

## Optimization of Production Logistics

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### ABSTRACT

The paper focuses on the optimization of production logistics within the selected company, which is going to relocate the machining centre to the Czech Republic. The aim of this paper was to design a suitable conveyor to optimize the machining centre's entire production process. On the basis of the company's input requirements, the necessary calculations were carried out, which led to the construction of the conveyor model. Proposing the model was preceded by selecting a suitable conveyor which will be used in production.

**Keywords:** production logistics, production optimization, conveyor.

### INTRODUCTION

The development of economy in all countries brings increased demands on companies. These are especially the issues of industrial logistics, personnel logistics, and green logistics,. In order to stay competitive, companies strive for providing high quality services, but also for reducing costs. Production logistics management is very important for the whole logistics process. The decisions taken in this part of the logistics process have a direct impact on the level of customer services provided, the ability of the company to compete with other companies, and on the level of sales and profit the company is able to make.

Optimization of logistics processes is a topical issue, as it influences the resulting price for the customer as well as the level of customer service. This paper is focused on the possibility of improving the logistics processes in a chosen company. It is the optimization of the production process in a selected company using designing a suitable conveyor transporter that would correspond to the conditions in that company [1, 2, 18].

### METHODOLOGY

For the purposes of this study, a company involved especially in foundry, machining, assembling and additional processes (e.g. manufacturing of moulds, quenching with a modified atmosphere, galvanic zinc coating, etc.) was considered. The company's production portfolio includes the production of filtration and hydraulic systems parts, handling equipment, machine tools, castings from zinc and aluminium alloys, low-pressure castings from aluminium and cast iron castings. The main customers are global and multinational automotive industry corporations. Since there is a steady increase in production, it is necessary to adapt the production organization to this trend. Another reason for optimization is the movement of the machining centre from Germany to the Czech Republic. The second requirement involves achieving leaner production in order to reduce the space. However, these requirements must be consistent with the effort for improving the customer service and the productivity of work. The whole production process consists of interdependent activities, and any unevenness or failure of a production process part will cause se-

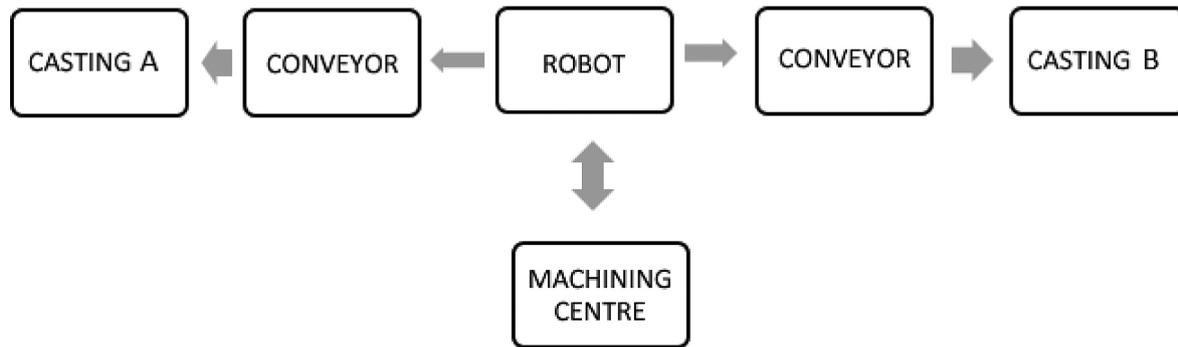


Fig. 1. Scheme of manufacturing process

rious problems in production. For this reason, an effective design of a production hall is necessary. The optimization will be focused on the machining centre. A new conveyor will be designed for this hall and it will be a part of the production line. The conveyor must conform to the requirements and layout of the hall. In the production hall, two types of castings will be machined. Figure 1 shows a simplified design of the production line [3, 16].

The requirement imposed to the machining centre is to process two castings in two minutes. After machining, the machine plates in the centre rotate. The robot with its arm, which is capable of removing two castings at the same time, moves the castings from the machine plate of the machining tool to the conveyor. The radius of the robot arm is 1.5 m. Therefore, the rotary plates of the machining centre, part of the input conveyor and part of output conveyor must be at the robot's arm reach. At the point of the input conveyor, the robot must be capable of reaching four castings. At the point of the output conveyor, it must reach at least two castings. Then the whole process is repeated.

## CASE STUDY

As already indicated above, the machining centre must be capable of processing two castings per minute. Then the machine plates rotate. Another aspect important for designing a suitable conveyor is the casting dimension. The distance between the conveyors is 550 mm. In the safety zone (behind the fencing), four castings of the given type must always have to be prepared. The zone for machine operators is set to 1,500 mm. The height of the conveyor must be between 460 and 700 mm above the ground. Given the size of

the production hall, the conveyor must be as narrow as possible, while the length must be about 2,000 to 3,500 mm. On the basis of these input values, the width of the conveyor is determined.

