispiel: Omega-Fertigung", Fachtagung Praxis der Fertigungsautomatisierung, Bad Soden, Germany, (1987)
- [6] D. Kappeler, "Sonderausgabe Fördertechnik: Die Endmontage ist nicht das Schlusslicht", Fördermittel Journal, pp. 48-53, (1990)
- [7] H. Fraissl, "Elektrohängebahn: Schneller als Power+Free", Materialfluss, pp. 42-44, (1985)
- [8] F. Eggenstein, "Elektrohängebahnen, Technik, und Entwicklung," Fördern und Heben, (1982)
- [9] H. Giessler, "Ein System wird zum Standard," Logistik im Unternehmen, (1987)
- [10] M. Kunzmann, "Ein konsequent wirtschaftliches Containertransportsystem", Transmatik 85. Kongress, Karlsruhe, Germany, (1985)
- [11] J. Schieleit, "Mobile Roboter in Elektrohängebahnsystemen", Verlag TÜV Rheinland, Köln, Germany, (1990)
- [12] J. Krug, "Automatiklager für fertigungsgerechte Flexibilität, -verketteter Materialfluß für Druckzylinder", Maschine und Werkzeug, pp. 28-34, (1989)
- [13] G. Uttscheid, "Elektrohängebahn", European Patent Office EP 0 567 122 A1, April 22, (1993)
- [14] G. Böttner, "Technische Berichte: Förderanlagen für die Automobilindustrie", Thyssen MAN, Neuhausen, Germany, (1986)
- [15] <https://www.iqsdirectory.com/articles/conveyors/overhead-conveyors.html>