STUDY ON THE TECHNICAL CONDITION OF THE SHEAVE WHEELS IN THE HOIST TOWER OF SLANIC PRAHOVA SALT MINE

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ABSTRACT: This paper approaches aspects concerning the technical and functional degradation of the sheave wheels in the hoist tower, which determines the need for replacing the whole operational group through designing and machining, so that it might provide the increase of the safe functioning of the hoist system.

With these in view, modern investigation analyses have been employed together with calculi so that the results were well grounded and allowed the devising and designing of new solutions, able to meet the concept of functionality and modernity. The settling of the previously mentioned issue appears to be applicable to other similar situations.

KEYWORDS: sheave wheel, slide bearing, shaft, hoisting plant, hoist tower

1. INTRODUCTION

The mine shaft hoisting equipment are industrial systems displaying increased complexity and importance for the technological process of extracting minerals. This category of equipment represents a decisive factor in the functioning of the mining plants; the modernization processes designed for maintaining exploitation and for increasing technical and economic performance represent the only feasible option for continuing the hoisting process.

Under such circumstances and in order that such devices keep functioning at their full capacity, they should be designed so that they provide a high degree of safety and rely on decreased operation and maintenance costs. In this context, problems regarding the functioning of the hoist utilized for the transport of the workers and the materials between surface to underground occurred at Slanic Prahova salt mine.

These problems were triggered by the technical damage of the sheave wheels, in general, and of guide pulleys (deflexion sheaves), in particular.

Guide pulleys (deflexion sheaves) are used in the case when the hoisting plant main drive together with the winding drums are located at the ground level. Guide pulleys (deflexion sheaves) are used for bringing the rope’s branches closer and for increasing rope’s winding angle on the drum, resulting in a fleet angle between 45 and 90 degrees, depending on requirements.

The constructive form of the sheave wheels differs depending on the profile used for manufacturing the rim and on the profiles on which the spokes are made of. The sheave wheels, as parts of the hoisting plant, are located in the tower, fitted on

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the sheave wheel’s shaft blocked through wedges; when functioning, they work as a joint body.

Both the guide pulleys (deflexion sheaves) and the shaft are supported by slide bearings located in the tower of the hoisting engine.

Figure 1 displays the damaged guide pulley (deflexion sheave), located in the hoist tower of Unirea Mine belonging to Slanic Prahova salt mines. The increased wear out of the wall of the hoisting rope groove has determined its cracking and then breaking, with consequences that have resulted in the equipment’s removal from operation.

With a view to determining mass loss due to the phenomenon of wear out, measurements of the mass of the damaged sheave wheel have been carried out.

The value of the measured mass has been compared with the initial mass of a new sheave wheel that resulted in the mass loss due to damage.

Figure 1.a displays the left sheave wheel (viewed from the hoisting device) that was damaged due to the breaking of the inner wall of the rope groove. The breaking occurred due to the diminishing of the wall thickness, Figure 1.b, determined by the adherence damage caused by the contact between the rope and the wall of the groove.

This damage of the lateral wall of the rope groove was also determined by the five lateral channels required for introducing the lining packages along the groove in the rim of the sheave wheel. Figure 1.c displays the sheave wheel suspended on a dynamometer, for weighting, while Figure 1.d shows the
dynamometer which was calibrated in laboratory before using it for measurements.

2. OVERVIEW ON THE DEVISING SOLUTION FOR THE 2500 mm SHEAVE WHEELS

In order to settle the new devising solution for the 2500 mm existing sheave wheels, a dimensional and devising mapping of the old sheave wheels was carried out. Figure 2 shows the devising solution of the sheave wheel’s hub that is in cast steel. The hub includes the central bushing collar on the extremities of which two flanges rigidized between one another through 10 rifts.

Figure 2
The sheave wheel’s hub with the shaft

Figure 3
Overall devising solution for 2500 sheave wheel
1 – 2500 mm actual sheave wheel; 2 – shaft; 3 – inclined wedges 36x15x370; 4 – left bearing; 5 – right bearing; 6 – bearing’s support plate; 7 – special bolt with square cap M27x140; 8 – flat collar M27; 9 – bolt nut M27; 10 – I30 beam in profile
On each exterior part of the flanges, ten radial seats are shaped where spokes are positioned; the spokes are attached each through three fitting bolts M20x85. Within the boring of the 160 mm-diameter hub, there are two wedge grooves with a width of 36 mm and located on the circumference, at a 120 degree angle.

