Transactions on Computational and Scientific Methods | Vo. 2, No. 2, 2022
ISSN: 2998-8780
https://pspress.org/index.php/tcsm
Pinnacle Science Press

Enhancing Coal Shearer Traction Units: Gearbox Optimization and Industry Applications

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Abstract: As the modernization of the coal industry advances, the haulage department of coal mining machinery faces elevated demands. Two fundamental requirements imposed on the haulage unit of shearers by the contemporary coal industry are increased traction and reduced size. Addressing the issue of the excessive volume of the traction unit, the reduction in size is accomplished by enhancing the transmission mode of the reduction unit, configuring the gear ratios of transmission gears at various levels, and optimizing the gear parameters at each level.

Keywords: Sheare; Traction department; Gearbox.

1. Introduction

Coal accounts for about 70% of China's energy consumption. At present, due to the downturn of the national economy, China's coal industry as a whole is in a downward cycle, but in the overall pattern of the national economy, coal occupies a pivotal strategic position; in the long run, coal's share in China's energy structure The proportion of coal will become smaller and smaller, but the characteristics of China 's coal-rich, lean, and gas-deficient resources determinethat coal is the main body of China 's energy consumption; in the long run, the rapid development of China 's macro-economy provides continuous growth in coal demand[1]. Withthe implementation and promotion of various national industry policies, the coal industry's concentration will be further improved, the industrial structure will be optimized, and the scale and modernization of the coal industry will be strengthened, laying an important foundation for the optimization and upgrading of the coal industry. basis.

As the vital part of the shearer, the traction unit is responsible for driving the entire shearer along the scraper conveyor. If there is a problem in the traction section, the entire shearer willnot work properly. The transmission mode of the reduction box of the traction unit is unreasonable, the layout of the transmission device is not compact, and the gear ratios of the transmission gears at all levels are unreasonably allocated, which makes the reduction box bulky, not only wasting downhole space, but also the long-term vibration will seriously affect the Service life. In this paper, the transmission mode, transmission arrangement, gear ratios and gear transmission parameters of the gearbox's reduction gearbox are improved[2].

2. Optimization Work

2.1. The Overall Layout of the Mechanical Transmission

The design is to solve the problems of determining the number of planetary gears, determining the number of stages of the reducer, and how to allocate the transmission ratio of the gears at each level under the given transmission ratio and input torque.The transmission method adopts three-stage fixed-shaft gear and two-stage NGW planetary series reduction.

Under the requirements of ensuring equal-strength design, a π-type mechanical transmission compact layout is proposed, with the traction motor at the bottom right and the output gear at the bottom left. Double requirements with transmission distance. The transmission method adopts three-stage fixed-shaft gear and two-stage NGW planetary tandem reduction mechanism. The transmission ratio is large and the structure is compact, which has created conditions for reducing the volume of the traction unit transmission mechanism[3,4]. The high-speed stage of the mechanical transmission device is planned to adopt two-stage helical cylindrical gear transmission, the intermediate stage adopts planetary gear transmission, and the final stage adopts open gear transmission in which the driving wheel and the double traveling wheel are meshed to make full use of the external space of the box. The introduction of idler 2 in the first-stage fixed-shaft straight-tooth transmission can not only provide a certain transmission ratio, but also give the working space of the foot traction motor, and it can also change the final defense line of the transmission to better complete the layout of the π-type gear system. The π-type layout is compact in installation, which can increase the effective space available, greatly reduce useless space, and make the assembly more compact. As shown in Figure 1.

2.2. Optimum Gear Ratio Configuration

Working parameters of the shearer: 24-hour continuous working system, service life of 17000h, driving power of 90KW; input torque of 591Nm, input/output speed of 1470/5.126rpm, total transmission ratio of 286.76, driving wheel to walking wheel transmission ratio of 1.467, reduction gearbox transmission ratio 195.518.

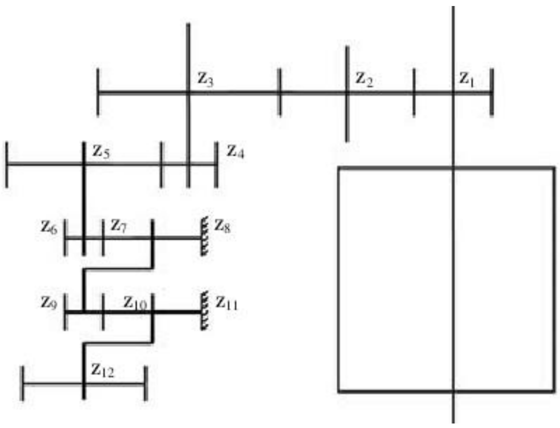

Fig 1. Drive system diagram

2.2.1 Optimization of gear ratio distribution of three-stage fixed-shaft gear train

According to the contact strength conditions, the objective function of the optimal distribution of the transmission ratio of the two-stage fixed-shaft gear train is obtained. The volume of the fixed-shaft gear train device is

$$V_1 = CK_1T_i\left[\frac{(u_1+1)(1+u_1^2)}{u_1}+\frac{(u_2+1)(1+u_1^2)u_1}{u_2}\right]$$

$$C = \pi[Z_E Z_H Z_\varepsilon]^2/2\sigma_H{}^2 \tag{1}$$

In the formula, K_1 is the load factor;T_i is the nominal torque transmitted by the pinion, Nmm; u is the gear ratio (for a fixed-axle gear train, it can be considered a gear ratio).

