The Modern Conveyor System and its Construction

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Abstract. Rexroth systems are the right solution to move materials and it ensures a smooth transfer of material along the tracks Modern conveyor system is often used in industrial automatization. Presented system offers a full and diverse range of custom conveyor types and solutions. Designed conveyor system is an example of the use of aluminum profiles for students of secondary industrial school as a teaching tool.

1 Introduction

Realized project and its Finite Element Analysis was resented in an article [1]. 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 [2]. 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 [2].
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, Fig. 1. 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 [2].

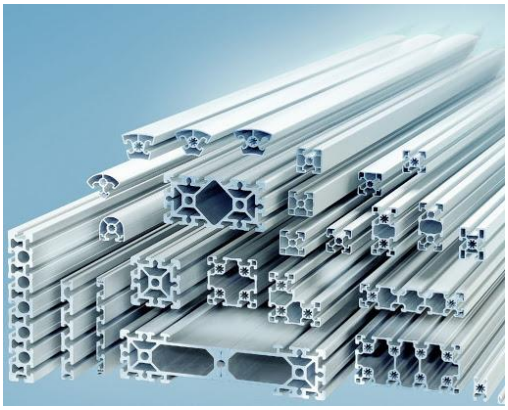

Fig. 1. Parts of MTS Ltd. product range [2].

2 Construction of the conveyor system

A Bosch Rexroth aluminum 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 [5,6,7].
The supporting part of the transfer system frame structure is a modular system made of aluminum alloy with dimensions 40x80 mm (see Fig. 2), 45x45 mm and 45x60 mm (see Fig. 3) 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 [11,12].

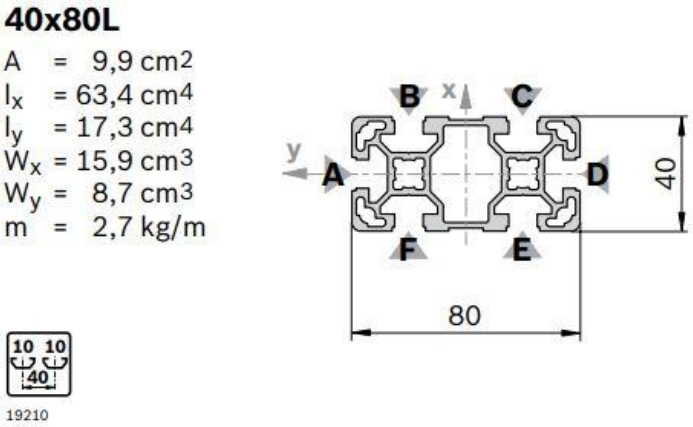

Fig. 2. Aluminum profile section 40x80 mm.

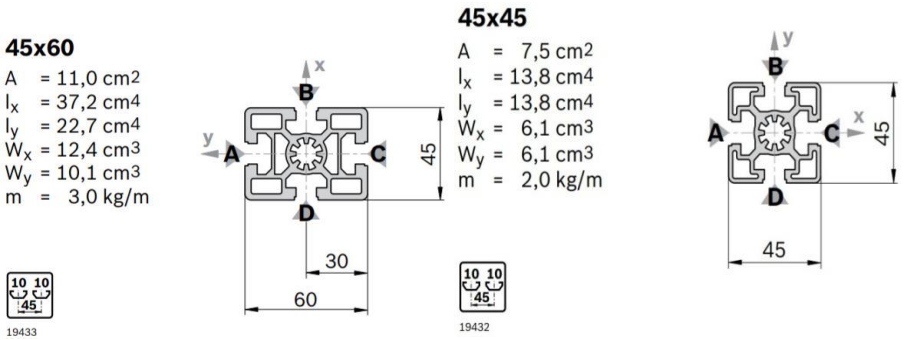

Fig. 3. 45x60 mm and 45x45 mm aluminum profile section.

A more detailed description of the design of the conveyor belt can be found in the article [1]. Here you will find mentioned Transfer Station, (see Fig. 4), use additional profiles to ensure attachment of electrical switchgear from Rittal and other aluminum profiles. Final model of modern conveyor system is shown in Fig.5.

