

CALCULATION AND 3D MODEL OF HYDRODYNAMIC COUPLING FOR BAND CONVEYOR DRIVE

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Abstract. *The subject of this paper is the calculation and formation of the engineering-structural documentation of the hydrodynamic coupling designed for the band conveyor drive. The paper describes harmonization of operation of the electric motor and the hydrodynamic coupling.*

In this paper, the calculation of the band conveyor and of the hydrodynamic coupling is shown, their basic geometric parameters as well as parameters of power. At the end, 3-D models of the hydrodynamic coupling, the electric motor and other structural parts are created. All the elements are modeled in the CATIA software.

Key words: *Hydrodynamic Coupling, Calculation, Band Conveyor*

1. INTRODUCTION

The production of coal which we use as the main fuel in thermo power plants of the Electric Power Industry of Serbia is realized in an open-cut mining of Kolubara and Kostolac mining basins. The coal from the open-cut mining is lignite with average thermal value of 7500 kJ/kg.

In this paper, a part of transport systems for coal transfer from Tamnava-Kolubara basin to further processing is presented. The open-cut mines are usually equipped with ECP system (excavator – conveyor - procastinator) for the strip of rubbish mining before coal itself. The excavator - rotation system is used for digging, the strip conveyor - for material conveying and the rotational procastinator - for storage of mining mass.

The conveyor is of horizontal striate type, set on sheet metal mountings or pontoons with the possibility of simple movement. During one setting, it provides transportation across the front width of 1100m. It receives the material from a small side conveyor that

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is directly connected with the position of the rotary excavator. The entire conveyor structure is made of steel profiles. The main part of the conveyor is a drive unit with electro-motor drive, power shift and transport belt. There is also a command position for the operator with radio link. In the whole system, it is necessary to synchronize the commands in order for the operation to be safe and without many delays. Considering the capacity, the drive unit has a high installed power and it is made of several asynchronous motors coupled with reduction gears. The electric motors are of high voltage ($U = 6000$ V) with a specially designed structure to reduce the value of the starting current.

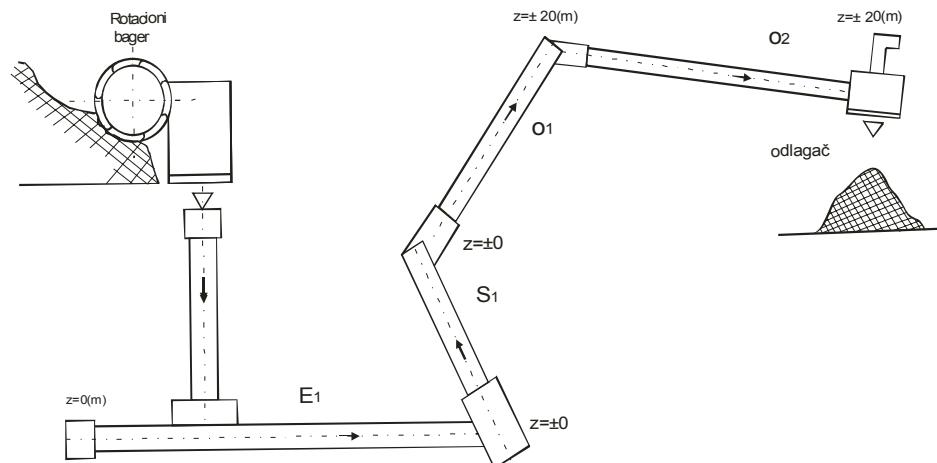


Fig. 1 Conveying Configuration for Lignite Surface Layer

Higher power electric motors may be directly activated only with implementation of hydrodynamic power transfer. For this transportation system, there is a special request that maximum value of network current should not exceed 550 A. This request is met only if more electric motors having smaller powers are used instead of only one. Switching on would be individual or in groups, with a larger or smaller interval between each start-up.

