REDUCERS FOR MAIN DRIVES OF ROLLING MILLS

Sergey LAGUTIN - Eugene GUDOV - Alexey KLOCHKOV
JS Co “EZTM”, Electrostal, Russia

Received (24.05.2012); Revised (21.05.2013); Accepted (05.06.2013)

Abstract: The experience of the Electrostal Heavy Machinery Plant in the design and production of special reducers and pinion stands for main drive of various rolling mills is summarized. Specificity of profiled and ball-rolling, piercing and reduction mills, mills for cold rolling tube and for the production of reinforcing bars are considered. The load sequence diagram depends both on the range of rolled products and variable loadings in a rolling cycle of a workpiece. Geometric parameters of gears are optimized by criteria of contact and bending equal strength both between the stages and within them. Technological means are provided and secured for carburizing, hardening and grinding of the teeth.

Key words: reducer, pinion stand, rolling mill, load sequence diagram.

1. INTRODUCTION

During the 70 years of its history Electrostal Heavy Machinery Plant (EZTM) has accumulated rich experience in design, manufacturing and delivery of complete rolling mills, both for Russia and other countries. The complex of machines and mechanisms for rolling mills is equipped with various special gearboxes used in the main drive as well as in the accessories. The traditional scheme of any rolling mill drive includes a main reducer, which provides the required gear ratio between the motor and the working stand, and pinion stand for distributing the transmitted torque between the rollers of the working stand [1-3]. The universal or gear spindles connect the pinion and work stands and provide the possibility of the drive when the distance between the working rollers changes after each re-sharpening. [4].

One of the ways to improve the working lines of mill is the combination the main reducer with pinion stand and other mechanisms, which allows reduction the production area, labor intensity and cost of the rolling product [3]. This paper describes the evolution of various special gearboxes for rolling equipment. Developments that are protected by patents of the Russian Federation [5-8] are mostly described.

2. DESIGN FEATURES OF REDUCERS FOR ROLLING MILLS DRIVE

The serial reducers of general application are designed based on the condition of constant load during the warranty period. In the design of the gearbox for the drive of the special-purpose machines the specific features of these machines (the drive loading sequence diagram first and foremost) must be considered.

Calculation of gear durability is performed using the software package REDUK 4.3, which was developed in the late 90’s under GOST 21354-87 by TSNIITMASH at the request and with the participation of EZTM.

An important feature of this package is the possibility to perform calculations of the strength of gears for the expected sequence diagrams loading. The calculation results determine the torque on the output shaft of the gearbox, allowed by contact and bending endurance of the teeth of the each stage.

In the design of multi-stage gearbox its main geometrical parameters: center distances and gear ratios of stages, modules and width of gears must be selected in such a way as to ensure equal safety factors for each of the mentioned criteria. As the source data in the loading sequence diagram changes, each of these torques changes significantly both in absolute value and the ratio between them. Geometric proportions of the gearbox that are optimal for a constant loading usually require significant changes to the stepwise loading sequence diagrams.

The designer of special gearboxes for main drive of particular mill, can and should know and accept:
- Product range rolled on this mill and the expected percentage of time engaged with each rolling size,
- Modes (torque and speed) for each of the rolling sizes,
- The ratio of working and idle strokes per rolling cycle.

Based on these data it is necessary to build a loading sequence diagram for each of the steps that specifies:
- The ratio of the drive shaft torque to the highest one,
- The relative duration for each of the torques,
- The frequency of rotation of the drive shaft, r.p.m.

For example, the piercing mill of the tube aggregate "400" of Seversky Tube Work is planning to pierce the workpieces with Ø400 and Ø290 under the rolling conditions given in Table. 1.

Loading sequence diagram is drawn in relative units beginning from the step with the highest torque and allows counting up to 10 steps. In this example, five steps are included as shown in Table. 2.
### Table 1. Mode parameters of rolling

<table>
<thead>
<tr>
<th>Mode parameter</th>
<th>Workpiece dia, mm</th>
<th>400</th>
<th>400</th>
<th>290</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle feed rollers, degree</td>
<td>11</td>
<td>9</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Rolling torque, kNm</td>
<td>1300</td>
<td>1100</td>
<td>850</td>
<td></td>
</tr>
<tr>
<td>Idle torque, kNm</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Workpiece speed, r.p.m.</td>
<td>60</td>
<td>60</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Cycle time rolling, sec.</td>
<td>65</td>
<td>65</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Time under load (machine), sec.</td>
<td>24</td>
<td>27</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Time of idle strokes (pause), sec.</td>
<td>41</td>
<td>38</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Percentage of the mill loading, %</td>
<td>20</td>
<td>20</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Loading sequence diagram