Suitable conveyor types for transporting castings include flat belt conveyor, belt conveyor, and chain conveyor. After consultation with the management of the company, chain conveyor was chosen for its space requirements compared to belt conveyor and high resistance to the external environment. Chain conveyors consist of the following parts: drive pulley, return idlers, supporting structure with a guide rail and articulated belt with tension assembly. The layout of the workplace is very important for the design. On its basis, several basic dimensions of the conveyor will be calculated. In the paper, only some of the calculations, based on which the conveyor is designed, are mentioned [4, 5, 12, 16].

The conveyor dimensions are partly given by the company. The height of the conveyor must be between 460 and 700 mm above the ground; it will thus be determined at 600 mm. The width of the conveyor is not given, but it is necessary to design a conveyor that would be as narrow as possible, taking into account the operating capacity of the machine and layout of the production hall. The width of the conveyor is three times the average casting width, because it is necessary to take the space for the frame and sprocket wheels into account  $(170+165/2=167.5 \text{ mm})$ .

The design of the conveyor length and the location of the conveyor relative to the zero point selected on the machine plates of the machining centre are influenced by the requirements of the company, workplace layout and the minimum distance the machine operators must access. The company has determined the length of the conveyor between 2,500 and 3,000 mm. The centre

of the front input conveyor surface from its front on the machine centre in the x-axis can be within a range from the minimum distance where the conveyor does not interfere with the robot stand, which corresponds to 720 mm, and the maximum distance (1910), which is defined by fencing. The company's requirement is that the robot must be able to reach 4 castings in the safety zone. Therefore, the conveyor in the x-axis can be moved only by 290 mm (1910-720 = 1190 – 900= 290 mm). The value of 900 mm is the size of four castings placed side by side with a gap between them, increased by the size from the edge from which castings cannot be removed [6, 7, 14, 17].

The position of the conveyor was determined based on calculations. The distance was determined as the distance in the x-axis x 720 mm from the front end. The distance of the coordinate in the y-axis was determined by summing the width of the output conveyor, its distance from the front end, the distance between the conveyors, which is determined by the company's requirement, and a half of the width of the input conveyor (550+200+550+250=1550 mm).

At this point, the whole length of the conveyor was determined. The overall length includes the safety distance (fenced zone) and unfenced zone for machine operators. In the fenced zone, the distance is 1,190 mm and the zone for machine operators is 1,500, which is 2,690 mm in total (rounded off to 3,000 mm).

### Calculation of amount of material transported

The transport speed was determined as 0.1 m/s.

$$Q_m = 3600 \times \frac{m}{t_K} \times v [Kgh^{-1}] \quad (1)$$

$$P_r = \frac{m \times g \times f \times v_K + \frac{1}{2} m \times a_p \times v_p}{2} \quad (5)$$

$$P_r = \frac{69.5 \times 9.81 \times 0.15 \times 0.1 + \frac{1}{2} 69.5 \times 0.5 \times 0.1}{2} = 5.982 W \quad (6)$$

### Transmission spindle

Before calculating the forces acting on the spindle, it is necessary to calculate the torque. The calculation was based on output revolutions and engine power values. The torque is 1041174 Nm.

Formula for calculating the force acting on the spindle:

$$Q_m = 3600 \times \frac{1,2}{0,1905} \times 0,1 \doteq 2268 [Kgh^{-1}] \quad (2)$$

The calculation of the amount of the material transported can also be expressed as a number of pieces per hour as follows:

$$Q_K = \frac{Q_m}{m} = 3600 \times \frac{v}{t_K} [h^{-1}] \quad (3)$$

$$Q_K = \frac{2268}{1,2} = 3600 \times \frac{0,1}{0,1905} \doteq 1890 ks [h^{-1}] \quad (4)$$

The calculations above indicate the amount of the material transported in continuous operation [8, 11, 13].

### Engine with gearbox

On the basis of the agreement with the SEW-USOCOME company, an engine with a transmission will be used. It is a worm gearbox with engine power of 0.12 KW. The weight of the engine with gearbox is 22 kg. Due to its dimensions (345 × 178 × 141.5 mm) it would be too large; therefore, chain transmission was used in order to meet the requirement for the smallest conveyor width possible.

