Article citation info:
Dzieniszewski G., Rak Ad., Kuboń M., Kowalczyk Z. 2023. Application of CAD Systems in Designing Material Handling Equipment. *Journal of Research and Applications in Agricultural Engineering* 68 (1): 19–24. https://doi.org/10.53502/FMSE4272

Łukasiewicz
Poznań
Institute of
Technology

Journal of Research and Applications in Agricultural Engineering

Journal website: https://tech-rol.eu/

Application of CAD Systems in Designing Material Handling Equipment

Grzegorz Dzieniszewski [a,b] * (https://orcid.org/0000-0002-2712-1131)
Adrian Rak [b]
Maciej Kuboń [a,c] (https://orcid.org/0000-0003-4847-8743)
Zbigniew Kowalczyk [c] (https://orcid.org/0000-0001-8001-2092)

[a] Department of Technical Sciences and Design, State Academy of Applied Sciences in Przemyśl, Poland
[b] Department of Mechanics and Technology, Rzeszów Technical University, Poland
[c] Department of Production and Power Engineering, University of Agriculture in Krakow, Poland

Article info
Received: 06 May 2023
Accepted: 04 September 2023
Published online: 06 September 2023

Keywords
mechanical technology
material handling equipment
CAD systems

The possibilities of CAD system and FEM application in the process of designing material handling equipment were presented. The key importance of the computer systems that aid the engineering work in integrated design and production was indicated. The economic, time and technical advantages resulting from the replacement of empirical and strength tests with those conducted in the form of computer simulations were demonstrated. The usefulness of CAD and FEM systems in designing material handling equipment was confirmed.

DOI: https://doi.org/10.53502/FMSE4272

1. Introduction

Proper control of the roller conveyor helps to increase the efficiency of internal transport processes. The use of the finite element method enables the number of empirical tests to be limited. However, it may have some limitations in the case of load-bearing systems subjected to variable forces. A roller conveyor with an innovative solution of intelligent drive rollers is such a case. The application of CAD and FEM systems in the process of designing material handling equipment is a standard in many fields of technology where load states of structures are known and established. In the case of material handling equipment, the risk of temporary overloading of the load-bearing system caused by the concentration of load units or overloading with load units that are excessively heavy should be taken into account. The use of Inventor software is an Autodesk product and belongs to mid-range CAD/CAE systems. Due to the popularity of this software in medium-sized enterprises, the application of this software in this work and assessment of the usefulness of the Inventor package in the structural analysis of material handling equipment was justified.

In recent years during production in enterprises, an increasing degree of mechanization and automation of production processes can be observed. This is increasingly more often related to the replacement of people and traditional machines with new structural solutions [1]. Devices used to transport finished products and materials used during production are progressively more often replaced by devices that are

* Corresponding author: maciej.kubon@urk.edu.pl

more efficient, safer and more economic. Transport devices considerably influence the quality of production processes and ensure a high level of protection of the transported objects [2, 3]. It is thanks to these devices that internal logistics has developed significantly. The proper design and selection of suitable transporters directly influence the production time and lead times. Internal transport based on conveyors is used in all production-oriented industries [4, 5, 6]. Thanks to the development of a modern industry focused on robotics and automation, the interest in transport based on conveyors is growing to a large extent. Transport devices of this type work continuously, which is undoubtedly is their great advantage. [7,8,9]. Conveyor-based transport routes are relatively easy to design since any number of modifications to such transport exists. A modern roller conveyor consists of modules, which enable any shaping of the transport route of objects [10, 11, 12]. It is thanks to the various conveyor modules that horizontal and vertical transport, the transport of materials along curves or the creation of transport gates for other types of transport is possible. Roller conveyors may serve as transport between a production hall and warehouse, and may take a direct part in the production process, which influences the work efficiency and limits costs related to the employment of people for transport. Moreover, modern roller conveyors have the ability to integrate and communicate with other production equipment in the enterprise.

