Proceedings of the 17th International Conference on Manufacturing Systems – ICMaS
ISSN 1842-3183
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REPLACEMENT OF CLASSICAL GEAR BOXES WITH ONE OR TWO STEPS GEAR REDUCERS IN HEAVY MACHINE TOOLS

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Abstract: *The paper presents variants of replacing of gear boxes in heavy machine tools with standard type systems of modern reducers having a reduced size, high power, and reduced backlash. The classical gear boxes contain different mechanisms: shafts, bearings, gears, rods, etc. These are specific components, in most of cases being produced by machine tool producers with considerable costs. The modern reducers that could replace the gear boxes are produced by specialized producers with a quality and prices preferable to classical solutions.*

Key words: *gear box, step reducer, heavy machine tool, special reducer, .*

1. INTRODUCTION

In case of machine tools, the specific mechanisms for adjustments in the main kinematic chains has been and are being yet the gear boxes [1]. Starting from the driving electric motors with one or maximum two speeds, usually 750, 1000, 1500 and rarely 3000 rot/min. The role of these systems is to reduce the speed at the level of the last mechanism. In case of the classical gear boxes the output speeds are for example in the range 10-2000 rot/min (for example in case of lathes). The electric motors used at present for these kinematic chains are AC electric motors with speed adjustment through current frequency variation [2]. These motors have an adjustment characteristic of the type shown in Fig. 1.

Up to a speed equal to the nominal speed n_{nom}, the adjustment is achieved at constant torque, and after that up to the maximum value of the speed n_{Max}. The adjustment is done at constant power [3]. Usually, in case of the used in the main kinematic chains, the values for n_{nom} are in the range 1500-2000 rot/min and for n_{max} in the range 6000-9000 rot/min. The adjustment of all these motors is achieved continuously, and one observes that for the main kinematic chains the adjustment at constant power, which is preferred for bots types of machine tools, is adequate. Therefore, the kinematic requirements are

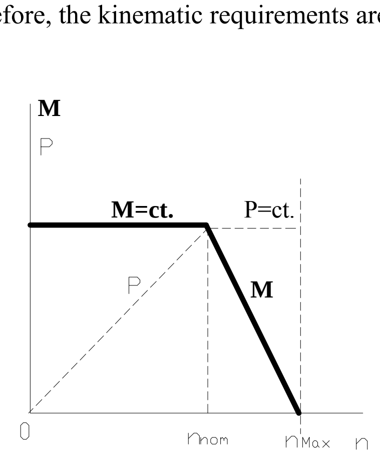

Fig. 1. Torque/power-speed characteristic.

achieved by means of electronic adjustment systems, without being necessary gear boxes. In this way, the main spindles with integrated motors appeared and also feed kinematic chains with motors coupled directly on the ball screw. These solutions are not recommended in heavy machine tools, vertical lathes, boring and milling machines, heavy lathes, etc., because for satisfying the requirements of necessary torque very big sizes electric motors results [4]. In these machines, the main spindle speeds being more reduced, two steps gear boxes are used. From the discussion above, one can observe that for the classical applications the gear boxes were dimensioned as *mechanisms for speed reduction*, whereas in the presented cases they would be calculated as *torque amplifiers*.

2. CONSTRUCTION OF GEAR BOXES WITH TWO STEPS AND ELECTRICAL COMMUTATION

A modern variant, used in new or refabricated machine tools is that of two steps gear boxes for machine tools, produced by specialized companies [5]. These have a series of advantages, such as:

- greasing circuit separated by the rest of the machine, fact that contributes to the reduction of the heat transmission to the main spindle;
- low noise;
- simple and compact construction with direct coupling to the driving motor;
- high efficiency (over 95%);
- minimum backlashes;
- changing of speed domain is achieved by means of an integrated device in the gear box actuated electrically;

The kinematic scheme of such of a gear box, having the transmission ratios 1 / 1 and 1 / 4 is presented in Fig. 2.