### Calculation of the chain

For the main part of the conveyor, the 10B-1 chain was chosen. Firstly, the forces acting on chain were determined. The pallet mounted on the plate moves in the direction of the force F and produces the friction force acting in the opposite direction. Inertia force F<sub>s</sub> acts on the DESKA with the pallet in the same direction as the friction force. The last forces acting are the normal force F<sub>n</sub> acting in the opposite direction than the gravitational force F<sub>g</sub>. The power transmitted by one chain can be calculated as follows:

$$F = \frac{2 \times M_K}{D} \tag{7}$$

Calculation of the force acting below the sprocket wheel with 21 cogs:

$$F_1 = \frac{2 \times M_K}{D_1} \left[ N = \frac{Nmm}{mm} \right] \tag{8}$$

$$F_1 = \frac{2 \times 104174}{106.51} = 1959.14 \text{ N} \tag{9}$$

Calculation of force acting below the sprocket wheels with 34 cogs.

$$F_2 = \frac{2 \times M_K}{D_2} \tag{10}$$

$$F_2 = \frac{2 \times 104174}{172.05} = 1210.97 \text{ N} \tag{11}$$

Figure 2 shows the calculation of balance forces and reactions:

$$R_B = \frac{F_2 \times (b + c) - F_1 \times a}{d} \tag{12}$$

$$R_B = \frac{1210.97 \times (72.55 + 146.65) - 1959.14 \times 41.4}{205,2} = 898.32 \text{ N} \tag{13}$$

$$R_A = F_1 + 2 \times F_2 - \frac{F_2 \times (b + c) - F_1 \times a}{d} \tag{14}$$

$$R_A = 1959.14 + 2 \times 1210.97 - \frac{1210.97 \times (72.55 + 146.65) - 1959.14 \times 41.4}{205.2} = 3482.76 \text{ N} \tag{15}$$

On the basis of the equations, the reactions in the bearings A and B were identified.

Subsequently, the bending moment was calculated. The maximum bending moment was identified at 72.55 mm based on the calculation,. For combined stress, reduced stress is given, which is defined as the sum of the torsion and bending stress vectors. The sub-calculations are not showed in the paper. Next, we use the reduced bending moment in the equation for calculation of the stress and express the diam-

eter d in the critical point to obtain the value  $d \geq 23$  mm. The diameter of the transmission spindle must be greater than 23 mm. The spindle deflection of the  $y=0.0645$  mm beyond the maximum allowed limit. The results indicate that the spindle must be adjusted.

### Drive spindle

On the basis of the calculations, it was determined that the diameter of the drive spindle is 25

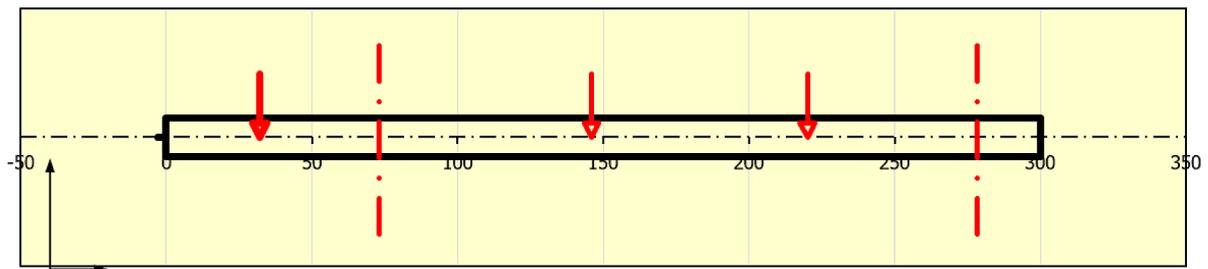


Fig. 2. Forces acting on transmission spindle

mm, which means that the drive shift corresponds with the calculation. Figure 3 shows the deflection of the spindle with the diameter of 25 mm.

**Parts transmitting the torque**

For transmitting the torque from the transmission spindle to the sprocket wheels, tight splines were used. Tight splines were chosen in accordance with the ČSN 02 2562 standard – Tight spline  $b \times h \times l$  (spline breadth  $\times$  spline height  $\times$  spline length).

The breadth and height of the spline are given by the diameter of the spindle. For the 30 mm diameter, the corresponding breadth is 8 mm, while the corresponding height is 7 mm. The length of the spline can range between 20 and 90 mm. In this case, spline with the dimensions of 8x7x28, which corresponds to the technical standard, will be chosen. The calculation of the spline consists of the punching and shear check.

**RESULTS**

It followed from the calculations for the transmission spindle that the smallest acceptable diameter of the spindle is 23 mm. A spindle of such a diameter would not withstand the strain anticipated. Therefore, the diameter has been increased to 30 mm. The deflection, due to which the spindle was not suitable, has changed from  $y=0.0645$  mm to  $y=0.019$  mm. New deflection is shown in Figure 4.

