Design of Machines and Structures, Vol. 9, No. 1 (2019), pp. 58–63.
https://doi.org/10.32972/dms.2019.007

EXAMINATION OF DESIGN METHODOLOGY OF SCREW CONVEYORS

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Abstract: The following article examines the design methodology of screw conveyors. The most significant steps are discussed concerning the design of the apparatus and the use of the tool for machine tools as a service component is explained.

Keywords: *screw conveyor, design theory, methodology*

1. INTRODUCTION

A drastic increase can be perceived in the operation of the production tools so the automation of machining processes requires that the auxiliary processes should be performed automatically by structural units and equipment without direct human intervention [1], [2]. The examination of the design methodology in this article refers to a screw conveyor. Screw handling unit is one of the most used machines with continuous operation with some theoretical questions from János Benkő and Sándor Verdes [3], [4]. The University of Miskolc, Faculty of Mechanical Engineering and Information Technology boasts a wealth of knowledge in the design methodology of various machines and equipment that was utilized in this topic [5], [6], [7], [8].

2. DETERMINATION OF BOUNDARY CONDITIONS

The boundary conditions necessary to start the design phase of the system were defined. The amount of material separated by the machine was determined based on the performance of the milling machine and the maximum applicable size of the tool. During the calculations the maximum allowable cutting speed and feed rate were counted. By multiplying the amount of separated material by the volumetric factor of the chip, the volumetric flow rate of the actual chip volume to be discharged in one minute was obtained. In the case of milling machines, the chip is characterized by a screw, a spiral or a fragmented shape with a volumetric factor of from 3 to 25 [9]. During the designing phase the calculations were executed by using the highest value. The bulk density of the material being transported was determined because it is required to be known to be able to calculate the transport capacity in terms of (tonne per hour).

3. Geometric scaling

In case of screw conveyors the geometric scaling of the snail could be determined based on formulas for determining the expected transport capacity and maximum speed [10], which could be described as:

$$D = \sqrt[5]{\left[\frac{240Q}{3{,}6\pi\left(\frac{S}{D}\right)\rho_h\emptyset}\right]^2 \frac{\mu}{2g9{,}55^2\left[cos\delta\sqrt{\mu^2+1}+sin\delta tg(\alpha+\rho)\right]}} \tag{1}$$

The “D” parameter in the equation is the nominal diameter of the screw in meters, the “Q” in the transport capacity ton/hour, the “n” the rev of the worm shaft per minute, the “s” the pitch of the screw spiral in meters, “ρ_h” the bulk density in kg/m^3, “Φ” filling factor, “g” acceleration due to gravity m/s^2, “μ” coefficient of friction, “δ” is the inclination angle of the transport direction in degrees, “ρ” is the angle of friction expressed in degrees, “α” is the pitch angle in degrees, and “s/D” is a standard value. The diameter obtained is the same as the minimum diameter of the screw, which must be multiplied by the safety factor. The obtained result was rounded up to a standard value. By knowing the diameter of the screw conveyor, the minimum speed was calculated as a function of the expected capacity. Being able to determine the proper operating parameters of the material handling unit, the maximum transport capacity at maximum speed should be calculated.

4. Design of body parts

During the design of the body elements, mechanical connections to the bed were designed at the first stage. Designing an adapter was necessary as it forms an intermediate element between the machine and the chip carrier, ensuring the proper connection surfaces between the two units. During the design it was so important to seek the proper shaping of the bearing and fixing points. Consideration should be given to the proper support of the auger lines at several points so that the material flow cross-section is reduced to a minimum. It was investigated and identified where the material should be counted, as suitable collecting elements should be placed at appropriate points. If the purpose is the transportation and separation of different states, the appropriate design solutions should be provided to ensure that these functions can be performed during machine operation. Because of the fact that the material is to be collected at one point, the connection of the screws was necessary. A well-designed chamber at the material transfer points was created to ensure a smooth flow of the process. Suitable structural elements were provided for connection to geared motors and ancillary components. The appropriate filtration and collection of the separated liquids was ensured by means of a container. Based on the results of the structural elements, the geometrical and various connection dimensions can be determined. The dimensions of the required length of the screw rows were determined.