The electric motor *ME* (1) is fixed directly on the gear box *CV* (2). The motor shaft drives off the gear 3. If the sliding gear 4 is coupled in the first step (I), through the bolts inserted in the holes *a*, the motion is transmitted

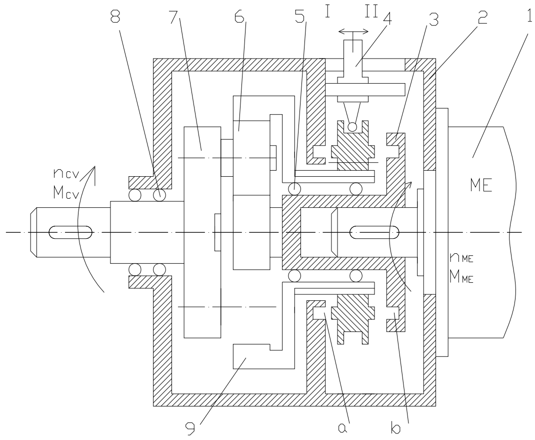

Fig. 2. Two steps gear box.

to the satellites 6 and then to the output shaft 8. The gear with internal teeth 9 is blocked. This stage enables the ratio 1 / 4.

If the sliding gear is on the second position (II), with pins in the holes *b*, the satellites 6 and gear 9 enable the ratio 1 / 1. The bearings are denoted with 5 and 8 respectively.

From the output shaft of the gear box, the motion is brought usually to the main spindle through transmissions with belts. This solutions eliminates the heat transfer and eventually of vibrations to the main spindle. Due to their construction, these gear boxes are considered as a extension of the electric motors. These construction can work in any position with the condition that the greasing to be enabled according to the recommendations of the producing company. In Fig. 3, the construction of such gear boxes is presented.

For the electric motor one consider as defining the following characteristics: P_{ME} – electric motor power, M_{ME} – rated torque of electric motor, n_{nom} – nominal speed, $n_{\max}$ – maximum speed. If one chooses a gear box with the ratio 1 / 4 and 1 / 1 and considers that the efficiency is 100 %, we obtain the adjusting characteristics at constant torque and constant power respectively shown in Fig. 4.

In case of heavy machine tools, for turning, milling, boring, etc., one prefers operation at constant torque.

It is considered the case of an electric motor with P_{Me} = 40 kW, M_{ME} = 254 Nm, n_{nom} = 1500 rot/min., $n_{\max}$ = 6500 rot/min, coupled with a gear box with i_1 = 1 / 4 and i_2 = 1 / 1.

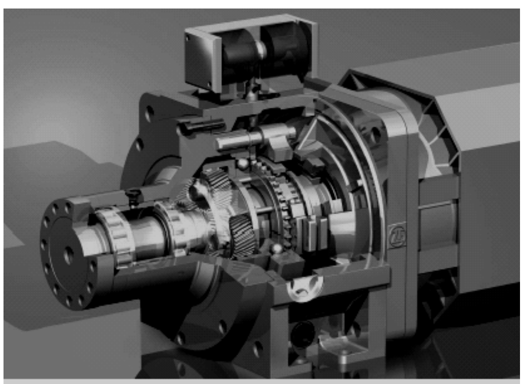

Fig. 3. Construction of a motor integrated with a two steps gear box.

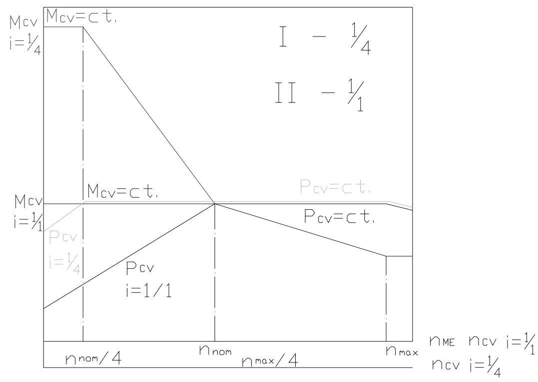

Fig. 4. Torque and power diagram vs. speed.

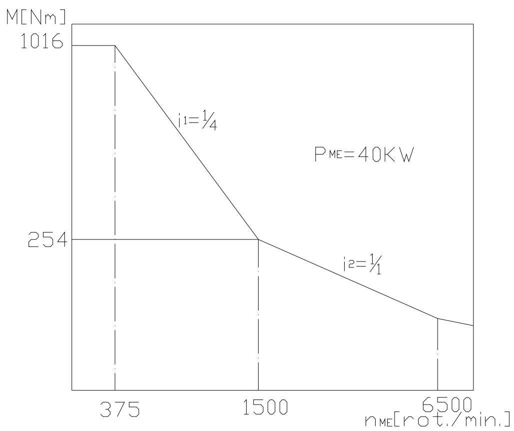

Fig. 5. Output shaft torque diagram.

