Construction design and structural analyse of transfer system

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Abstract. Modern transfer system device is used in industrial automatization and it ensures a smooth transfer of material along the tracks. The transfer system model was created in CAD system. Finite-element and modal analysis was created in Ansys Workbench software. The system consists of aluminium profiles from Bosh Rexroth firm, and it contains electric, pneumatic and control elements.

1. Introduction

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. 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 (figure 1). Part of the company is a strong and experienced team of mechanical and electrical designers, programmers and skilled assembly technicians [1].

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.

Figure 1. Part of MTS Ltd. product range [1].
2. Construction of the transfer system

A modular aluminum profile system from Bosh Rexroth was used, which has become a worldwide standard in the production of transfer system and similar equipment such as: frames, jigs, protective walls, workbenches [2–4]. This modular profile system is one of the largest in the world with more than 100 different types of profiles [5]. Aluminum profiles are further subdivided according to the slots. Here are three types of slots that slot width is 5.5 mm, 7.3 mm or 10 mm and the tensile force in the slot is from 3 000 N to 17 000 N. With such a large range of strength aluminum profiles, we can create different types of products such as lightweight covers, racks, frames, or heavy-duty workbenches and equipment [6, 7].

2.1. Transfer system frame

The supporting part of the transfer system frame structure is a modular system from Bosh Rexroth made of aluminum alloy with dimensions 45×45 mm (figure 2), 45×60 mm (figure 2) and 40×80 mm (figure 3) with a stable 10 mm slot. This is a transfer system that will have to bear higher loads on both tracks, such as electric motors, pallets with material and ending transfer stations [8, 9].

![Figure 2. 45×60 mm and 45×45 mm aluminum profile section.](image)

![Figure 3. Aluminum profile section 40×80 mm.](image)

When assembling the structure, it was necessary to secure the electrical switchboard of the dimensions 600×600 mm from Rittal, which is located between the supporting components of the transfer system in the frame of the transfer system. This fixation was provided by two profiles of 45×45 mm type with a stable slot width 10 mm, which are fastened by supporting struts between the supporting structure of the transfer system. These two profiles serve as reinforcement elements of the whole structure and help overall stability and load-bearing capacity of the frame construction.
The best option from the economic and practical point of view was to create an additional construction using aluminum profiles of 40×80 mm (figure 4).
Transfer surface consists of a sheet of dimensions 250×360×5 mm of PVC material, because of its excellent resistance to chemicals, wear, low resistance to pallet transfer and its low weight. The supporting frame made of 45×45 mm type profiles serves as a holder for pneumatic cylinders (figure 5).

**Figure 4.** Construction of the transfer station.  
**Figure 5.** Final version of the transfer station.

### 3. Construction design of modern transfer system in CAD system

For the design of the transfer system we decided to use Inventor software, which is computer software (CAD) developed by Autodesk. It uses the concept of parametric design, which is mainly used to create technical drawings for mechanical purposes. It is found in many areas such as automotive, architecture, construction, etc. Autodesk was created in 1982 by John Walker with 12 partners. It publishes several software packages including AutoCAD, 3ds Max and Alias [4].

We obtained all models of used components from manufacturers, especially from Bosh Rexroth. Model is shown in figure 6.

**Figure 6.** Transfer system model in Inventor.

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. Construction of transfer system model and profiles in ANSYS program
The simple construction of the transfer system consists of profiles of various dimensions (figure 1). The entire structure was created in the Ansys Workbench using Line Bodies (figure 7). Each line has been assigned a corresponding profile type using the Cross Section. It is necessary to pay attention to the orientation of individual profiles.

Figure 7. Transfer system frame in Ansys.

3.2. Boundary conditions, load and material
The transfer system is firmly anchored to the floor of the workplace (figure 8), displacement in direction X, Y, Z is equal to null (4× point A). In point B, D the electric motors act with their weight \( m = 15 \) kg. Electronical distributor weight is setup in C. Palette weight together with Transfer support weight is setup in G, H.

The material properties of the aluminum profiles given by the manufacturer precisely define the characteristics of the profiles and the permissible values of the different loads (table 1).

Table 1. Aluminum alloy material constants.

| Parameter                     | Values          |
|-------------------------------|-----------------|
| Density                       | 2770 (kg m\(^{-3}\)) |
| Tensile yield strength        | 710 000 (MPa)   |
| Compressive yield strength    | 280 (MPa)       |
| Tensile ultimate strength     | 310 (MPa)       |

Figure 8. Boundary conditions.
3.3. Static Analysis

Figure 9 shows the total deformation of the transfer system. The maximum deformation value is 0.69 mm. It is 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 (figure 10) [10].

![Figure 9. Total deformation of transfer system.](image)

![Figure 10. Total bending moment.](image)

The maximum bending moment value is read from figure 10, \( M_0 = 179.92 \text{ N.m} \). The bending modulus of section \( W_0 = 15.9 \text{ cm}^3 = 0.0000159 \text{ m}^3 \) is given by the manufacturer for the 45×80 mm profile from Bosh Rexroth [2]:

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

(1)

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 \( \sigma = 200 \text{ N mm}^{-2} \) (Aluminum Framing Bosh Rexroth 2011).

The safety rate of the designed structure \( k = 200 \text{ MPa} / 11.315 \text{ MPa} = 17.67 \). 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 [11, 12].

3.4. Eigenvalue Buckling

Eigenvalue Buckling analysis is used to identify the maximum load that can cause loss of stability and damage the analyzed structure [13, 14]. 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 (figure 12). The individual load factor values for loss of stability are shown in figure 11 [15–18].

![Figure 11. Load multiple values of eigenvalue buckling analysis for loss of stability.](image)
4. Conclusion

The modern transfer system was constructed using Bosh Rexroth aluminium profiles – figure 13 [2, 3]. Material transport is provided by two transfer tracks, which are driven by electric motors. The main control unit ensuring correct operation of the transfer system is an electrical switchboard. Operation of this control unit is provided by a fully touch control panel with appropriate control switches. The presence of the pallet in the working positions is ensured by inductive sensors. The position of the pneumatic pistons is evaluated by magnetic sensors. Pneumatic cylinders ensure the pallet passes smoothly across the plate of the transfer station. Pneumatic stops stop the pallet in the working position. The transfer system model was designed in Inventor CAD system. Ansys Workbench was used for the finite element analysis, and a simplified frame construction of the transfer system using Lines-Bodies was created. Subsequently, the types of aluminum profiles with different cross-sectional characteristics are assigned to the individual construction lines. The cross-section of the profiles was created in the Cross-Section program environment. Modal analysis was used to check model compatibility. Enough mesh density of 0.01 m was determined by sensitivity analysis. The critical points of the transfer system frame have been identified by static analysis [19–21]. Eigenvalue Buckling analysis was used to control the loss of stability [22].

The maximum bending stress at the connection point of the transfer system tracks with the conveyor structure is $\sigma_{\text{MAX}} = 11.315$ MPa, which fulfills the safety level $k = 17.67$. In the case of $73\times$ higher load, the stability of the frame would be lost [23, 24].

Designed and constructed unique modern transfer system is fully functional. All modules used are fully functional. The load-bearing capacity and robustness of the aluminum profiles used are sufficient and the frame of the structure will not be damaged or damaged under the given operating conditions.
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