The sheave wheel displaying a ratio between its width and its diameter lower than 1/10 (220/2630 = 0.083) only allows static balancing in accordance with the specifications found in the literature.

Figure 3 shows the overall designing having resulted from the mapping made at Unirea Mine. It contains all the details required for starting the redesigning and modernizing process. In accordance, Figure 4 displays the devising solution of the slip bearing, while Figure 5 exhibits the sheave wheel’s shaft.

**Figure 4**
Devising solution for the slip bearing of the sheave wheel
1 – lower bearing support; 2 – partial bearing; 3 – tenon M22x180; 4 – bolt nut M22; 5 – upper bearing support; 6 – partial greasing ring; 7 – greasing hood; 8 – bolt for the greasing hood; 9 – catch pin 2,5x10; 10 – bearing hood; 11 – bolt with jagged cylindrical head M5x10; 12 – Grower collar A5.

**Figure 5**
Devising solution for the shaft
The analysis of the devising forms of the sheave wheels shows that, in general, they are different from one other owing to the nature and profile of the rim and spokes, to the type of hub and to the model of bearing, etc. In accordance, specialized works assert that the durability of hoist ropes is positively influenced in the case when the rope groove is lined with wood, rubber, leather, plastic, etc. Nonetheless, the main drawbacks of all lining are the following ones: complicated devising of the sheave wheel’s rim; occurrence of timeouts during hoist due to the need for checking and replacing the lining; increase of manufacturing and maintenance costs of the sheave wheel.

In accordance with the data obtained and the devising documentation drawn out for the analysed sheave wheel, technical characteristics were settled and further compared with the values recommended by literature. The technical characteristics and the values recommended for the 2500 mm-diameter sheave wheel are displayed below.

### Table 1.
Technical characteristics of the 2500 mm sheave wheel

<table>
<thead>
<tr>
<th>No.</th>
<th>Appellation of technical characteristic</th>
<th>Notation</th>
<th>Measure unit</th>
<th>sheave wheel value</th>
<th>Recommended value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Rope diameter</td>
<td>d</td>
<td>mm</td>
<td>28</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>sheave wheel diameter</td>
<td>Dm</td>
<td>mm</td>
<td>2500</td>
<td>≥ 80*28=2240</td>
</tr>
<tr>
<td>3.</td>
<td>Curvature radius of the mantle ring's groove</td>
<td>r</td>
<td>mm</td>
<td>15</td>
<td>≥ 0.53*28=14.84</td>
</tr>
<tr>
<td>4.</td>
<td>Groove’s depth</td>
<td>h</td>
<td>mm</td>
<td>65</td>
<td>≥ 1.5*28=42</td>
</tr>
<tr>
<td>5.</td>
<td>Thickness of the lip of the groove's wall</td>
<td>a</td>
<td>mm</td>
<td>15</td>
<td>≥ 28/3+3=12.3</td>
</tr>
<tr>
<td>6.</td>
<td>Thickness of the full side of the rim under the groove</td>
<td>b</td>
<td>mm</td>
<td>30</td>
<td>≥ 28/3+10=19.3</td>
</tr>
<tr>
<td>7.</td>
<td>Opening angle of the groove</td>
<td>z</td>
<td>grade</td>
<td>42</td>
<td>2[°] = 40 ... 45</td>
</tr>
<tr>
<td>8.</td>
<td>Exterior diameter of the sheave wheel</td>
<td>De</td>
<td>mm</td>
<td>2630</td>
<td>≥Dm-d+2h=2264</td>
</tr>
<tr>
<td>9.</td>
<td>Width of the mantle ring</td>
<td>l+2a</td>
<td>mm</td>
<td>110</td>
<td>-</td>
</tr>
<tr>
<td>10.</td>
<td>Maximal width of the sheave wheel (bolts' area)</td>
<td>-</td>
<td>mm</td>
<td>345</td>
<td>-</td>
</tr>
<tr>
<td>11.</td>
<td>Mass of the sheave wheel</td>
<td>-</td>
<td>kg</td>
<td>1233.2</td>
<td>As low as possible</td>
</tr>
<tr>
<td>12.</td>
<td>Momentum of gyration of the sheave wheel</td>
<td>-</td>
<td>kg⋅m²</td>
<td>993.05</td>
<td>As low as possible</td>
</tr>
</tbody>
</table>