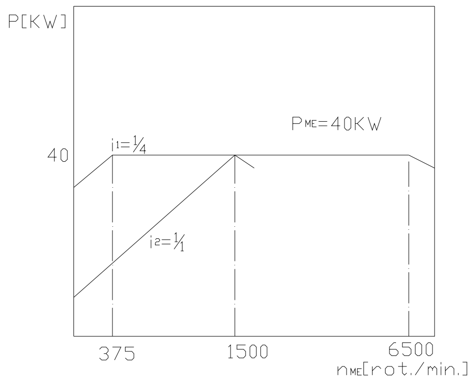

Fig. 6. Output shaft power diagram.

The torque and power characteristics at the gear box output shaft are shown in Figs. 5 and 6 respectively.

This system can enable speeds in the range 0 … 6500 rot/min, a constant torque of 1016 Nm for 0 to 375 rot/min, or 254 Nm for 0 to 1500 rot/min. Starting from 375 rot/min up to 1500 rot/min, the processing can be achieved at constant power of maximum 40 kW with a descending torque. Then, also with descending couple, the machine can be operated at constant power up to 6500 rot/min.

In case of heavy machine tools, these gear boxes are applied successfully in boring and milling machines (AF and AFP) and also in vertical lathes of the range SC14-SC33CNC.

Having in view the possibility of the electronic adjustment of the motor speed in a large range, the single problem that could arise is that of the reduced value of the torque. For solving these situations, we can use a torque multiplier with two steps mounted after the gear box previously presented.

2.1. Torque multiplier with toothed belts

The transmissions with toothed belts are used frequently at present due to the high powers and torques that can be transmitted and also to other advantages such as: constructive simplicity, reduced or null backlash at reversal, low noise, it does not need a greasing system, and have a smaller price than transmissions with gears. Usually, they are used in reducers with one step. In our case, a system with two steps adapted for a vertical lathe will be presented. A specific problem of these transmissions is that of the necessity of existence of belt stretching systems. Figure 7 shows a proposed construction.

The electric motor *ME* is coupled to the gear box with two steps *CV*. It gas the ratio 1 / 1 and 1 / 4. The motion is brought to the shaft I by means of the coupling *C*. If this is on the position I, the motion is brought to the shaft II through 1*D*1 / 1*D*2 = 2 / 3. From the shaft II, the motion is transmitted to the shaft III through the belts 2*D*1 / 2*D*2 = 2 / 3. From here, through the toothed belt transmission 1*D*3 / 2*D*3 = 1 / 1 the motion is transmitted to the shaft IV. Further, through the pinion Z_1 the crown Z_2 is driven and through it the plate.

If the coupling *C* is on the position II, the motion from the shaft I is transmitted directly to the shaft III, and from here through 1*D*3 / 2*D*3 and Z_1 / Z_2 to the plate. Thus, the multiplier enables two ratios: 1 / 2.25 and 1 / 1.

The operation of the system is described by the relations below:

$$C \to I$$

$$n_5 = n_1 \times \frac{1D1}{1D2} \times \frac{2D1}{2D2} \times \frac{1D3}{2D3} \times \frac{Z_1}{Z_2} \quad (1)$$

$$C \to II$$

$$n_5 = n_1 \times \frac{1D3}{2D3} \times \frac{Z_1}{Z_2} \quad (2)$$

$$C \to 0$$

$$n_5 = 0 \quad (3)$$

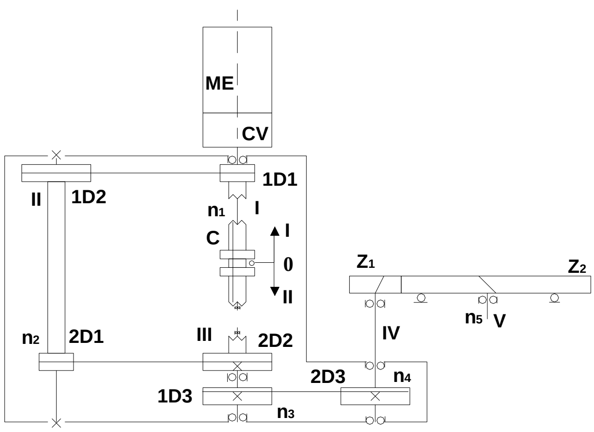

Fig. 7. Trasnmission with two steps transmission using belts.

