DESIGN OF MINE SHAFT ELEVATOR

Asst.Prof. Dr. Gerdemeli I.1, Candas A.2, Unalan M.3
Faculty of Mechanical Engineering Istanbul Technical University - Turkey1,2,3

Abstract: This study is focused on basic design of mine shaft elevator. After discussing design basic of mine shaft elevators and criticizing advantages and disadvantages of them, mine case study will be illustrated. The using of elevators is increasing too and this situation encourages contractors to pay attention to vertical transport systems in mine industry. Technology changes every single day and elevator technology has to be developed for comfortable and reliable transports in mine area. Using elevators at such kind of places is vital for working. New design parameters will be compared according to old design parameters.

Keywords: MINE, MINE SHAFT ELEVATOR, BASIC HOISTING INSTALLATION.

1. Introduction

Even ancient civilizations needed to use vertical transportation in their routine. Hence, humanity used some kind of lifting systems which were work with the help of human or animal resources or water power.

The first elevator, which had gear system and ropes, was designed by a Greek scientist Archimedes.

Since the 80s AD, elevators began to be used in the Colosseum, in Italy. Gladiators and wild animals were transported by lifting systems. So, those systems officially started to take an important place in people's lives.

Even though elevators began to be used, nevertheless, there was a big problem with them. There was not any safety system in case if the ropes ruptured. It was the main disadvantage of elevators until Elisha Otis solved this problem with the first safety system that was developed for vertical transport systems. That was a system with some springs which were connected to carry a rope. Hence, if the rope was torn, the spring would have pushed the tooth and that tooth would cover the guide rails. Thereby, the car could be easily stopped without any difficulties [3-11].

Kinds of Elevators:

- Passenger elevators,
- Hoist elevators,
- Service elevators,
- Car elevators,
- Elevators for the disabled,
- Mining elevators.

Mining:

Almost all underground mines all over the World have hoisting installations. A small number of these installations can also be found in open cast mines. Generally, they are mounted on the surface, but some hoisting installations are located underground in very deep mines [1].

The ore and waste from the development work are transported to the shaft station and then hoisted to the ground surface. This, as well as ascent and descent of men, supplies and tools, is accomplished by the mine hoisting plant [2].

Mining process is made in four steps;

- Searching and finding mineral deposits,
- Exploration, discovering of location, amount and removal a coast of the ore body,
- Preparation, preparing a map to remove the ore in the most effective way,
- Operation, a period of removing the ore body.

There are two kinds of mines. When an ore body is close to the surface, then there is no need to have a mine shaft. By the removing a surface of the territory by heavy construction equipments it would be enough to gain minerals. This kind of mines is called "opencast mining". Contrarily, if an ore body is very deep, then there is supposed to be a mine shaft. Even though that costs even more, an opencast mining would not be used for that deep excavations and that process is called "deep mining".

When it comes to design of a mine shaft, there are two options: circular shafts and horizontal shafts (Figure 1, Figure 2).

Circular shaft is the most commonly used one. If the shaft should be deep and shaft diameter is supposed to be more than 4.5 meters, circular shafts are the best choice. Because of their circular shape, they are easier by the usage. Rectangular shafts, which use timber supports, are still commonly used [13-14]. Timber supports, bricks, and concrete blocks are common types of shaft liners used in the shafts with short life-span expectancies in a competent rock. However, in a rocks exhibiting of a high lateral pressures, these liners don’t withstand crafts well due to the bending moments created along the length of the excavation.

2. Design of Elevator

To prevent a potential danger at mining elevators, their components should be chosen carefully by correct calculations. Basically a mining elevator can be seen on figure 3.

![Fig. 1 A circular mine shaft.](image)

Suspension ropes are enwrapped around a drum and counterweight is attributed to the end of the suspension rope and the other end is connected to the car.
During a car (cage in mine) rising, a counterweight accelerates it. Contrarily, when the car descends, the counterweight slows it up, and in the result the less power consuming of the engine occurs.

Guide rails are indispensable components of elevator systems as well. Not just they balance a car, they help the car to move properly as well.

Any suspension rope, which is used for elevators, should have at least 1.6 cm dimension and they are supposed to be high-strength ones.

There are safety mechanisms which work together with brakes and acceleration sensors on elevator systems. Those sensors should be used in every lifting system. Because of that fact, if the safety system stops the elevator all the time, then the components of system would be strained and damaged. Therefore, when a car needs to stop, then acceleration sensors would find out the a high velocity and warn brakes. After that brakes stop the tambour and the elevator stops.

On the other hand, as a safety gadget "rope brakes" is used.

