Technical solution of the modern conveyor system

L Jakubovičová1, P Kopas1, M Vaško1, M Handrik1

1Department of Applied Mechanics, Faculty of Mechanical Engineering, University of Zilina, Univerzitná 8215/1, Zilina 010 26, Slovakia.

lenka.jakubovicova@fstroj.uniza.sk

Abstract. The modern conveyor system finds its place in industrial automation. It offers a full and diverse range of custom conveyor solutions and types. Aluminium profiles offer huge range of different sizes. Conveyors are useful to move materials and smooth transfer along the tracks. Therefore, this paper aimed to designed conveyor system using by aluminium profiles. The aim of the paper is to point out the issue of modularity of our designed conveyor system through design and technological parameters that directly affect its use for the needs of practice. They can be installed almost anywhere, and they transport loads of all shapes, sizes and weights.

1. Introduction

Belt conveyors play an important role in the industry. They are used to transport material from one process to another, and they are used in conjunction with various transportation and machine equipment. The role of belt conveyors is often overlooked, as they are normally a piece of equipment that never makes too much trouble and runs for a long time before breaking down. People have used the principles of belt conveyors for thousands of years. In the 20th century, their application became more widely applied. Design of belt conveyors has improved over the years and now belt conveyors are an inevitable part of modern industry and everyday life. Belt conveyors are commonly used in many industries, including the automotive, agricultural, computer, electronic, food and beverage processing, aerospace, pharmaceutical, chemical, print finishing and packaging industries.

Future development of belt conveyors will surely lead to their low operating noise and costs, reduced maintenance and added durability. In the future, conveyor belts will be lighter and thinner with a better strength/weight ratio thus saving energy. Special attention will be focused on high strength and low stretch characteristics, antistatic and abrasion resistance and general imperviousness to oils, greases and others chemicals. Conveyor belts in the future will be longitudinally very flexible and laterally adequately stiff [1].

The modular conveyor belt system is a new concept in material handling. The modular conveyor belt is developing very rapidly because of its advantages, some of which include: standardized units and dimensions, easy assembly and repair, and flexible arrangement and variety of use. It is becoming an inevitable part of automated production and assembly lines in many industry branches.

Realized project and its Finite element analysis was resented in an article [2]. The project was realized in cooperation with MTS comp. Ltd. (hereinafter referred to as MTS). Since its inception, MTS has been a contractual partner of the German concern Robert Bosch GmbH, later Bosch Rexroth AG and Schmidt Technology Gmbh for the Slovak Republic [3]. This partnership represents a significant step forward in terms of quality and quantity of the offered range. MTS was established in 1996 and its operation follows
the tradition of construction of single-purpose machines and equipment, which is typical for the area of Slovakia where the headquarters and operation of the company is located. The range of products manufactured by the company is mainly focused on the electrical and automotive industries. Part of the company is a strong and experienced team of mechanical and electrical designers, programmers and skilled assembly technicians [3].

In cooperation with MTS Ltd., a modern transfer system was developed. The company provided us with the necessary material for the implementation of the project and allowed us to incorporate into the project the elements they use in production. Company offer more than 140 Bosch Rexroth aluminium profiles divided into 6 structural framing series. All the profiles are compatible with each other and are simply assembled as a kit. This modular profile system is one of the largest in the world with more than 100 different types of profiles [3].

2. Construction of the conveyor system
A Bosch Rexroth aluminium profiles was used, which has become a worldwide standard in the production of transfer system and similar equipment such as: frames, jigs, protective walls, workbenches [6,7,8].

The supporting part of the transfer system frame structure is a modular system made of aluminium alloy with dimensions 40x80 mm (Fig.1), 45x45 mm (Fig.2) and 45x60 mm (Fig.2) with a stable 10 mm slot. This conveyor system will have to bear higher loads on both tracks, such as electric motors, pallets with material and ending transfer stations [13, 20].

![Figure 1. Aluminium profile section 40x80 mm.](image)

![Figure 2. 45x60 mm and 45x45 mm aluminium profile section.](image)
A more detailed description of the design of the conveyor belt can be found in the article [2]. Here you will find mentioned Transfer Station, (Fig.3, Fig.4), use additional profiles to ensure attachment of electrical switchgear from Rittal and other aluminium profiles.

**Figure 3.** Construction of the transfer station.  
**Figure 4.** Final version of the transfer station.

Final model of modern conveyor system is shown in Fig.5.

**Figure 5.** Transfer system model in Inventor.

3. **Electrical part**

The electrical part consists of several main parts:
- Electric switch cabinet
- Electric Motor
- Sensors
- Siemens S-1200 PLC control and Siemens SIMATIC HMI control panel
3.1. Electrical switchboard
All designed electrical components and switching devices must be incorporated into the electrical switchboard. The Rittal switchgear electric low-voltage switchgear with dimensions 600x600x210 mm and IP66 protection standard (Fig. 6) meets the requirements. This protection standard provides protection for humans in contact with the bare part of the body as well as by any means of contact, furthermore it provides us with complete protection against foreign objects entering the switchboard, thus it is completely dustproof and resistant to intense jet water.