Given the size of the spindle, the diameter of the sprocket wheels was set to 30 mm. The bearings where the transmission spindle is mounted are set up to FLCTE 30. The dimensions of the bearings are U – 38.1 mm and H 112.5 mm. On the basis of the individual calculations, a chain conveyor

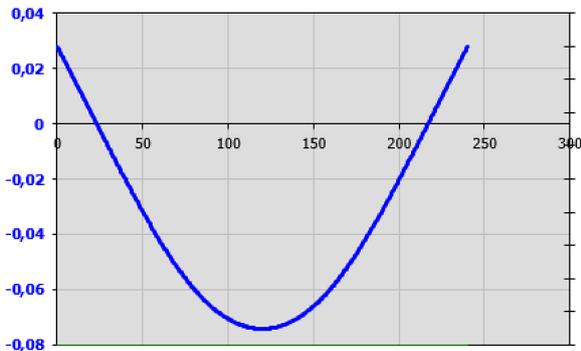


Fig. 3. Deflection of drive spindle [mm]

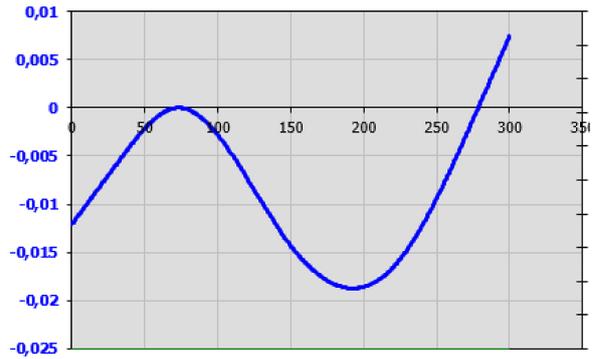


Fig. 4. Deflection of transmission spindle after changing the diameter [mm]

model was designed. Its most important parts include engine with a transmission. The engine is attached to the engine plate, which is fastened to the frame using screws. On the transmission, a spindle with a sprocket wheel with 21 cogs, which is a part of the secondary transmission system, is located. The transmission of the torque is ensured using tight spline. Through the chain, the torque is further transmitted over the tension pulley, which is also attached to the engine plate and the sprocket wheel (with 21 cogs) on the transmission spindle. In order to protect the operators from injury, the entire secondary transmission system is covered. The transmission spindle is mounted in the bearings with a casing, which are attached to the frame. On the spindle, there are two sprocket wheels with 34 cogs propelling the chains with the drivers. The sprockets are secured against axial movement along the spindle by means of locking rings. The transmission of the torque is ensured using the tight splines. The chains circulate between the sprockets on the transmission spindle and the drive spindle. The drive spindle is mounted in flanged bearings. The body of the bearings is secured

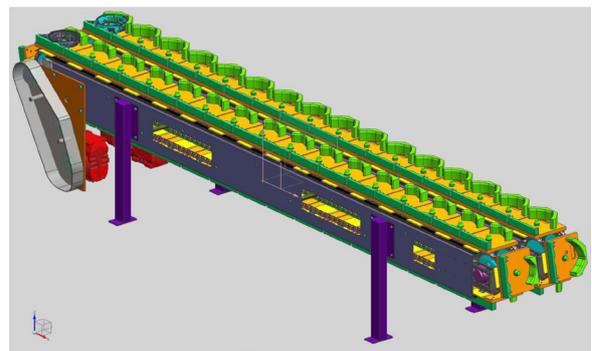


Fig. 5. Final version of the conveyor (3D model)

against axial movement by insertion in the bearings holder, which is bolted to the frame. Locking rings and set screw prevent axial displacement and overspinning of the sprockets. The final design of the conveyor is shown in Figure 5 [9, 10, 12].

## CONCLUSION

The objective of this paper was to show the optimization of the production process in a selected company. The company plans to move the machining centre from Germany to the Czech Republic. On the basis of the requirements of the chosen company, a production line was to be designed, with the aim to optimize the whole process. After consultation with the chosen company, a suitable conveyor for castings was to be designed. For a functional design of a chain conveyor, it was necessary to create a process that would ensure a sound solution. The process or algorithm of consecutive steps should consist of instructions, design, design control, and modification, according to the results of the control and final solution. The instructions should be as precise as possible, and should contain all important parameters. Creating the design involves calculations and their application. After the control part of the algorithm, the design is modified and subsequently, there is a result in the form of a functional design. At this point, the transmission spindle was corrected. If the correction did not happen, the functionality would not be ensured. For the whole casting production process, chain conveyor was chosen as the most suitable one.

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