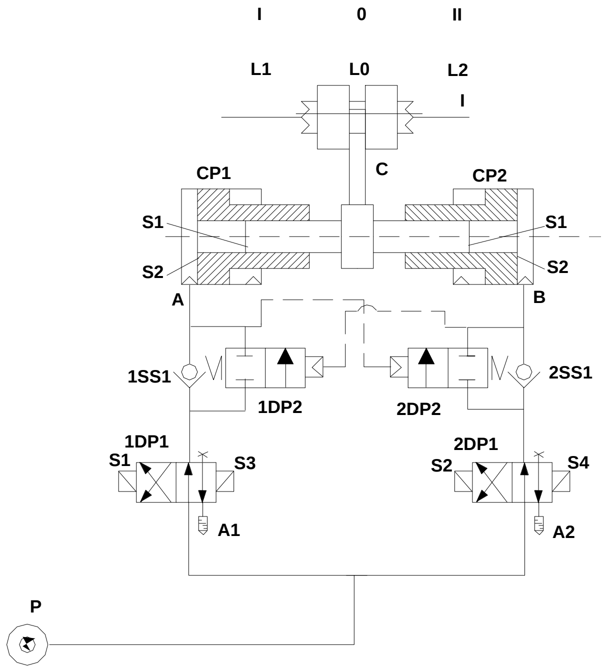

Fig. 8. Pneumatic scheme for driving off the coupling *C*.

For this variant there are for speed ranges that include the three ones obtained by the initial gear box. Also, the system has no backlash, and the multiplier needs no greasing system. The used constructive solution reduces the dimensions, and for the two belt transmissions a single stretching system is used. For this system to be used in feed kinematc chains, in CNC machine tools it is required the backlash takeover at the final transmission level pinion Z_1 / crown Z_2. depending on the machine tool type, one can use mechanical or hydraulic backlash takeover systems [4].

For the driving off of the coupling *C* it is recommended the use of a pneumatic system. It is preferred the pneumatic one instead of hydraulic one having in view the relative reduced necessary forces and the fact that it is desired no oil in the belt area.

In Fig. 8, the pneumatic scheme of the driving off the coupling is shown.

The shifting of the coupling *C* in three positions (I, 0, II) is achieved with the linear pneumatic motors *CP*1 and *CP*2. They are telescopic motors, with the active surfaces *S*1 and *S*2. The confirmation of the three positions is

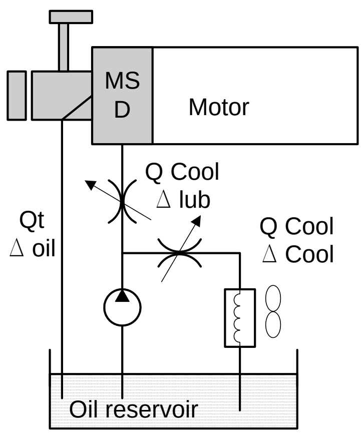

Fig. 9. Gear box cooling using an air cooler.

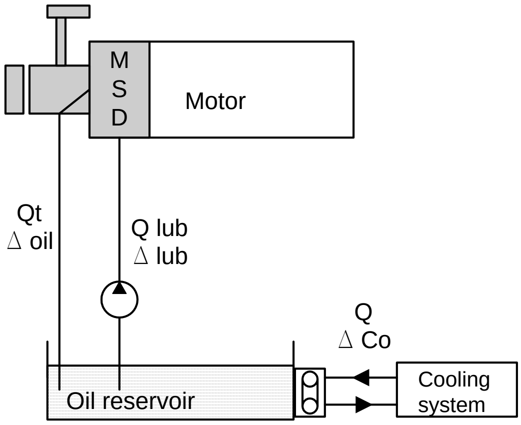

Fig. 10. Cooling system for the whole oil tank.

achieved by means of inductive limiters *L*1, *L*0, and *L*2. The coupling *C* can shift on the shaft I. The selection of the position is done with the distributors 1*DP*1 and 2*DP*1. The maintaining on the ordered position is achieved with the distributors pneumatically controlled 1*DP*1 and 2*DP*1 and also with ball check valves 1*SS*1 and 2*SS*1. For noise reduction, the dampers *A*1 and *A*2 are used.

For cooling and greasing the integrated gear boxes two solution are used. In the first case, the oil cooling is achieved using an air cooler (Fig. 9), in derivation with regard to the main circuit. The second variant means the oil cooling from the entire tank using a cooler (Fig. 10).

3. CONCLUSIONS

The gear boxes with two steps presented in this work are simple and modern solutions for driving the main kinematic chains in heavy machine tools. These gear boxes are produced by specialized companies and have minimum backlash and low noise. Usually, they are used in cases when two adjustment steps are sufficient, the necessary torques being obtained from usual electric motors. For avoiding an extra dimensioning of the electric motors, for big values of the necessary torque one can use special reducers.

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