According to the principle of equal strength, the transmission power of all levels is equal, and the constraint conditions are obtained after simplification.

$$\frac{d_1}{d_3} = \sqrt[3]{\frac{u_2(u_1+1)}{u_1^2(u_2+1)}} \tag{2}$$

In the formula, d_1 and d_3 are the diameters of the driving gears of the two-stage transmission high-speed and low-speed stages, respectively.

In order to ensure the bearing capacity of the gear, the strength and rigidity of the gear shaft, the life of the bearing and the grinding of the shaft gear, the transmission ratio of the single- stage gear fixed shaft reduction drive must be 1~7, that is,$1 \le u_1 \le 7$,$1 \le u_2 \le 7$.

From the above constraints, it is concluded that the reduction ratio of the high-speed fixed-axis gear is $u_1 = 1.36$ and $u_2 = 1.38$,low speed fixed shaft gear reduction ratio is $u_3 = 1.38$.

2.2.2 Planetary gear train transmission ratio optimization The total volume of the planetary transmission is

$$V_2 = \frac{CK_1T_1}{n_{P1}}\cdot\frac{u_{aH1}}{u_{aH1}-2}(u_{aH1}-1)^2 + \frac{CK_2T_2}{n_{P2}}\cdot\frac{u_{aH2}}{u_{aH2}-2}(u_{aH2}-1)^2$$

$$= CK_1T_1\left\{\frac{u_{aH1}(u_{aH1}-1)^2}{3(u_{aH1}-2)}+\frac{u_{aH2}(u_{aH2}-1)^2}{4(u_{aH2}-2)}\right\} \tag{3}$$

In the formula, T_1 and T_2 are the pinion input torques of the low-speed and high-speedplanetary decelerations, respectively,K_1 is the load factor.

Calculate the diameter of the sun wheel indexing circle according to the contact intensity

$$d_a \ge K\sqrt[3]{\frac{T_a K_A K_{H\epsilon} K_{HP}}{C\varphi\sigma_{Hlim}^2}\frac{u}{u-2}} \tag{4}$$

In the formula, T_a is the working torque of the sun gear; K_a is the working condition coefficient; K_{he} is the comprehensive coefficient;K_{hp} is the uneven coefficient of load distribution.

When assigning the transmission ratio, the total transmission ratio is known, that is $u_1u_2u_3u_4u_5$ =195.518,In order to ensure the bearing capacity of the gear, the transmission ratio of the high-speed stage should be 4~8.Therefore, the constraint of the high-speed stage is$4 \le u \le 8$.

The multi-stage series NGW planetary transmission has a low-speed gear ratio of 4 to 5, so the constraint condition of the low-speed gear ratio is $4 \le u \le 5$.

The design is based on the principle of equal strength, and the transmission power of each level is equal, that is, T_n= input power, and the constraint conditions of equal strength are simplified It can be concluded that the high-speed planetary speed reduction transmission ratio is u_4=5.71, and the low-speed planetary speed reduction ratio is u_5=5.61.

$$\frac{5}{6}\frac{u_{aH2}(u_{aH2}-1)^3(u_{aH2}-2)}{(u_{aH2}-2)(u_{aH1}-1)^3} = 1 \tag{5}$$

3. Optimize Design Results

The search space was constructed according to the obtained constraints. The design examples were optimized and the design results were rounded. The main parameters of the gear train obtained by the final optimization results are shown in Table 1.

Table 1. Optimization results of matching parameters

Numbering	Number of teeth	Modulus	Modification coefficient	Tooth width	Center distance
1	25	5	0.542	86	153
2	34	5	0.554	82	
3	47	5	0.496	78	210
4	20	6	0.504	88	291
5	75	6	0.496	84	
6	14	6	0.581	86	100
7	17	6	0.442	84	
8	66	6	0.436	87	255
9	17	8	0.579	97	177
10	25	8	0.473	140	
11	69	8	0.679	145	385

4.Conclusion

The volume of the optimized reduction box is 20% smaller than the original volume. The optimized reduction ratio is within the range of deceleration allowed by the reduction box of the haulage unit of the coal mining machine, which reduces the space occupied by the traction unit under the well.

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