The aim of the paper is to verify the effectiveness of numerical methods in the process of designing material handling equipment. The applied Ansys environment enables calculations of complex structures. However, the quality and consistency of the model subjected to simulations are conditions for obtaining the proper accuracy of calculations.

2. Methodology of work

The methodology of the study is based on determining the weight and dimensions of the transported material, designing the conveyor frame, selecting the roller drive, and creating a program that controls the operation of the conveyor. The scope of considerations includes the design of the conveyor frame structure using FEM analysis, selection of the electric motor that drives particular conveyor sections and selection of the transmission that serves as the roller driver. The program and electrical documentation of the PLC were also prepared. The conveyor is controlled by means of the PLC. Thanks to this solution, only the sections of the conveyor where the transported object is placed are activated. When no object is placed on the conveyor, the controller turns off individual conveyor sections. The last practical element of the operation was the preparation of structural and electric documentation of the proposed solution for in-house transport.

The design assumes that the designed roller conveyor is a modular structure, which enables the route of transporting objects horizontally to any distance to be shaped. It was assumed that the distance of transporting objects depends on the number of conveyor modules. The length of a single conveyor module is 2244 m, whereas the width of a single module is 850 mm, and the height is 900 mm. Figure 1 presents a single conveyor module.

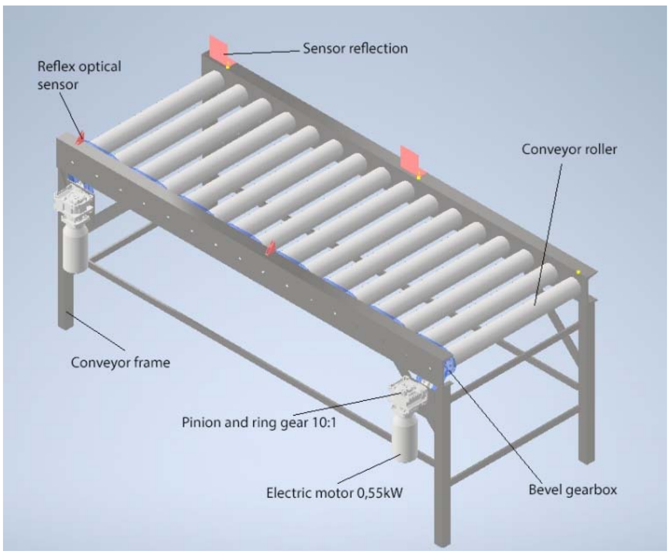

Fig. 1. Construction of section of roller conveyor

Source: Author's own work

The designed roller conveyor serves to transport various types of objects during their production, storage or for other applications. The calculations were made for the most unfavourable situation, namely the transport of steel plates with maximum dimensions of 600x800x100 mm. The conveyor consists of modules, each module consists of two separate sections. Each section is equipped with 8 rollers with a diameter of 80 mm and length of 736 mm. The drive is performed with an electric motor with the power of 0.55 kW co-operating with a gear box, the so-called geared motor, which is connected to one conveyor roller by means of a roller chain. The roller driven by the electric engine is connected to the next roller of the conveyor using a chain transmission. The chainwheels mounted on the rollers have 12 tines and a diameter equal to 98.1 mm. The wheel spacing is 132 mm. The speed of the transported element is 0.5 $\frac{m}{s}$ and acceleration 0.5 $\frac{m}{s^2}$. A reflex sensor was used to excite the motor's power supply, which, thanks to the use of PLC enables the rollers to be switched on, on which the element is located. After transporting the element, some of the rollers with no element are automatically turned off. Control of the conveyor takes place thanks to the PLC installed in the control cabinet. The controller program is responsible for correct turning on and off the of the conveyor and switching on particular parts of the conveyor. The conveyor is turned on with a bistable start/stop button. The conveyor may also be turned off at any time by pressing the emergency stop power button. The conveyor may also be turned off at any time by pressing the emergency stop power button. Figure 2 presents a set of 5 conveyor modules.