<table>
<thead>
<tr>
<th>Torques on the drive shaft in the relative units:</th>
<th>1,000</th>
<th>0,850</th>
<th>0,050</th>
<th>0,650</th>
<th>0,050</th>
</tr>
</thead>
<tbody>
<tr>
<td>The relative duration of the torque action:</td>
<td>0,074</td>
<td>0,083</td>
<td>0,243</td>
<td>0,243</td>
<td>0,300</td>
</tr>
<tr>
<td>Rotational speed of the drive shaft, r.p.m.:</td>
<td>350,0</td>
<td>350,0</td>
<td>350,0</td>
<td>480,0</td>
<td>480,0</td>
</tr>
</tbody>
</table>

The source data also include the maximum short-run torque around which the contact and bending strength of the teeth are verified under the peak load, both accidental and periodical, that act less than 5% of the work time, for example, in the moment of the workpiece capture. The nature of the load application - single-sided or reversible, symmetrical or asymmetrical should be specified.

In addition to the results of the strength calculation of the gears, the cited program provides source data for the calculation of shafts and bearings, in particular the forces acting in meshing and speed of each of the shafts for the first step of the sequence diagram. Also the factors of sequence diagram related to the highest point are calculated for the design of shafts $E_v$ and bearings $E_p$ (for this example $E_v = 0,721$ and $E_p = 0,624$).

### 3. PIERCING MILL MAIN DRIVE.

Two-stage herringbone reducer CD-1600 is designed to drive each of the two working rolls of piercing mill. At a mass of 77 tons, it is one of the largest gearboxes, manufactured by EZTM. But its main advantage is not its weight but technical characteristics.

In its designing our earlier experience allowed optimization of the gear parameters based on the contact and bending equal strength of each stage that take into account the technological capabilities of hardening and gear-cutting equipment as well as the above sequence diagram loading.

A number of bold design and technological solutions were proposed and tested. One of them was a shrink fit of finally cut gear rims on the hub with a preliminary calculation of the teeth deformation after the press-on. Such solutions have allowed us for the first time in our practice to manufacture reducer with rated torque at low speed shaft 1000 kNm.

Two gearboxes of this type for the tube aggregate "400" were furnished for the Seversky Pipe Plant and successfully operated under the heaviest rolling conditions. The regular monitoring of the gearboxes showed that after a short time running-in wear of the teeth active surfaces their condition was stabilized, and after more than five years, the gears did not require replacement parts.

Moreover, currently the plant management has decided to upgrade the piercing mill by increasing the electric motors capacity from 4000 to 6000 kW. In doing so, EZTM set the task to build the gears in the existing gearbox housings, which allows the increase of the low-speed shaft torque to 1300 kNm. This problem was solved by replacing the materials and increasing the hardness of gears. In particular, the hardness of through hardened high-speed herringbone pinions was raised to Rockwell 42..47, which required significant improving the technology of their thermal and mechanical processing.

### 4. COMBINED GEARBOXES FOR THE MAIN DRIVE OF ROLLING SECTION MILLS.

Rolling section mills are designed for production of round and polygonal rods, angles, channels and other types of long products. To ensure full crimp the rolled material in the mills working stands with the horizontal position of the work rolls axes must alternate with the vertical arrangement. The drive for each horizontal mill stand is powered by a three-stage helical reducer combined with pinion stand.

The drive for vertical work stands is set to work through the combined bevel-helical gearboxes. [3] The last stage of these gearboxes is hollow gear shafts, within which the connecting spindles are placed. Gear ratios decrease from cage to cage, providing the increased speed of rolling with the draw ratio and ride diameter of the work rolls. The drive shafts of all gearboxes are installed at the same level that allows the placement of the drive motors on a common platform and to simple maintenance. (Figure 1)

To move the vertical working stand for setting and handling, its frame must be equipped with a screw-driven lift, which is usually built as worm gear reducers. One of the latest designs has a zone free of the main gears in the bottom of the main gearbox, where the worm gear lifting mechanism is placed. [8] The combination of the main
and auxiliary drives allowed reduction of the production cost and simplification of the installation and maintenance of all setup and improvement of reliability of the drive. To drive the horizontal housingless stands was able to realize a very compact design solution, in which the spindles that move the work rolls, skipped through the hollow gear shaft of the combined gearbox that allows to bring the drive close to working stand and to reduce the shop area. [3]

The described combined gearboxes have been mounted in the rolling mill 450 for Helwan Steel Plant in Egypt, in the mill 650 for Isfahan Steel Plant in Iran, in the mill 350/250 for Steel Plant "Electrostal" and for a number of other mills.