We work on a mine elevator. Their calculations:

Due to the high velocity (10.63 m/s), a DC motor is used for the system. From the catalogue, 1GG5631-5EQ40-2XY5 type DC motor is chosen.

\[ P = \frac{Q}{2} \]

\[ Q = 32 \text{ ton} \]

\[ N = 1651.18 \text{ kW} \]

\[ \text{In case of using two motors:} \]
\[ N = \frac{1651.18}{2} = 825.6 \text{ kW} \]

For the engine rpm (n):

\[ n = \frac{9550 \times \text{rpm} \times N}{M_t} \]

3. Parameters of Elevator

**Fig. 2 A horizontal mine shaft.**

In case if the velocity increases 15 % more than its normal speed, the tachometer, which is connected to the suspension rope, steps into the system and sends signals to a controller. Then the controller evokes a compressor. The compressor pumps air through respectively a water separator, manually switch off and check valve. A check valve prevents air from turning back to the compressor. Additionally, even when the compressor stops, on the side of the brake air pressure still remains in a satisfactory level. After the check valve, air divided into two arms and goes to the magnetic valves. If the valves are energized, the air supply is shut off. However, in case if energy is shorted, then which goes to the brake, is opened and the pressured air fill up the rope brake cylinder. The air pushes the pistons and the rope, which is between the pistons, is stuck, hence, the car stops.

**Fig. 3 A mining elevator**

**Fig. 4 The scheme of the mine shaft elevator.**

\[ N = 1651.18 \text{ kW} \]

\[ N = \frac{1651.18}{2} = 825.6 \text{ kW} \]
Tab. 1 Parameters of elevator

<table>
<thead>
<tr>
<th>Item</th>
<th>Technical Characteristics</th>
<th>Type and Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-rope frictional</td>
<td>Main guide wheel diameter</td>
<td>3500 mm</td>
</tr>
<tr>
<td></td>
<td>Pulley diameter</td>
<td>3500 mm</td>
</tr>
<tr>
<td></td>
<td>Max rope static tensile</td>
<td>887 kN</td>
</tr>
<tr>
<td></td>
<td>force</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max rope static tensile</td>
<td>78.48 kN</td>
</tr>
<tr>
<td></td>
<td>force diff.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rope quantity</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Max. hoisting speed</td>
<td>10.63 m/s</td>
</tr>
<tr>
<td>Motor</td>
<td>Type</td>
<td>JGG5631-SEQ40-2XV5</td>
</tr>
<tr>
<td></td>
<td>Power</td>
<td>1120 kW</td>
</tr>
<tr>
<td></td>
<td>Rotation speed</td>
<td>58 r/min</td>
</tr>
<tr>
<td></td>
<td>Voltage</td>
<td>720 V</td>
</tr>
<tr>
<td></td>
<td>Current</td>
<td>1620 A</td>
</tr>
<tr>
<td></td>
<td>Inertia moment</td>
<td>174 kgm²</td>
</tr>
<tr>
<td></td>
<td>Motor weight</td>
<td>7450 kg</td>
</tr>
<tr>
<td>Head rope</td>
<td>Type</td>
<td>6×19+FC</td>
</tr>
<tr>
<td></td>
<td>Rope diameter</td>
<td>40 mm</td>
</tr>
<tr>
<td></td>
<td>Tensile strength</td>
<td>1670 N/mm²</td>
</tr>
<tr>
<td></td>
<td>Unit weight</td>
<td>6.1 kg/m</td>
</tr>
<tr>
<td>Vessel</td>
<td>Type</td>
<td>5.3 m³ double-deck car</td>
</tr>
<tr>
<td></td>
<td>Counterweight</td>
<td>22000 kg</td>
</tr>
<tr>
<td></td>
<td>Dead weight</td>
<td>15300 kg</td>
</tr>
<tr>
<td></td>
<td>People carried</td>
<td>104 people</td>
</tr>
<tr>
<td>Crane</td>
<td>Lifting capacity</td>
<td>16t + 16t</td>
</tr>
</tbody>
</table>

\[ M_{N} = \text{Rated torque (16200 Nmm, from the catalogue)} \]

\[ n = \frac{95500 \times 95 \times 1120}{16200} = 627 \text{ r/min} \]

Rotation speed:

\[ n_{V} = \frac{v \times 60}{n \times \pi D_{F}} \]

\[ D_{F} = \text{Pulley diameter (3500 mm)} \]

\[ n_{p} = \frac{10.64 \times 60}{n \times 3.5} = 58 \text{ r/min} \]

4. Selection of the Suspension Rope

The degree of severity of each bend can be equated to a number of simple bends. A simple bend is defined by the rope travelling over a semi-circular groove where the radius of the groove is about 5 – 6% greater than the nominal rope radius. The number of simple bends corresponds to an equivalent number of pulleys \( N_{\text{quiv}} \), which can be derived from:

\[ N_{p} = N_{N} + N_{p} \]

\[ N_{\text{quiv}} = K_{p} (N_{N} + 4 \times N_{p}) \]

\[ K_{p} = \left( \frac{D_{F}}{D_{p}} \right)^{3} \]

\[ D_{F} = \text{Drive pulleys' diameter} \]

\[ D_{p} = \text{Other pulleys' diameter} \]

\[ K_{p} = \text{Proportion of drive pulleys' diameter with the other pulleys} \]

\[ N_{N} = \text{Number of pulleys with simple bends} \]

\[ N_{p} = \text{Number of pulleys with reversed bends} \]