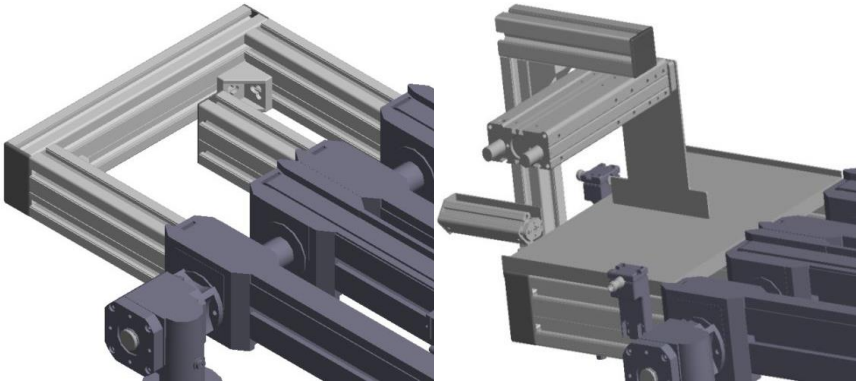

Fig. 4. Construction of the transfer station and final version of the transfer station.

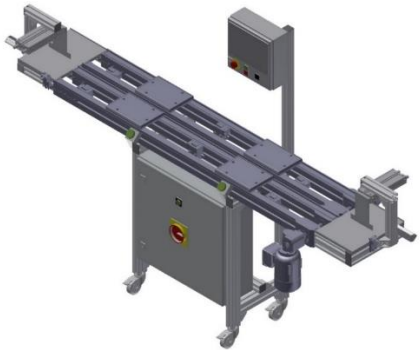

Fig. 5. Transfer system model in Inventor.

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 (see 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.

Fig. 6. Final cabinet design.

3.2 Electric motor

Two electric motors were used to drive the conveyor belts [19], an alternating asynchronous three-phase motor from Rexroth model 3,842,503,783 (see Fig. 7). 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.

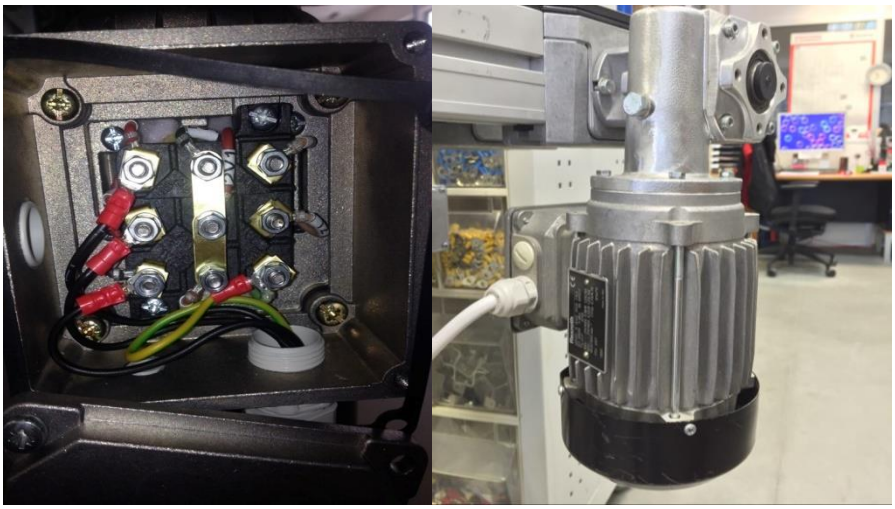

Fig. 7. Connecting the electric motor to the star and Electric motor with gearbox.

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.
The Balluff inductive sensor type BES004N was used to detect the presence of the pallet in which the built-in metal parts are located (see Fig. 8) This sensor was placed in special plastic sensor holders and attached to the conveyor frame or pneumatic stops (see Fig. 8).

Fig. 8. Balluff sensor BES004N (Balluff.com) and Sensor located in bracket.

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 aluminum, 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 down 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 and was extended by Siemens SM 1223 DC / DC module (see Fig. 9). 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.

Fig. 9. PLC SIEMENS S7-1200 and SM1223 DC / DC Expansion Module.

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 [18].
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 aluminum 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 following Table 1.

Table 1. Parameters of Rexroth pneumatic cylinder type 0822063039.