Fig. 2. Set of five conveyor modules
Source: Author's own work

The conveyor frame is a welded structure made of steel profiles. To ensure adequate strength of the connection, fillet welds were used. The horizontal profiles are C-shaped, to which conveyor rollers were mounted. The C-shaped steel profiles were used in the structure since they have a sufficiently wide flat surface thanks to which, reflex optical sensors and co-operating light reflectors can be mounted without any obstacles . Thanks to the use of horizontal profiles, the so-called C-sections, a cover for the roller chain and cooperating chainwheels was made. The vertical profiles are ones with a square cross-section. Flat bars are responsible for stiffness of the structure. The profiles used to build the conveyor frame were built of hot-rolled structural steel S235.

Figure 3 presents the drive system of a single module. Each conveyor module consists of two sections driven with 0.55 kW electric motors cooperating with the geared motor, which is connected to one of the conveyor rollers with a pin chain. The first roller is connected to the motor; it drives the second roller and that one drives the next one. Each section of the conveyor is connected on this principle. A 16B roller chain with a scale equal to 25.4 mm is responsible for the drive of individual rollers.

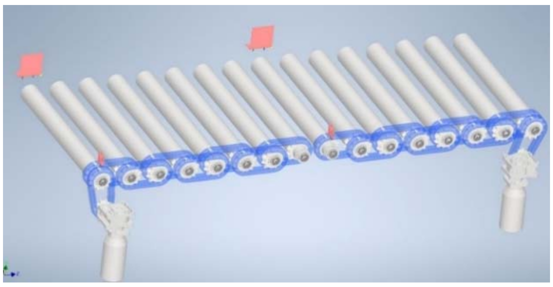

Fig. 3. View of conveyor drive system
Source: Author's own work

3. Results and discussion

The obtained results of the strength analysis enable optimization of the structure. In the first phase of the simulation, the load and material limiting stress ratios that are threshold values were obtained. Due to the complex nature of the conveyor loads, it was decided to strengthen the structure by using larger cross-sections of load-bearing elements. It was also justified by the dynamic loads on the rollers and the real risk of overloading the device during its exploitation. Recalculations of FEM carried out for the optimised structure showed a correct safety coefficient and enabled the structure to be considered as optimal for the assumed operating conditions.

The design of the conveyor included determination of the initial assumptions and the type of transported elements. The calculations are presented for the most unfavourable situation, namely the heaviest elements which can be transported by the conveyor, i.e. steel plates [13, 14,1 5]. Calculations were performed that enabled selection of the motor to drive the part of the conveyor. Bevel gears were selected, and chain gear calculations were made. Axle bearings, thanks to which the conveyor rollers may rotate, were selected and the minimum diameter of the screw core was selected to secure the roller in the conveyor frame.

FEM strength analysis was carried out in the Autodesk Inventor 2023 program. The CAD/CAE environment is an Autodesk product and belongs to the mid-range software group. The capabilities and application of the software position Inventor below the NX system by Siemens. Because of its price competitiveness and extensive support for academic centres, Inventor software is particularly popular in medium-sized construction centres and production enterprises. The software ensures sufficient structural modelling and analysis options as demonstrated in this paper.

The FEM analysis was based on the force of gravity of the heaviest transported object, i.e. steel plates with the dimensions 600x 800x100 mm. In the FEM calculations, the presence of two steel plates in one conveyor section was assumed. In order to conduct the analysis, the weight of the transported plates was calculated, then the centres of gravity of the plates were determined. The forces from the centre of gravity of the transported material were applied to the conveyor frame.

The method of distribution of the forces of gravity coming from the steel plates is presented in Figure 4.