Therefore:

\[ K_{p} = \left( \frac{3.5}{3.5} \right)^{3} = 1 \]

\[ N_{\text{equiv}} = 7.1 \]

\[ K_{p} = \text{Proportion of drive pulleys' diameter with the other pulleys} \]

\[ N_{p} = \text{Number of pulleys with reversed bends} \]

Hence:

\[ N_{\text{equiv}} = N_{\text{equiv}} (t) + N_{\text{equiv}} (p) = 7.1 \]

\[ 2 = 9.1 \]

Even though the suspension rope, which has 38 mm in diameter, is available. As it selected from the catalogue, that rope is shown as “-38 mm”, which means that this rope is a special product and costs pretty much. Thus, if the construction is able to handle the difference of weight, then we should use 40 mm diameter suspension rope. Between 38 mm and 40 mm suspension ropes, for 730 meters height, there is difference in 438 kg and the system is able to handle this difference. Therefore, as the suspension rope of the elevator is chosen as 40 mm diameter.

5. Selection of the Guide Rails

The calculations will be done in terms of the guide rails which are chosen from the catalogue.

\[ n = \text{The number of suspension ropes} \]

\[ i = \text{Rope selection factor} \]

\[ g_n = \text{Gravitational acceleration} \]

\[ F_{\text{max}} = g_n \times (P + Q + H)/(n.i) \]

\[ S = \frac{\text{Tmin}}{F_{\text{max}}} > S_{f} \]

\[ \text{Tmin} = \text{Min. rupture force according to the standards} \]

\[ H = \text{The weight of the suspension ropes provided that if the car is at the bottom} \]

\[ n = \text{The number of suspension ropes} \]

\[ i = \text{Rope selection factor} \]

\[ g_n = \text{Gravitational acceleration} \]

\[ F_{\text{max}} = 9.81 \times \frac{(15500+8320+4453)}{(4 \times 2)} \]

\[ F_{\text{max}} = 32160.53 \text{ N} \]

\[ S = \frac{\text{Tmin}}{F_{\text{max}}} > S_{f} \]

\[ \text{Tmin} = 887 \text{ kN} \]

\[ S = \frac{887000}{32160.53} = 27.58 > 6.811 \]

\( S_{f} \) (The suspension rope is reliable)

Even though the suspension rope, which has 38 mm in diameter, is available. As it selected from the catalogue, that rope is shown as “-38 mm”, which means that this rope is a special product and costs pretty much. Thus, if the construction is able to handle the difference of weight, then we should use 40 mm diameter suspension rope. Between 38 mm and 40 mm suspension ropes, for 730 meters height, there is difference in 438 kg and the system is able to handle this difference. Therefore, as the suspension rope of the elevator is chosen as 40 mm diameter.

Even though the suspension rope, which has 38 mm in diameter, is available. As it selected from the catalogue, that rope is shown as “-38 mm”, which means that this rope is a special product and costs pretty much. Thus, if the construction is able to handle the difference of weight, then we should use 40 mm diameter suspension rope. Between 38 mm and 40 mm suspension ropes, for 730 meters height, there is difference in 438 kg and the system is able to handle this difference. Therefore, as the suspension rope of the elevator is chosen as 40 mm diameter.
The guide rails should be calculated according to three situations:
1) In case of safety system works;
2) Nominal use by moving
3) Nominal use by having loaded
For the x-axial;
The bending stress is:

\[ F_x = \frac{k_1 \times g_x \times (Q_x + P_x \times x)}{h} \]

\( h \): The distance between the car's rollers of the rail (4500 mm)
\( k_1 \): 3 (a constant coefficient of impact)
\( F_x = 205.898 \text{ N} \)
\( F_y = 0 \)
\( M_y = \frac{3205.898 \times 3000}{16} = 115818.06 \text{ Nmm} \)
\( \sigma_y = \frac{115818.06}{11300} = 10.25 \text{ N/mm}^2 \)

The bending:

\[ F_k = \frac{k_1 \times g_k \times (P + q)}{n} \]

\( F_k = \frac{3 \times 9.81 \times (8320 + 15500)}{147} = 4768.86 \text{ N} \)

Selection of buffers and brakes are made by calculation and catalogue findings.
Ropes are a vital part of the mine shaft elevators, the safety of hoisting being largely dependent upon their reliability.
All calculation are made by computers again and both values are compared and design parameters are decided by engineers.

6. Conclusions

Elevator (hoisting) design for Mine Shaft systems is the subject of the study. Design for Mine Shaft is considered for basic well. Elevator parameters are calculated and the values of design parameters for both computers are compared. An analyze of computer and the calculations are investigated.

References

[14] https://wiki.queensu.ca/display/mine448/Mine+Shaft+Development