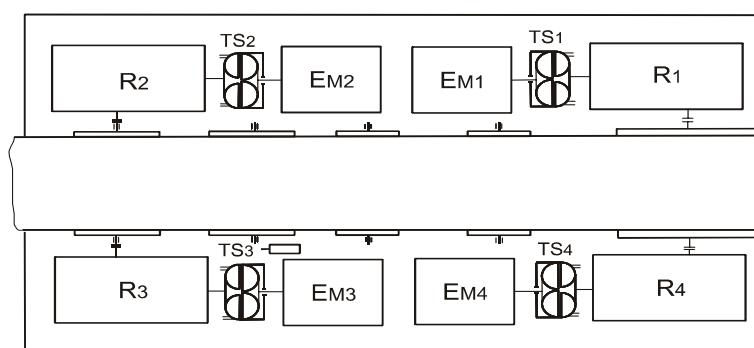


Fig. 2 Scheme of Conveyor Power Transport

2. CALCULATION OF THE BASIC PARAMETERS OF THE BAND CONVEYOR

In this part, the calculation of the basic parameters of the belt conveyor and the hydrodynamic coupling will be presented.

Basic data for the conveyor are:

- Capacity of conveyor: $Q = 350 \text{ m}^3/\text{h}$
- Length of conveyor: $L = 1100 \text{ m}$
- Conveyor inclination: horizontal
- Type: band, striate
- Conveyed material:

a) rubbish mining - moist earth:

$$\rho = 1,7 - 1,9 \frac{\text{kg}}{\text{dm}^3},$$

$$\alpha = 30 - 35^\circ$$

b) lumps:

$$\rho = 0,7 - 0,9 \frac{\text{kg}}{\text{dm}^3},$$

$$\alpha = 32^\circ$$

where: ρ – is material's density,

α – is the angle of the natural decline during motion with speeds up to 5m/s.

Analytical formula for the conveyer's capacity is:

$$Q = 3600 \cdot A \cdot v \quad (1)$$

$$A = 0,16 \cdot B^2 \cdot \operatorname{tg} \alpha \quad (2)$$

where:

A – is cross-section of material,

α' - is angle dependent on the angle of natural materials when moving,

B – is standard width of a band.

Since we use a striate conveyor, the section of material is much bigger and can be calculated using the formula:

$$A_0 = 0,16 \cdot B^2 \cdot \operatorname{tg} \alpha' + 0,5 \cdot (B_R + B_V) \cdot 0,5 \cdot (B_R - B_v) \cdot \operatorname{tg} \alpha_v \quad (3)$$

where, $\alpha_v = 20^\circ$ and $B_v \approx 0,4B$ are common values for derived conveyor.

Increasing angle α_v to the values of $30^\circ - 40^\circ$ increases the capacity for 20 – 30%, but significantly decreases the life of the band. Since the conveyor filling is done with certain unevenness, the value of $\alpha' = 0,5$, $\alpha = 16^\circ$, may be taken for calculation, and in this case:

$$A_0 = 0,09 \cdot B^2.$$

From the equation for striate conveyor capacity (1), now it is possible to determine the speed necessary to achieve the given capacity:

$$v = \frac{Q}{324 \cdot B^2} \quad (4)$$

For the given capacity of $3500m^3/h$ and the conveying length of $1100m$, it has been accepted that the width of a band is $B = 1600mm$. By replacing in formula (4), we obtain the value of $v = 4,2 m/s$. Recommended values are between $1 - 5 m/s$.

The drum diameter should be optimally selected considering the band's lifetime and provision of circumferential force, (F_0).

Usually, the diameter is calculated from:

$$D = k \cdot i \text{ (mm)} \quad (5)$$

where:

k – is factor of safety from band delamination and it is in between the limits $k = 125 - 150 [mm]$ for stationary conveyors,

i – is the number of band layers which ranges between $i = 8 \div 13$.

By calculation we get $D = 130 \cdot 9,5 = 1250 [mm]$, and after that we adopt the standard diameter $D = 1250 [mm]$.

