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DRIVING POWER VERIFICATION OF THE APRON FEEDER FOR ORE TRANSPORTATION

Abstract

This paper gives the methodology for driving power calculation of an apron feeder for ore transportation on the example of the apron feeder DO-F in the open pit of the Copper Mine Majdanpek. The analysis was done by calculation for given operating parameters. The apron feeder layout is also presented, as well as the technical characteristics of the driving unit elements.

***Keywords**: apron feeder, power calculation, layout, technical characteristics*

1 INTRODUCTION

Within the Complementary Mining Project on copper ore mining from the South Mining District deposit in the Copper Mine Majdanpek, which predicted an increase in capacity of ore mining and processing to 8.5 Mt per year, it was necessary to make the project documentation for verification the capacities of transportation systems for ore and overburden in the new operating conditions. Technical Project on reconstruction the transportation systems for ore [1] included the apron feeder DO-F, designed for ore transportation from the open orestorage for ore under the belt conveyor C1 to the loading portion of the belt conveyor F in terms of verification its driving power.

2 TECHNICAL DESCRIPTION

Technical characteristics of apron feeder:

- capacity: $Q = 1600 \left[\frac{t}{h}\right]$
- type of material: copper ore
- size of material: $GGK = 200[mm]$
- bulk density of material: $\rho = 1860 \left[\frac{kg}{m^3}\right]$
- transportation length: $L = 6.4[m]$
- maximum inclination angle of conveyor: $\beta = 0[°]$
- material lift on conveyor: $H = 0[m]$
- conveyor speed: $v = 0.12 \left[\frac{m}{s}\right]$
- height of fixed side walls: $h = 1.35[m]$
- width of conveyor-plates length: $b = 1.829[m]$

The apron feeder layout is shown in Figure 1 and Figure 2.

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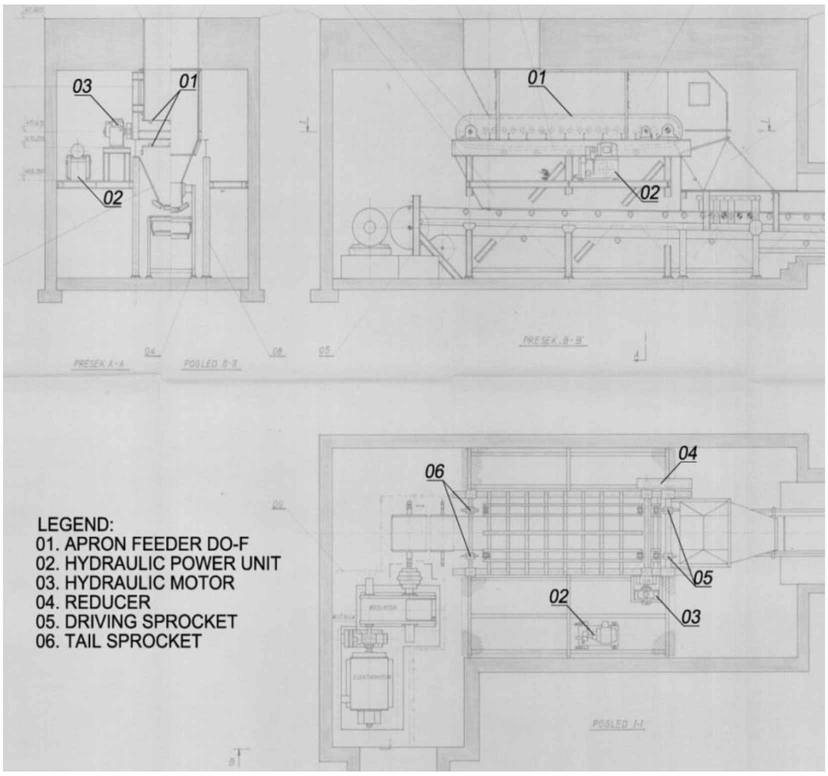

Figure 1 *Apron feeder DO-F layout in plan view and section views*

Figure 2 *View of apron feeder DO-F*

The apron feeder consists of a steel construction, driving unit, driving sprocket, tail sprocket, carrying and return rollers, chain and plates. The apron feeder is with fixed side walls.

The driving unit consists of a hydraulic power unit, hydraulic motor and single stage reducer.