5. Selection of standard elements

In the following phase, standard parts such as bearings for geared motors and clutches can be selected. In terms of bearing, it is advisable to select from the range of pre-assembled bearing units, however, where the bearings are surrounded by flowing material, it is preferable to choose a plain bearing to utilize the advantageous installation dimensions. To achieve proper operation, in the case of the motors with worm geared motors, it is advisable to select the low speed and high torque. When selecting the clutch, care must be taken to be able to transfer the power of the drive motor when coupling long axes to be able to tolerate angular defects and reduce harmful dynamic effects.

6. CONTROL

The control of the parts is necessary because it shows whether the parts have been selected correctly. The motors are checked based on the power required to drive each auger line, which depends on static and dynamic loads. The material part added to the trough was considered to be a mass point, and it was assumed that the mass point moves on the surface of the screw base and on the helical edge of the auger, and the factors of friction can be considered to be constant. Thus, starting from the differential equation of the mass point moving on the helical axis [3], the components of forces acting in each direction could be determined as follows:

$$K_x = -Ncos\varphi + Bsin\alpha sin\varphi \tag{2}$$

$$K_y = -Nsin\varphi - Bsin\alpha cos\varphi \tag{3}$$

$$K_z = Bcos\alpha \tag{4}$$

Where “N” is the force of the trough wall, “B” is the force exerted on the helical, and “φ” is the angle of rotation of the quasi-permanent state. In addition to the weight of the screw, the bearings are loaded by the same forces as “N” and “B”, but the direction is its opposite, so the radial bearing load is:

$$F_r = \sqrt{(Ncos\varphi - Bsin\alpha sin\varphi)^2 + \left(Nsin\varphi + Bsin\alpha cos\varphi + G_{csiga}cos\delta\right)^2} \tag{5}$$

Using the parameters defined so far in *Equation (6)*, the performance which is required to move the material can be determined.

$$P_1 = c\left[K_x v_x + K_y v_y + K_z v_z\right] \tag{6}$$

In the case of the nearly horizontal conveyors, only the z-direction velocity component is not zero, and “c” is a factor that takes internal resistances into account. Determination of the performance requirement of friction:

$$P_2 = \frac{d}{2}\omega(\mu_t F_z + \mu_r F_r) \tag{7}$$

Where “d” stands for the axis diameter, “ω” the circular frequency, “μ_t” is the axial bearing factor of friction, “F” is the axial load force, “μ_r” is the radial bearing factor of friction and “F_r” is the radial load value. The power required to overcome the acceleration resistance plays a role when the material needs to be accelerated from zero, determined by *Equation (8).*

$$P_3 = Q_{max} v^2 \tag{8}$$

In the equation “Q_{max}” is the maximum transport capacity and “v” is the speed. Based on all the results of the previous calculations, all performance can be calculated as follows:

$$P_{all} = c' \frac{P_1 + P_2 + P_3}{\eta} = [W] \tag{9}$$

In the equation "c" is the safety factor and "η" is the efficiency of the drive. The motors are suitable if their rated power is greater than the power requirement of the screw. The selected clutches were checked at the maximum permissible torque [11]. For plain bearings, the check was based on permissible surface pressure [12].