In band conveyors, we take into account the resistance in bearings of supporting rolls and drums, as well as the resistances to the band rolling over the rollers. Considering the thickness of the band, its bending resistance may be neglected. Total resistance for horizontal conveyors is calculated according to the following formula:

$$F_0 = k \cdot (2q_{tr} \cdot L \cdot w_x + q \cdot L \cdot w_{ter}) \quad (6)$$

where:

k – is additional resistance coefficient,

q_{tr} – is band's mass per its length [kg/m],

w_x – is resistance coefficient of empty band,

w_{ter} – is resistance coefficient of full band,

L – is length of conveyor [m],

q – is material mass per band's length [kg/m].

Required power for driving the horizontal band is given by expression:

$$P_0 = k \cdot (c \cdot L \cdot v + 0,00015 \cdot Q_m \cdot L) \quad [kW] \quad (7)$$

where:

k – is additional resistance coefficient at end drums (for values $L > 45m$, $k = 1$)

$c = (2q_{tr}w_x)$ – is coefficient of roller bearing ($c = 0,068$ for row bearing),

$Q_m = \rho \cdot Q [kg/h]$ – is hourly mass capacity,

$L[m]$ – is the length of conveyor.

By replacing the values it is obtained that necessary power required for driving the band is $P_0 = 1420 [kW]$. This high value of the nominal power cannot be obtained by one driving unit – one electromotor. Thus, the two driving drums are adopted each having electric motors with power of $400 kW$, the total amount being $P_m = 4 \cdot 400 = 1600 kW$.

Electromotor is short-circuited, high voltage and asynchronous with the following characteristics:

- Power voltage – $U = 600 \text{ V}$,
- Nominal power – $P = 400 \text{ kW}$; $\cos\varphi = 0,87$,
- Shaft speed – $n = 1480 \text{ min}^{-1}$,
- Engine efficiency – $\eta = 0,93$,
- Nominal mass – $m = 3250 \text{ kg}$.

3. CALCULATION OF BASIC PARAMETERS OF THE HYDRODYNAMIC COUPLING

The calculation of the geometrical parameters of a hydrodynamic coupling is based on one-dimensional model of fluid flow, and on the theory of conformity. The main purpose of this calculation method is to provide the means for designing a hydrodynamic coupling corresponding to the predefined working characteristics.

The starting inputs that will be used for determining the geometrical parameters of the hydrodynamic coupling are defined by design requirements. These requirements necessarily include:

- P – power transmitted to the pump shaft by the driving machine,
 n_p – pump shaft speed,
 η – clutch efficiency,
 ρ – working fluid density,
 ρ_s – model – coupling working fluid density,
 p – working pressure.

The calculation of the hydrodynamic coupling geometrical parameters can be represented according to the next algorithm (Fig. 3).

In the selection of the hydrodynamic coupling, we use the manufacturer's nomogram and for the coupling D-650, the following data are read from the nomogram: the charge of coupling is $Q = 34 \text{ dm}^3$, while specific charge of the working space is $q = 0,72$.

4. 3D MODEL OF THE HYDRODYNAMIC COUPLING

Using the mathematical model presented in the previous section, the numerical algorithm for calculating the main dimensions of a pump, as well as a turbine impeller is developed. For that purpose, the MathCAD software was used. Geometrical modeling of the hydrodynamic coupling's prototype was carried out in the CATIA program because of the possibility to use a modeling approach as well as an external application for calculation.