The low-voltage switchgear consists of components such as the WDU 4 type terminal block; terminals type WDU 2,5; terminals type WDU 1,5 / ZZ; level clamp ZDK 2 from Weidmüller; AC pulse power supply from MEAN WELL, whose output values are 24V 0 ~ 1.7A with output 40 W; EATON type PL7-C16 / 3 three-phase circuit breaker with a rated current of 16A; two circuit breakers, also from EATON type PL7-C6 / 1; 6A single-phase circuit breaker protects the power supply and 10A circuit breaker PL7-C10 / 1; single-phase service socket; SIEMENS safety socket relay whose coil uses 24V AC voltage; PLC control from SIEMENS Simatic S7-1200 and extension module for SM 1223 DC / DC control; Scalance XB005 five port switch from SIEMENS; motor starters from Telemecanique type TeSys LUCA 1 XBL for smooth operation of conveyor electric motors; Schneider safety green warning light; 25 A main switch EATON type P1-25.

3.2. Electric motor
Two electric motors were used to drive the conveyor belts [20], an alternating asynchronous three-phase motor from Rexroth model 3,842,503,783 (Fig.7, Fig.9). The electric motor was connected to the star. Using this kind of electric motor connection, we achieved the following values: Power - 0.18 kW, Speed - 1590 rpm.

Since we use the TS2plus conveyor track system, we have chosen a gearbox from Rexroth type 3 842 527 868, whose values are: GS 14-1, i = 20.
3.3. Sensors
The conveyor system includes several types of sensors to detect the presence of a pallet, the condition of the air pressure in the pneumatic distributor, or the position of the pneumatic piston in the cylinder [12]. The Balluff inductive sensor type BES004N was used to detect the presence of the pallet in which the built-in metal parts are located. (Fig.9) This sensor was placed in special plastic sensor holders and attached to the conveyor frame or pneumatic stops (Fig.10).

The Rexroth type 0 830 100 435 magnetic sensor detects the position of the pneumatic cylinder piston. In the grooves of each pneumatic cylinder there are two pieces of a magnetic sensor. As the cylinder is made of aluminium, the sensors only sense the position of the piston, which is made of steel, and are designed to determine whether the piston is in the working position (extended) or in the basic position (retracted). The pressure sensor from Aventics model PE5 is the latest type of pressure sensor and is used to sense the pressure in the pneumatic conveyor system. If the pressure falls outside the set limit, the entire system will automatically fall for safety reasons.

3.4. Siemens S-1200 PLC control and Siemens SIMATIC HMI control panel
PLC is a device that serves to solve several complex tasks in automation. The SIEMENS PLC version SIMATIC S7-1200 was used (Fig.11) and was extended by Siemens SM 1223 DC / DC module (Fig.12). The basic control systems of these PLCs are the ideal solution for flexible and efficient automation tasks.
of our type. It features a wide range of technology features, integrated I (input) / O (output) interfaces, and saves space in the cabinet thanks to its compact design.

![Figure 11. PLC SIEMENS S7-1200.](image1)

![Figure 12. SM1223 DC / DC Expansion Module.](image2)

Controlling the entire conveyor belt serves the control panel from SIEMENS type SIMATIC HMI KTP700 Basic Color, which includes a seven-inch widescreen full-touch display with eight full-function buttons [19]. The control panel is fitted in a smaller type of electrical switchboard size 200x200x100 mm from Rittal. Along with the control panel, the switchgear also includes an Emergency Stop button (Central Stop), two OP voltage control buttons and a three-position key switch. Communication between all control units (PLC, OP) is provided by five slot switches from SIEMENS, type SCALANCE XB005.

### 4. Pneumatic mechanisms

These mechanisms use air to transmit energy. They may perform linear, rotary or oscillating movements. A pneumatic cylinder from Rexroth type MNR: 0822063039 was used to move the pallet along the transfer plate. It is a double-acting pneumatic cylinder with sliding guide. The construction consists of a piston rod, piston and guide rods with a flange. The guide rod serves as a lock against rotation. The body of the pneumatic cylinder is composed of anodized aluminium alloy. The sliding plate is made of stainless steel. In the case of piston and guide rods, stainless steel is used. The parameters of the pneumatic cylinder are given in Table 1.

| Parameter          | Value          |
|--------------------|----------------|
| Manufactured by    | Rexroth        |
| Device Type code   | 0822063039     |
| Piston diameter    | 25 mm          |
| Process temperature| -10 ... 70 °C  |
| Operating pressure | 1.5...8 bar    |
| Weight             | 2900 g         |

Table 1. Parameters of Rexroth pneumatic cylinder type 0822063039.