The hydraulic power unit with label AF5-72M-21-40H consists of a variable displacement hydraulic pump driven by electric motor with an auxiliary charge pump, tank and pipelines with suitable fittings (pump circuit schematic is shown in Figure 3 and its view in Figure 4).

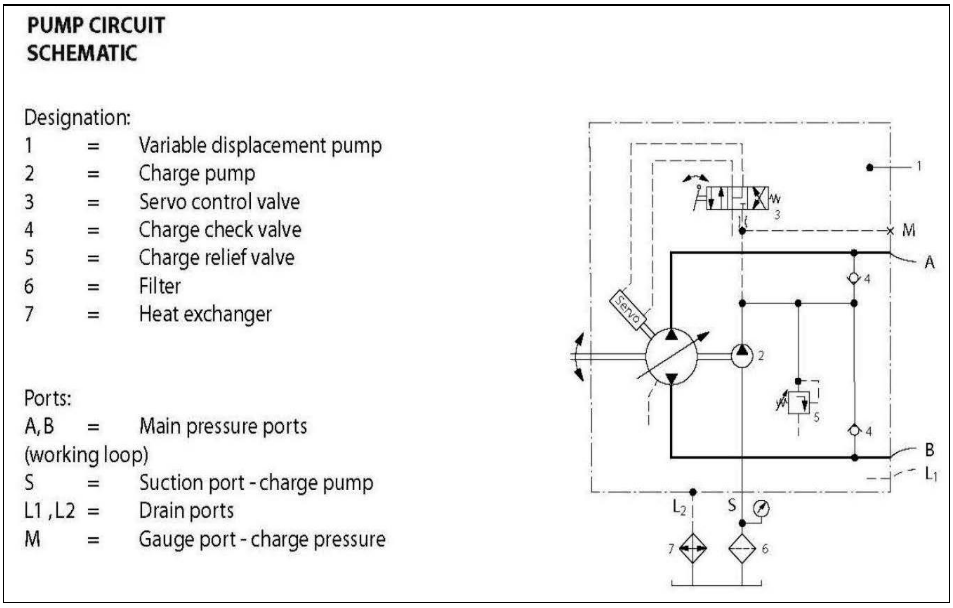

Figure 3 *Hydraulic scheme of hydro pump PV23*

The driving unit has the possibility of speed regulation thanks to the flow rate control regulation of the hydraulic pump, while the hydraulic motor has no possibility of flow rate regulation (motor circuit schematic is shown in Figure 5 and its view in Figure 6).

Technical characteristics of electric motor:

- installed power of electric motor: $P = 37[kW]$
- electric motor speed: $n = 1475[min^{-1}]$

Technical characteristics of hydraulic pump:

- label: PV23
- type: axial piston
- maximum pressure: $p_{max} = 200[bar]$
- maximum displacement: $q = 89\left[\frac{cm^3}{rev}\right]$
- speed: $n = 1475[min^{-1}]$
- working pressure: $p = 0 - 200[bar]$

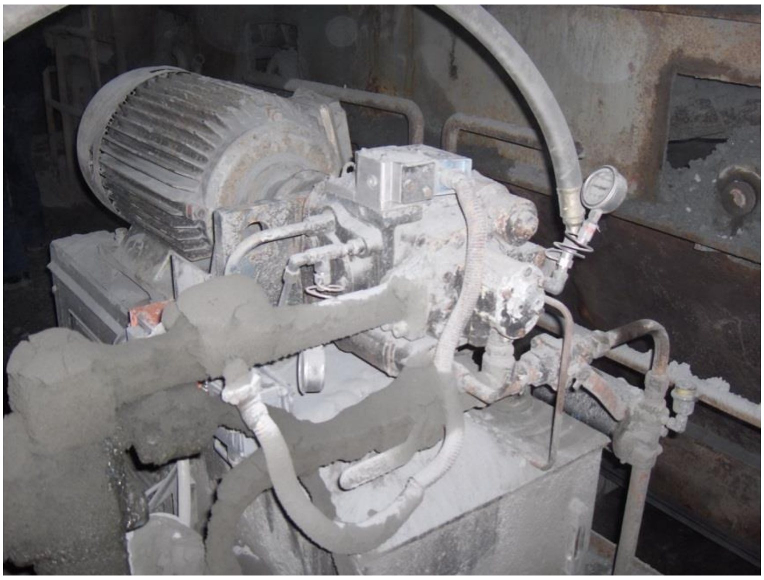

Figure 4 *View of hydraulic pump PV23*

Technical characteristics of hydraulic motor:

- label: MH187JC
- type: radial piston
- maximum pressure: $p_{max} = 200[bar]$
- displacement: $q = 3060\left[\frac{cm^3}{rev}\right]$
- nominal torque: $M = 4938[Nm]$
- maximum torque: $M = 9571[Nm]$
- speed: $n = 3 - 36[min^{-1}]$
- working pressure: $p = 0 - 200[bar]$

Technical characteristics of single stage reducer:

- number of gear teeth on hydraulic motor shaft: $z_1 = 20$
- number of gear teeth on driving sprocket shaft: $z_2 = 120$
- ratio: $i = 6$

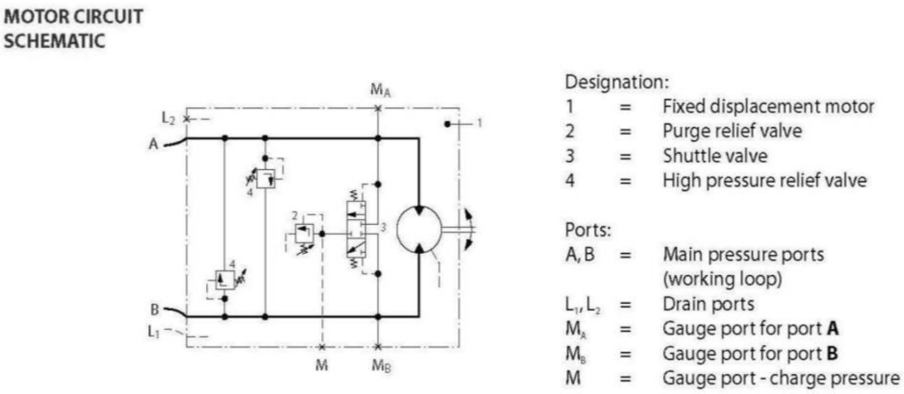

Figure 5 *Hydraulic scheme of hydro motor MH187JC*

Figure 6 *View of hydraulic motor MH187JC*

3 CALCULATION

Calculation is aimed at determining the required driving power of apron feeder and is given by [2] and [3].

- The required conveyor speed is:

$$v = \frac{Q}{3600 \cdot h \cdot \psi \cdot b \cdot \rho} =$$
$$= \frac{1600}{3600 \cdot 1.35 \cdot 0.8 \cdot 1.829 \cdot 1.86} \left[\frac{m}{s}\right]$$
$$= 0.12 \left[\frac{m}{s}\right]$$

where

$\psi = 0.8$ –coefficient of filling

- The required conveyor width with respect to the lump size of load is:

$$b \geq X_2 \cdot a + 200[mm] =$$
$$= 2.7 \cdot 200 + 200[mm] = 740[mm]$$

where:

$X_2 = 2.7$ –coefficient for sorted material

$a = 200[mm]$ –maximum lump size

The conveyor width meets the terms of lump size of load.

- The maximum static tensile force in chain is according to [3]:

$$S_{max} \approx 1{,}05 \cdot \{S_{min} + w \cdot [(q_t + q_0) \cdot L + q_0 \cdot L]\} + W_b =$$
$$= 1.05 \cdot \{2000 + 0.13 \cdot [(36333 + 2597) \cdot 6.4 + 2597 \cdot 6.4]\} + 94895 =$$
$$= 133273[N]$$

where:

$S_{min} = 2000[N]$ – minimum tensile force in chain

$w = 0.13$ – resistance coefficient of chain for sliding bearings and hard working conditions

$$q_t = \frac{Q \cdot g}{3.6 \cdot v} = \frac{1600 \cdot 9.81}{3.6 \cdot 0.12}\left[\frac{N}{m}\right] = 36333\left[\frac{N}{m}\right]$$ – weight of the load per length unit

$$q_0 = 600 \cdot b + A = 600 \cdot 1.829 + 1500\left[\frac{N}{m}\right] = 2597\left[\frac{N}{m}\right]$$ – weight of floor per length unit

$A = 1500$ –coefficient for floor length over 0.8 m and heavy floor type

- Force due to material friction with the hopper fixed sides is:

$$W_b = \mu_1 \cdot h^2 \cdot \rho \cdot g \cdot n_b \cdot l_b = 0.58 \cdot 1.35^2 \cdot 1860 \cdot 9.81 \cdot 0.82 \cdot 6[N] = 94895[N]$$

where:

$\mu_1 = 0.58$ - friction coefficient between the material and steel

$\varphi = 38°$ - angle of natural material falling

$l_b = 6{,}0[m]$ - lateral side length

$n_b = \frac{v+1.2}{1+sin\varphi} = \frac{0.12+1.2}{1+sin38°} = 0.82$ – coefficient of lateral pressure

- Pulling force on the drive sprocket is:

$$W = S_{max} - S_{min} = 133273 - 2000[N] = 131273[N]$$

- Power required to overcome the resistance forces of apron feeder motion is:

$$P_{TR} = \frac{W \cdot v}{1000 \cdot \eta} = \frac{131273 \cdot 0.12}{1000 \cdot 0.8}[kW] = 19.7[kW]$$

where:

$\eta = 0.80$-mechanical efficiency

- Cross section area of hopper opening is:

$$A = b \cdot c = 1.829 \cdot 1.6[m^2] = 2.93[m^2]$$

where:

$c = 1.6[m]$ - length of hopper opening

- Hydraulic radius of hopper opening is:

$$R = \frac{b \cdot c}{2 \cdot (b+c)} = \frac{1.829 \cdot 1.6}{2 \cdot (1.829 + 1.6)}[m] = 0.43[m]$$

- Internal friction coefficient of material is:

$$\mu = tg\varphi = tg38° = 0.78$$

- Coefficient of mobility is:

$$m = 1 + 2 \cdot \mu^2 - 2 \cdot \mu \cdot \sqrt{1+\mu^2} = 1 + 2 \cdot 0.78^2 - 2 \cdot 0.78 \cdot \sqrt{1+0.78^2} = 0.24$$

- Pressure force of material column on hopper opening is:

$$T = \frac{A \cdot \rho \cdot R \cdot g}{m \cdot \mu} = \frac{2.93 \cdot 1860 \cdot 0.43 \cdot 9.81}{0.24 \cdot 0.78}[N] = 122804[N]$$

- Power required to overcome losses due to the friction force caused by pressure of material column is:

$$P_P = \frac{T \cdot v \cdot \mu_1}{1000} = \frac{122804 \cdot 0.12 \cdot 0.58}{1000}[kW] = 8.5[kW]$$

- Total required apron feeder driving power is:

$$P = P_{TR} + P_P = 19.7 + 8.5[kW] = 28.2[kW]$$

4 DISCUSSION OF CALCULATION

As can be seen from the calculation the total required apron feeder driving power consists of the power required to overcome the resistance forces of apron feeder motion, and the power required to overcome losses due to the friction force caused by pressure of material column. The motion resistance force consists of the resistance force of carrying and return strands of apron feeder, the force due to raising material which is zero in this case because it is a horizontal conveyor, and force due to material friction with the hopper fixed sides. The resistance forces depend on operating parameters of conveyor, physical properties of material, and structural characteristics of feeder. The existing electric motor $P_{EM} = 37[kW]$ is satisfactory in terms of power.

Considerable speed reduction from electric motor to drive sprocket is obtained, in this case, applying the hydrostatic transmission and one stage reducer. The application of variable displacement hydraulic pump enables the speed regulation of apron feeder so that during start of drive, the apron feeder works with a minimum speed, and nominal speed is obtained at the steady operating conditions. Using the appropriate fittings in the hydraulic installation, the system overload protection is secured, i.e. maintenance the required operating parameters of oil. The single stage reducer transmitting the motion from the shaft driven by the hydraulic motor to the shaft with drive sprocket is positioned in such a way that the hydraulic motor shaft is free from radial force. Low speed of conveyor $v < 0.2[m/s]$ ensures the relief of inertial forces that occur during operation of chain conveyors. Thus, the driveline ensures correct and reliable operation of apron feeder in given conditions.

5 CONCLUSION

The exposed methodology for power calculation of apron feeder is one of the ways to calculate the verification in selecting a driveline or driveline verification for operation in the new working conditions. The equipment manufacturers also provide their own methods for calculating the required power of apron feeder which to a lesser extent vary from manufacturer to manufacturer. Likewise, various examples of power calculation of apron feeder can be found in literature, but basically the exposed method represents the logic of calculation.

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