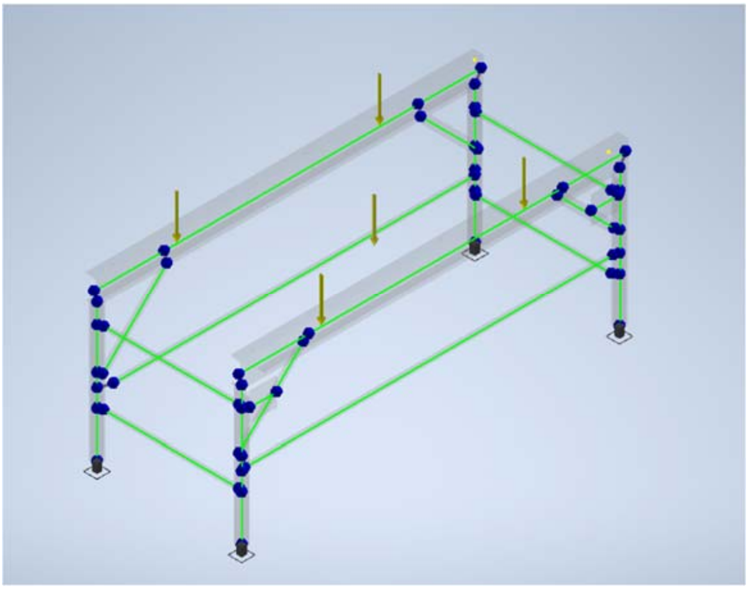

Fig. 4. Distribution of forces of gravity of transported element.
Source: Author's own work

As a result of the FEM strength analysis, a displacement of 0.2509 mm from the drive side was obtained. Deflection of the beams is not equal on both sides of the conveyor since from the drive side, undercuts were made in the conveyor profile in order to mount the drive system and use the drive chain of the conveyor rollers.

Figure 5 presents the deflection arrow of the conveyor beams.

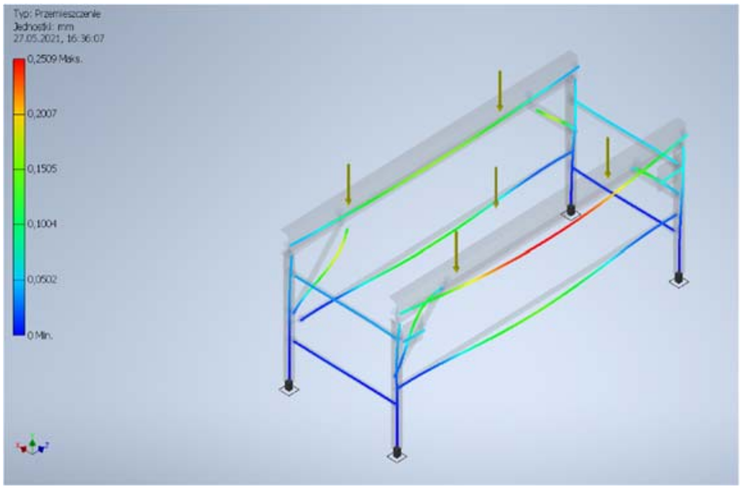

Fig. 5. Displacement (deflection arrow) of loaded beams
Source: Author's own work

Moreover, during the FEM analysis, simulation of the stress distribution was performed, which is presented in Figure 6.

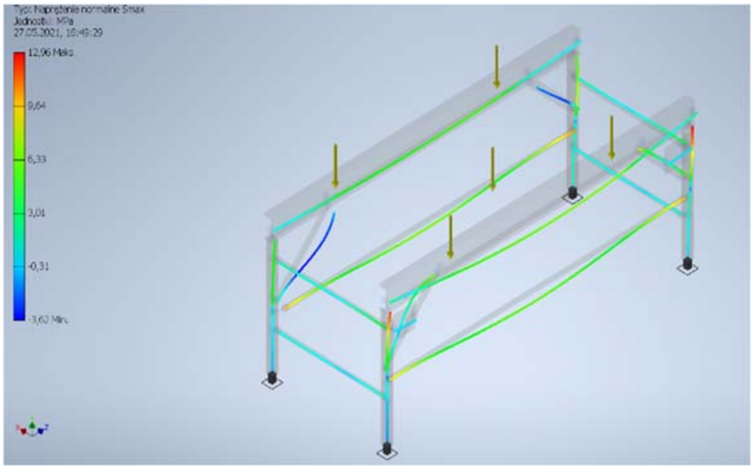

Fig. 6. Distribution of stress in conveyor frame subjected to loads from force of gravity of transported materials
Source: Author's own work

The strength calculations of the conveyor frame structure presented above enable the conclusion to be drawn that the selected profiles and the structure of the conveyor frame were designed properly. Thanks to the FEM calculations, one may be certain that the structure of the conveyor frame guarantees adequate strength and meets the structural assumptions. In the analysed frame structure, there are safe values of deformation and stresses resulting from the action of gravity of the transported elements. The displacement and stresses occurring in the frame do not exceed the admissible values so there is no influence on the strength of the designed conveyor frame.