### 3. CALCULATION BREVIARY FOR FUNCTIONAL AND DIMENSIONAL CHECKINGS

In order to settle the functioning conditions, a calculation model for determining the loads that stress the sheave wheels has been drawn out. The scheme of the equipment upon which the calculation model relies in order to determine the loads of the sheave wheels is displayed in Figure 6.

The calculation breviary started from the positioning sizes of the sheave wheels’ axis against the drum of the hoisting engine and tower allowing the determining of the geometrical functioning elements of the sheave wheels, such as:

- Minimal distance between the axis of the drum and the vertical axis of the rope, in mm:
  \[ b_{mi} = 0.6 + H + Dm = 1.805 \cdot 10^4 \]  \( (1) \)
- Resistance factor of rope winding
-Rope’s safety coefficient at breaking
\[ C_{src1} = \frac{S_{rc}}{\varepsilon_1 S_{1\text{max}}} = 8.37 \]  
\[ C_{src2} = \frac{S_{rc}}{\varepsilon_2 S_{2\text{max}}} = 8.36 \]

-Angle between two consecutive spokes
\[ \theta = \frac{360\pi}{180} = 0.628 \]

-Reactions in the spokes clamping points, in N:
\[ R = 0.5 \cdot P_{c1} \cdot 1 = 1.905 \cdot 10^4 \]

-Maximal contact pressure along length unit, in N/mm
\[ P_{clr} = \frac{(1 + \varepsilon_1) S_{rc}}{Dm \cdot \sin(\varepsilon_2 - 0.5)} = 8.37 \]

**Figure 6**

Scheme of the calculation model of the loads of the sheave wheel

The slide bearing of the sheave wheel was checked for contact pressure (Fig.7); in accordance, for the anti-friction alloy Y-Pb98, which has an admissible value for the pressure-speed product equal with 6, a safety coefficient of 6.63 for a rope speed of 4 m/s, namely 30.56 rot/min has resulted.

In the case when at the location of the passage hole through the beam, a 1 mm free clearance comes out and at the location of the passage hole through the foot of the bearing a 1.5 mm free clearance comes out, then a rotation angle of the sheave
wheel’s axis of 0.34 degrees comes out. This rotation angle of the sheave wheel’s axis is higher than the existing rotation angle $\beta_m = 0.327$ degrees.

$$A_{cal} = d_c \cdot l_c \cdot N_c = 1.56 \cdot 10^4$$

- Contact pressure, in N/mm$^2$:
  $$p_{cal} = \frac{R_s}{A_{cal}} = 4.712$$

Figure 7
Calculation scheme (a) and variation model of the rotation angle of the bearing’s axis depending on the free clearance between the draw bar of the bolt and the passage hole (b)

4. CONCLUSIONS

This study shows the need for designing new solutions able to match the needs requirements of functioning and designing of the hoisting plant so that it might resist longer. The calculations, reasoning extracted and comparative analyses show a series of important elements, such as:
- The high contact pressure between the rope and the sheave wheel’s groove determines a rapid damage of the wood lining of the groove;
- The replacement of the groove’s lining was difficult and determined long interruptions of the functioning of the hoisting engine;
- The devising of the sheave wheel from founded parts set up to the spokes through fitting bolts is a complex construction with increases manufacturing costs;
- The devising of the slip bearing and its functioning at the moment of the mapping raises a lot of questions regarding the manner of exploitation of the sheave wheel in time;
- Tower rotation and torsion due to landslides require the permanent checking of the positioning of the sheave wheels against the hoisting engine, of the value of the rope deviation angle when winding on the sheave wheel.
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