Parameter	Value
Manufactured by	Rexroth
Device Type code	0822063039
Piston diameter	25 mm
Table 2. Process temperature t	-10 ... 70 °C
Operating pressure	1,5....8 bar
Weight	2900 g

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 (see Fig. 10). 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 (see Fig. 10). The terminal is controlled by the MULTISIM connector, which is connected to the input slots of the PLC control.

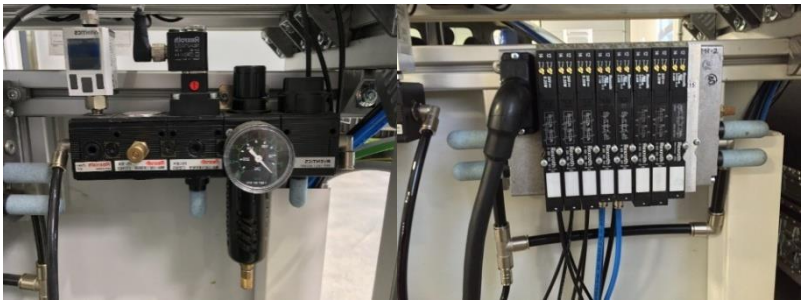

Fig. 10. Pneumatic valve terminal and Pneumatic air treatment.

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 (see Fig. 11).

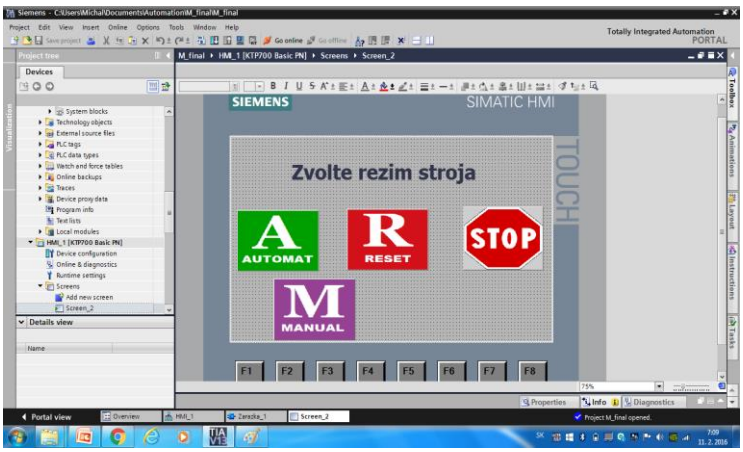

Fig. 11. HMI panel graphical environment.

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 (see Fig. 12) [3,4,8].

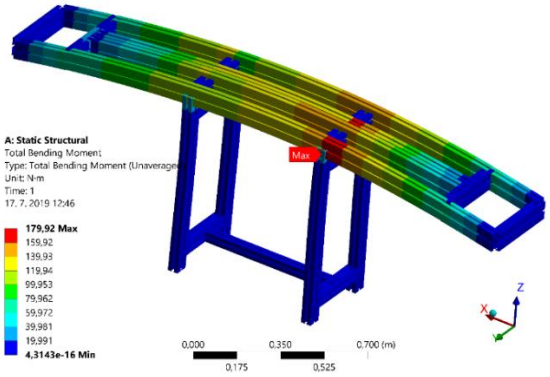

Fig. 12. Total Bending Moment.

The maximum bending moment value is read from figure 10, M_o = 179.92 N·m. The bending modulus of section Wo =15.9 cm^3 = 0.0000159 m^3 is given by the manufacturer for the 45x80 mm profile from Bosh Rexroth [5].

$$\sigma_{OMAX} = \frac{M_o}{W_o} = \frac{179.92\ [\text{N.m}]}{0.0000159\ [\text{m}^3]} = 11.315\ MPa \qquad (1)$$

The maximum value of bending moment at the most loaded track of profile is σ_{oMAX} = 11.315 MPa. The maximum permissible bending moment given by the manufacturer is σ = 200 $N.mm^{-2}$. (Aluminum Framing Bosh Rexroth 2011).

The safety rate of the designed structure k = 200MPa/11.315 MPa=17.67. In common practice, the safety level is used for this type of construction equipment k=1,5 to 2, ⇒the design meets all safety requirements [16,17].