5. MAIN DRIVE OF BALL-ROLLING MILL

The balls are made by hot rolling between two helical grooved rolls, which are intersected at a small angle and are rotated in the same direction. The complexity of gear box designing for these mills is the need to transfer high torques at small distance between the output shafts. In the latest mill designs we changed the traditional layout of the gearbox relative to the working stand and thus reduced the weight of gear box from 23 to 8 tons, maintaining its carrying capacity. [7]

Ball-rolling mills with the main drive reducers of this design were delivered and successfully used in Guriyevsk and Bekabad, in Mexico and India.

6. REDUCING-STRETCHING MILL DRIVE

One of the main design requirements for this drive is the closest possible location of the three-roll working stands. To achieve this goal some one- or two-stage gears are arranged in three rows in a single case of the main gearbox. They provide rotation of the output shafts with the increased speed of rotation governed by a prescribed law. The first of such gearboxes with 24 output shafts is described in detail in [1]. Further improvement of the design of this gearbox allowed reduction of its weight from 88 to 55 tons.

The last reducer of this series was designed in 2006 for 15-cage mill of Dnepropetrovsk Pipe Plant. The design feature of this gearbox is the possibility of its installation at an inclination angle to the horizon to 60°, as required by the conditions of rolling.

7. GEAR STANDS FOR REINFORCED BAR

Manufacturing pre-stressed concrete is considerably simplified if rebar profile is made with a screw groove. [6]. During rolling these profiles the rotation of working stand rolls must be carefully synchronized, which is provided by engagement of two helical gear-shafts of the gear cage. On the other hand, in the process of setting up the cage working rolls should smoothly rotate relative to one another, providing a match of their gauges. To resolve this contradiction, pinion cage design has provided the possibility of axial displacement of one herringbone shaft.

Figure 3 shows the design of such pinion stand. It contains one input pinion shaft with two helical crowns of different directions and two output shafts. Helical crown 1 of input shaft engaged with the rim of the lower output shaft 2 via stray gear 3. The second helical crown 4 is engaged with the rim of middle output shaft 5.
When setting up the position of the working stand calibrating rolls the input gear shaft can move axially using a mechanism, which includes a "screw-nut" couple and the worm gear. With this move one of the output shafts rotates relative to the other one into alignment of the work rolls gauges, after which the unit is fixed in this position.

The proposed solution was implemented in the design of the working line finishing mill stand 350 for Donetsk Metallurgical Plant.

8. MAIN REDUCERS FOR CRT MILLS.

A distinctive feature of the drive of cold rolling tube mills is the rapid reciprocating motion of a massive working stand. As a result, dynamic loads arise, which even with the partial equilibration are comparable with the work loading and may even exceed it considerably.

Approximate change of the output torque value of the gearbox during a double stroke of the working stand is shown in Figure 4. In this graph, $\alpha$ is the angle of rotation of the crank, $T_q$ is the workload with the friction force, $T_d$ is the torque of inertia forces, $T$ is the total torque. As can be seen from the figure, the value of torque $T$ is not only essentially variable, but at the end of the working and particularly idling strokes can even change sign, turning the electric motor as a generator.

In 2007, the mill CRTR-350 was delivered to the company TISCO, China, and successfully put into operation. Currently, a similar mill is being produced by our plant for the WILH.SHULZ GmbH, Germany.

9. CONCLUSION

In order to correspond today's world level the design of the main drive special reducers for various rolling mills should:

- take into account the specifics of the mill operation, first of all the load sequence diagram depending both on the expected range of rolled products and on the rolling cycle of a single piece;
- optimize the geometric parameters of the gears by the criterion of equal contact and bending strength both between the stages and within each of them;
- provide and ensure manufacturing all gears with high hardened, carburized and ground teeth.

REFERENCES

[5] Pat №1776211, RF, Int. Cl. B21 B35/12 Pinion stand of Main Drive of Rolling Mill (Kovtushenko A.A et al)
[6] Pat. №2009742 RF. Int. Cl B21 B35/12. Lengthwise Rolling Mill for Periodic Sections (Serman B.A. et al)
[7] Pat. №2162025 RF. Int. Cl B21 H1/14. The Main Line of Ball-Rolling Mill (Kovtushenko A.A et al)
[8] Pat. №2163174 RF,. Int. Cl B21 B13/06. Multistrand Vertical Longitudinal Rolling Stand. (Serman B.A. et al)