4. Conclusions

The used FEM calculations made it possible to carry out a series of strength simulations of the designed roller conveyor. It is worth noting that conducting similar strength tests in practice would require the physical construction of the conveyor and the outcome of the strength tests would result in destruction of the load-carrying structure with each loading test. In the analysed case, after the design stage, the structure was materialised, and the simulation and strength results were confirmed in empirical tests.

The aim of the work including verification of the effectiveness of CAD and FEM numerical methods in the process of designing material handling equipment was achieved. It was proved that the applied Ansys environment enables calculations of complex structures. Nevertheless, the quality and consistency of the model subjected to simulations is a condition for obtaining the appropriate accuracy of calculations.

Thanks to FEM calculations, it is theoretically possible to be certain that the structure of the conveyor frame guarantees adequate strength and meets the structural assumptions. Nonetheless, structural practice indicates that this usually requires additional empirical verification. In the analysed frame structure, there are safe values of deformation and stresses resulting from the action of gravity of the transported elements. The displacement and stresses occurring in the frame do not exceed the admissible values so there is no influence on the strength of the designed conveyor frame.

The use of CAD and FEM systems is advisable in the process of constructing material handling equipment and the Inventor software environment meets the necessary requirements for its application to the discussed structural problem.

References

[1] Garbowski L., Rutkowski I., Wrzosek W.: Marketing. Punkt zwrotny nowoczesnej firmy. Polskie Wydawnictwo Ekonomiczne Warszawa, 1998, 390.
[2] Goździecki M., Świątkiewicz H.: Przenośniki. WNT, Warszawa, 1979.
[3] Dobrzański L.: Podstawy nauki o materiałach i metaloznawstwo. WNT, Warszawa, 2002, 536.
[4] Fijałkowski J.: Transport wewnętrzny w systemach logistycznych- wybrane zagadnienia. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 2000.
[5] Skowronek C., Sarjusz-Wolski Z.: Logistyka w przedsiębiorstwie. Polskie Wydawnictwo Ekonomiczne, Warszawa, 1999.
[6] Tonndorf H. G.: Logistyka w handlu i przemyśle. Wydawnictwo Profesjonalnej Szkoły Biznesu, Kraków, 2000.
[7] Ficoń K.: Procesy logistyczne w przedsiębiorstwie. Impuls Plus Consulting, Gdynia, 2001, 35.
[8] Korzeń Z.: Logistyczne systemy transportu bliskiego i magazynowania. ILiM, Tom III. 1999, 127.
[9] Sołtysik M.: Istota i cechy zarządzania logistycznego. Gospodarka materiałowa i logistyka, 1994, 7/8, 145-145.
[10] Gładyskiewicz L.: Przenośniki taśmowe, Teoria i obliczenia, Wrocław, 2003.
[11] Broel – Plater B.: Układy wykorzystujące sterowniki PLC. Projektowanie algorytmów sterowania. Wydawnictwo Naukowe PWN, 2008.
[12] Broel – Plater B.: Sterowniki programowalne – właściwości i zasady stosowania. Wydawnictwo Uczelniane Politechniki Szczecińskiej, Szczecin, 2002.
[13] Dietrich M.: Podstawy konstrukcji maszyn. Tom 2. PWN, 2012.
[14] Kurmaz L.: Podstawy konstrukcji maszyn – projektowanie. PWN, 1999.
[15] Osiński Z.: Podstawy konstrukcji maszyn. PWN, 2002.