7 Eigenvalue Buckling

Eigenvalue Buckling analysis is used to identify the maximum load that can cause loss of stability and damage the analyzed structure [9,10]. 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. The individual load factor values for loss of stability are shown in Fig. 11 [13,14,15].

8 Conclusion

Modular conveyor was set up from Bosh Rexroth aluminum profiles (see Fig. 13) [5,6]. 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 aluminum types of different aluminum profiles where connected to the individual lines. The different aluminum 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 [11,18,19] of the conveyor frame. And for stability of the conveyor frame was used Eigenvalue Bucking analysis [18].
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 aluminum 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.

Fig. 13. Transfer System.

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Acknowledgments

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References

1. L. Jakubovičová, P. Kopas, M. Handrik, M. Vaško, R. Grega, P. Šulka Construction design and structural analyse of transfer system. IOP Conference Series: Materials Science and Engineering, 776, 1, 012032 (2020).
2. MTS modern technology systems, https://www.mts.sk/.
3. T. Tomaszewski, J. Sempruch Fatigue life prediction of aluminium profiles for mechanical engineering, Journal of Theoretical and Applied Mechanics, 55, 2, 497-507 (2017).
4. R.B. Mei, L. Bao, C.S. Li, J.K. Wang, X.H. Liu FE analysis of 6063 aluminium profiles with complex cross-section during online quenching processes. Mechanika, 2, 99-106 (2015).
5. Bosh Rexroth AG 2014 Transfer system TS2plus, Version 6.0.
6. Siemens 2019 Aventics 2019, https:www.aventics.com/de/.
7. Autodesk 2019, https:autodesk.com.
8. Y. Turygin, P. Božek, I.V. Abramov, Y.R. Nikitin Reliability determination and diagnostics of a mechatronic system. Adv. in Sci. and Technol. Research J., 12, 2, 274-90 (2018).
9. M. Macko, A. Mrozinski, A. Prentki Simulations CAE of wood pellet machine. In: Matec Web of Conferences, 254, 02028 (2019).
10. M. Macko, A. Mroziński Computer Aided Design of Wood Pellet Machines. In: Rusiński E., Pietrusiak D. (eds) Proceedings of the 14th International Scientific Conference: Computer Aided Engineering. CAE 2018. Lecture Notes in Mechanical Engineering. Springer, Cham (2019).
11. R. Grega, J. Krajňák, P. Baran The Reduction Of Vibrations In A Car - The Principle Of Pneumatic Dual Mass Flywheel. Zeszyty Naukowe Politechniki Śląskiej, 84 (2014).
12. T. Skrúcaný, F. Synák, M. Kendra, S. Milojević Air conditioning and selected vehicle characterictics. In: Applied Engineering Letters, 5, 1, 8-15 (2020).
13. R. Grega, J. Krajnak, L. Zulova, G. Fedorko, V. Molnar Failure analysis of driveshaft of truck body caused by vibrations. Engineering Failure Analysis, 79, 208-215 (2017).
14. P. Kassay, J. Homisin, M. Urbansky, R. Grega Transient torsional analysis of a belt conveyor drive with pneumatic flexible shaft coupling. Acta Mechanica et Automatica, 11, 1, 69-72 (2017).
15. W. Piekarska, Kubiak, Žmindák Issues in numerical modeling of phase transformations in welded joint. Procedia Engineering, 177, 141-48 (2017).
16. M. Saga, M. Dudinsky, P. Pechac Implementation of discrete fully stressing into structural optimization. In: Scientific journal of Silesian University of Technology – Series Transport, 76, 105-12 (2012).
17. A. Sapietová, V. Dekýš, M. Sapieta, P. Pecháč Application of computational and design approaches to improve carrier stability. Procedia Eng., 96, 410-418 (2014).

18. J. Homisin, R. Grega, P. Kassay, G. Fedorko, V. Molnar Removal of systematic failure of belt conveyor drive by reducing vibrations, In: Engineering Failure Analysis, 99, 192-202 (2019).
19. G. Domek, A. Kołodziej, M. Dudziak, T. Wozniak Identification of the quality of timing belt pulleys. Proc. Engineering, 177, 275-280 (2017).