7. DESIGNING PROCESS

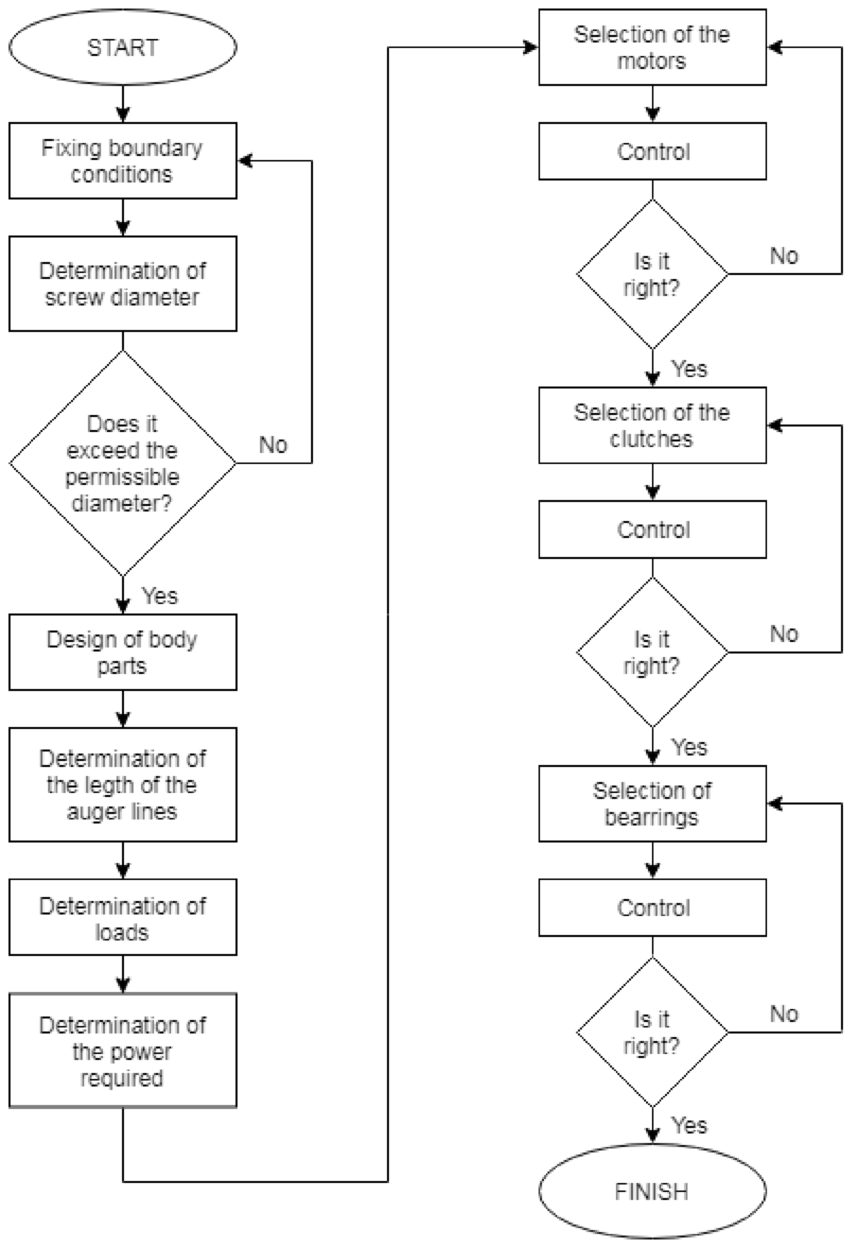

Figure 1. Designing process

8. Summary

The following article demonstrates that the applied design methodology can be used effectively in the design of screw material handling equipment.

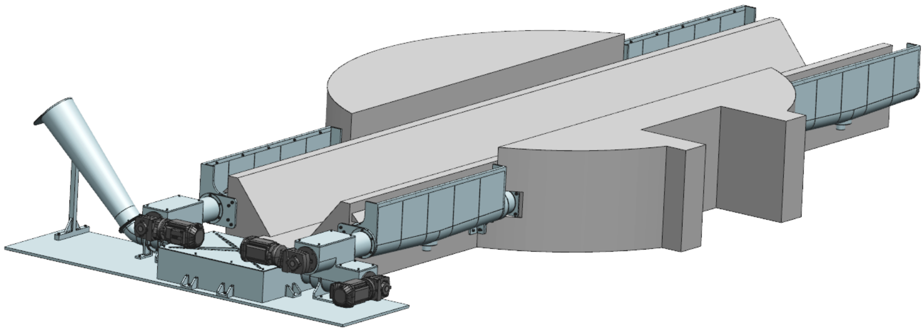

Figure 2. The screw conveyor and the base of the machine

The screw conveyor is shown in *Figure 2* designed on the basis of the design methodology presented in *Figure 1*. The schematic model of the bed of the serviced machine can also be seen in *Figure 2*. The method can be successfully applied to the geometric dimensioning and designing of the screw conveyor. The following method is also suitable if the screw material handling unit is a part of a machine tool. The geometric dimensioning of the structure can be effectively done by the predetermined and fixed boundary conditions. Based on the developed dimensions, the method can be used to accurately determine the static and dynamic loads of the auger lines, which can be used to select and check commercially available standard parts. The use of the design methodology was proved to be successful during the design and control of a universal milling machine's chip conveyor unit in a project.

Acknowledgement

The described article was carried out as part of the EFOP-3.6.1-16-00011 *Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation* project implemented in the framework of the Széchenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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