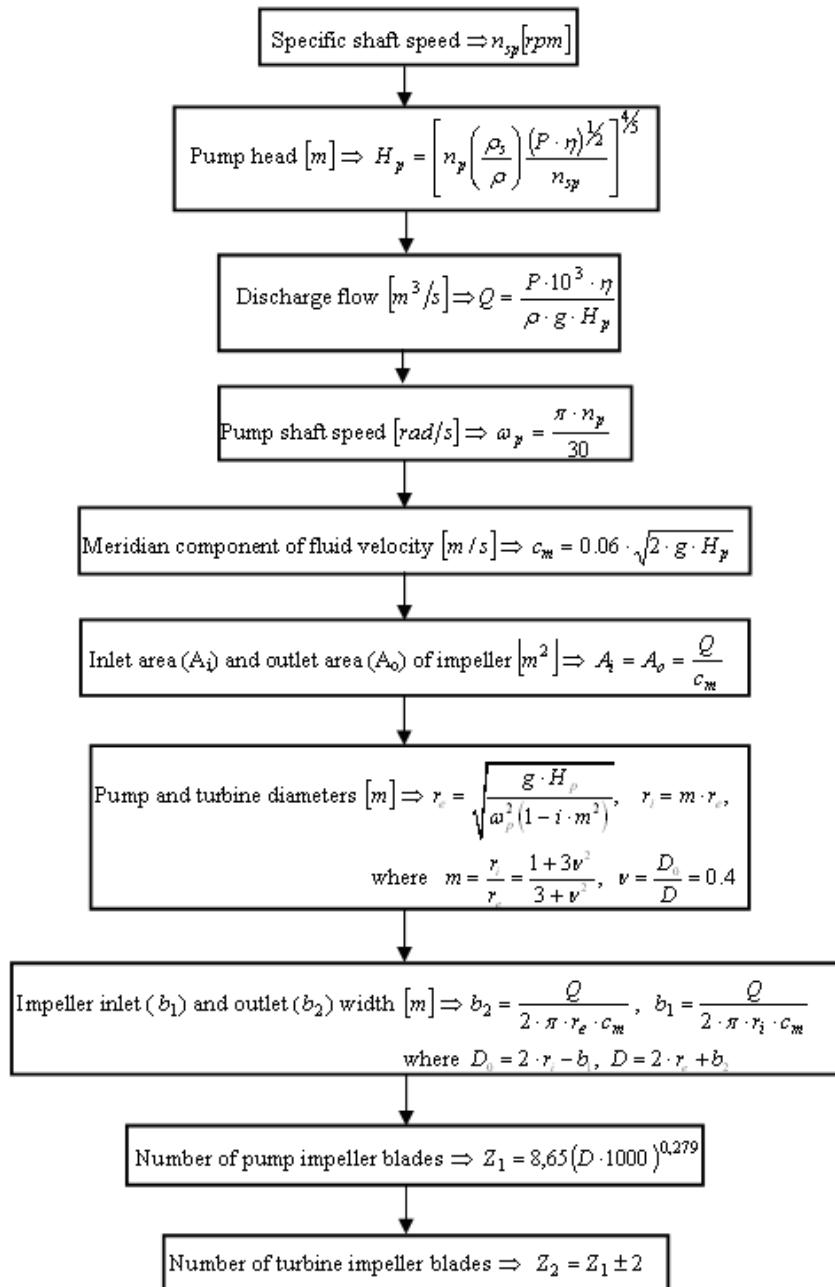


Fig. 3 Algorithm of Calculation of Hydrodynamic Coupling

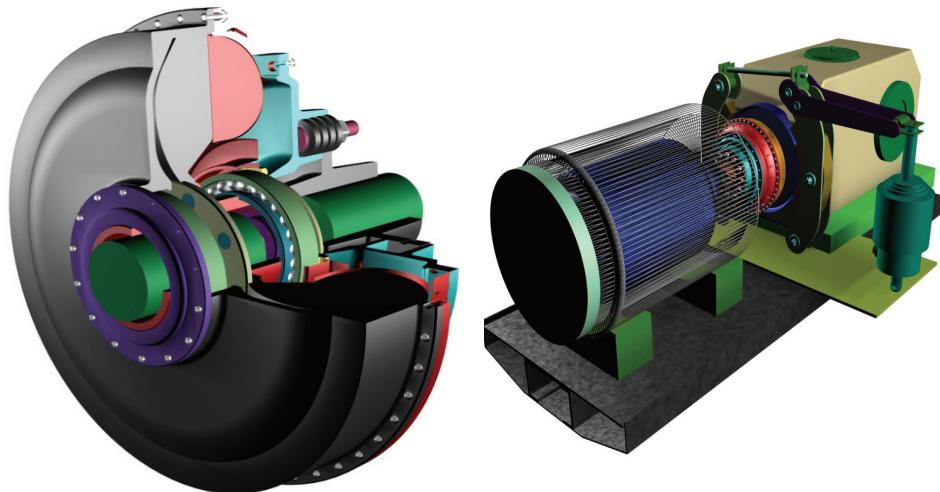


Fig. 4 Three-quarter Section of the Hydrodynamic Coupling

Fig. 5 Assembly of the Electric Motor and the Hydrodynamic Coupling

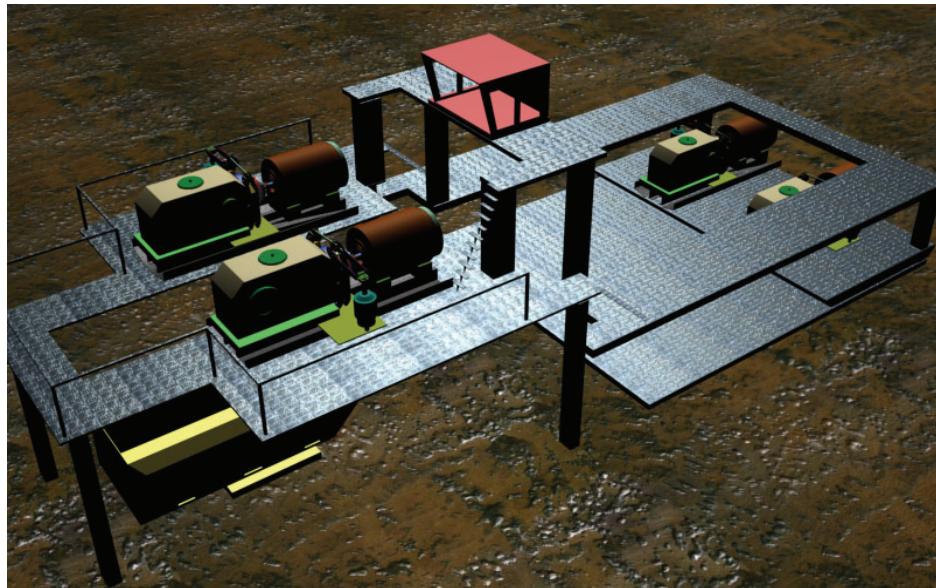


Fig. 6 Arrangement of Hydrodynamic Couplings in the Hall

CONCLUSION

In this paper, the calculation procedures as well as 3D model of the hydrodynamic coupling used to drive a band conveyor are presented. Based on the calculations of the electric motor, the band conveyor and the hydrodynamic coupling, the basic geometrical parameters and parameters of power are obtained. The overall calculation is performed for real data using the MathCAD software. The paper also presents 3-D models of hydrodynamic coupling, as well as of the basic elements of the band conveyor, modeled in the Catia software.

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PRORAČUN I 3D MODEL TURBOSPOJNICE ZA POGON TRAKASTOG TRANSPORTERA

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Predmet ovog rada je formiranje konstruktivno-tehničke dokumentacije hidrodinamičke spojnice za pogon trakastog transportera. U radu je prikazano usaglašavanje rada elektromotora i hidrodinamičke spojnice.

U okviru rada dat je proračun trakastog transportera i proračun hidrodinamičke spojnice, njihovih osnovnih geometrijskih parametara, kao i parametara snage. Na kraju kreiran je 3-D modeli hidrodinamičke spojnice, elektromotora kao i ostalih elemenata konstrukcije. Svi delovi su modelirani u programskom paketu Catia.

Ključne reči: *Hidrodinamička spojница, proračun, trakasti transporter*