Pneumatic stop by Rexroth model VE2, serves to stop one or more pallets. When pressure is released, the gate is closed by a spring and the workpiece pallet is stopped. The pneumatic stop can hold loads up to 200 kg. The stops are mounted inside the conveyor tracks, a number of six pieces and attached to them by a sensor holder.
4.1. **Pneumatic valve terminal and pneumatic air treatment**
Control of the entire pneumatic part is provided by pneumatic air treatment, which consists of the main valve, filter, pressure gauge (barometer), condensate drain-automatic, coil and digital pressure sensor (Fig. 13). Next to it there is a pneumatic valve terminal, which consists of solenoid valves, which are connected to form a block of a valve system with a common power supply and a controller, this connection is called a valve terminal (Fig. 14). The terminal is controlled by the MULTISIM connector, which is connected to the input slots of the PLC control.

![Figure 13. Pneumatic valve terminal.](image)

![Figure 14. Pneumatic air treatment.](image)

5. **Programming of PLC and HMI panel**
To program all functions of the conveyor belt, Siemens Totally Integrated Automation Portal (TIA Portal) software was used provided by MTS Ltd. in full version with appropriate licenses. Most of the time was devoted to programming. The program contains over 2000 lines of commands and conditions. The final result was programmed by the PLC together with the Touch Panel, in which a graphical environment was created for the touch control of the conveyor (Fig. 15).

![Figure 15. HMI panel graphical environment.](image)

6. **Static Analysis**
The maximum deformation value is 0.69 mm on the end of the free hanging part of the transfer system, which is not under the load and the bending moment is equal to zero. Therefore, it is not necessary to put so much emphasis on evaluating the deformation of the transfer system, but it is more important to focus on the analysis of the bending moment, Fig. 16 [4,5,9].
The maximum bending moment value is read from Fig. 16, \( M_0 = 179.92 \text{ N.m} \). The bending modulus of section \( W_o = 15.9 \text{ cm}^3 = 0.0000159 \text{ m}^3 \) is given by the manufacturer for the 45x80 mm profile from Bosh Rexroth [6].

\[
\sigma_{OMAX} = \frac{M_0}{W_0} = \frac{179.92 \text{ [N.m]}}{0.0000159 \text{ [m}^3\text{]}} = 11.315 \text{ MPa}
\]

The maximum value of bending moment at the most loaded track of profile is \( \sigma_{OMAX} = 11.315 \text{ MPa} \). The maximum permissible bending moment given by the manufacturer is \( \sigma = 200 \text{ N.mm}^{-2} \). (Aluminium Framing Bosh Rexroth 2011)

The safety rate of the designed structure \( k = \frac{200 \text{Mpa}}{11.315 \text{ MPa}} = 17.67 \). In common practice, the safety level is used for this type of construction equipment \( k=1.5 \) to \( 2 \), \( \Rightarrow \) the design meets all safety requirements [17,18].

7. Eigenvalue Buckling

Eigenvalue Buckling analysis is used to identify the maximum load that can cause loss of stability and damage the analyzed structure [10,11]. In practical terms, the loss of stability for the first condition is most likely to occur. The load applied to the transfer system frame would have to increase 73 times, Fig. 17. The individual load factor values for loss of stability are shown in Fig. 18 [14,15,16].
8. Conclusion

Modular conveyor was set up from Bosh Rexroth aluminium profiles, Fig. 19 [6,7]. Material is moving by two tracks propelling by electric motors. Control unit with inductive and magnetic sensors managing complete functionality and correct transport of material. As interface between human and control is used touch display and switchboard. The conveyor was designed in Inventor CAD system. For the FEM (finite element analysis) was used Ansys. The conveyor frame was simplified by Lines-Bodies. Then different aluminium types of different aluminium profiles were connected to the individual lines. The different aluminium profiles were prepared in the Cross-Section program. For model compatibility control was used modal analysis. By sensitivity analysis was set up finale mesh density of 0.01 m. With static analysis were find out critical points [19,20] of the conveyor frame. And for stability of the conveyor frame was used Eigenvalue Bucking analysis, [19]. Based on finale results were was identified bending stress in critical points max 11 MPa what mean safety level $k=17$ and find out that the stability of the frame would be lost with higher load than 73 times was conclude the conveyor system as robust save and fully functional.

The analyzed conveyor with aluminium profiles is an example for students of technical and vocational schools how to easily and practically to design and create a fully functional conveyor with electrics, pneumatic and control parts.

The result of the research activity was the design and construction of a fully functional modular conveyor. The use of such designed conveyor systems will ensure their optimal use in technical practice.
for small and large manufacturing companies. The information obtained is therefore directly applicable to the electrical and automotive industries [21].

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9. References
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