REMANUFACTURING OF FEED KINEMATIC CHAINS OF HEAVY MACHINE-TOOLS

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Summary: *The paper hereby presents theoretical and experimental research with regard to the modernization of the feed kinematic chain of heavy lathes. Pinion-rack mechanisms – either classic or hydrostatic variants – are usually provided when large longitudinal travels (over 6 m length) are needed. A new variant with ball-screw as final mechanism has been successfully applied on a 20-m longitudinal travel CNC engine lathe.*

Key words: *remanufacturing, CNC engine lathe, ball-screw mechanism.*

1. INTRODUCTION

Now there are havy machine tools that wew produced between 1970-1989 and wich are technically surpassed and morally worn out. There basic structure is identically or almost identically to that of the new machines produced by great firms worldwide. Buying such machines means big financial efforts. Besides there high prices other expenses are needed such as transportation, installation, staff training expenses. When the machine is remanufactured its basic structure remains the same and the principal and/or advance cinematic chains, hydraulic installations and command systems, usually CNC, are remanufactured.

Machine tools remanufacturing is a new and modern solution that is often used by specialized firms from Europe and the U.S.A. Usually heavy and very heavy machine tools are designed and manufactured to work 15-20 years. It has been noticed that the moral wew is bigger than the physical one. Also it have been notice that the basic structure – the mechanical part – is the best preserved and the electrical, hydraulic and pneumatic systems have the highest were. Often these systems need several reparations, even before the settled date-lines. When the machine is remanufactured an architectural reconfiguration can be made using the old modules which are rearranged depending on the new technological demands. When the machine is remanufactured the following points are in view: the machine tool's technical simplification, the safety increase in working, a cut in the maintenance and reparing expenses, a increase of the techical performance. It has been noticed that the remanufactured heavy machine tools performances are superior to that of new ones and the price is lower. Also it is more profitable to remanufacture a machine tool 2–3 times that to produce a new one. The quality of a remanufactured machine tool is higher than of a new one because the techical characteristic are known and they can be improved. In conclusion the remanufacturing is an important engineering domain.

2. PRESENTATION OF CONSTRUCTIVE SOLUTION

The engine lathe that has been remanufactured developed about 20 m longitudinal feed motion by using the kinematic diagram below (figure 1) as originally designed by its producer more than 25 years ago.

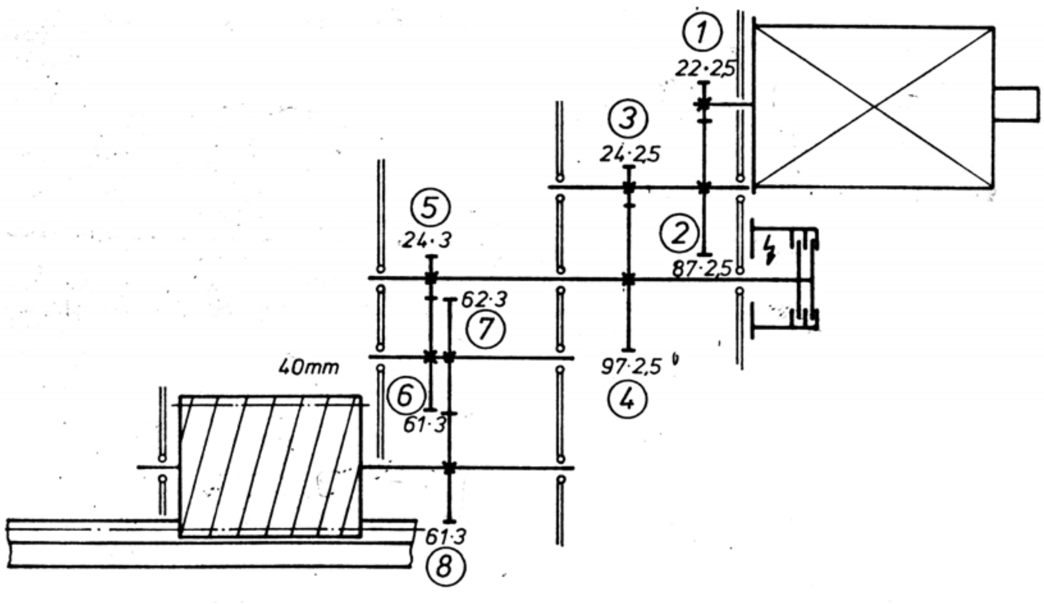

Fig. 1. *The originally kinetic diagram*

A gear reducer transmits motion from the electric motor to the final 40 mm pitch worm. This worm engages with a rack made of modules of approximate 1 m length each. The hydrostatic type worm has a complicated design with hydraulic pockets and circuits on each flank. It has been proved that design is not the right solution since the working conditions determine local wear requiring frequent and costly repairs. When refabricating the machine the above mentioned mechanism had to be changed. Changing it with a new similar mechanism was out of question not only from technical point of view, but also due to cost reason: there was only one producer of such type of rack and its prices were very high. Under those circumstances and taking into consideration the related advantages a ball-screw design was adopted. That new solution kept the gear reducer for rotating the ball-screw nut (which is radial-axially borne) on the ball-screw fixed at its ends.

There were two disadvantages:

- the producers of ball-screws offered only ball screws of 6-8 m length,
- the deflection of long ball-screws caused by their weight and the distance between rests was too big.

The first disadvantage was overcome by finding a producer that manufactured a ball-screw with 20 mm pitch and 20 m length of three modules which were mounted directly on the machine. Five additional swinging rests hydraulically actuated were used in order to annul the deflection. A second hydraulic system ensured the straining of the ball-screw and the compensation of the length variation caused by temperature variation. Figure 2 shows the kinematic diagram of the new variant.

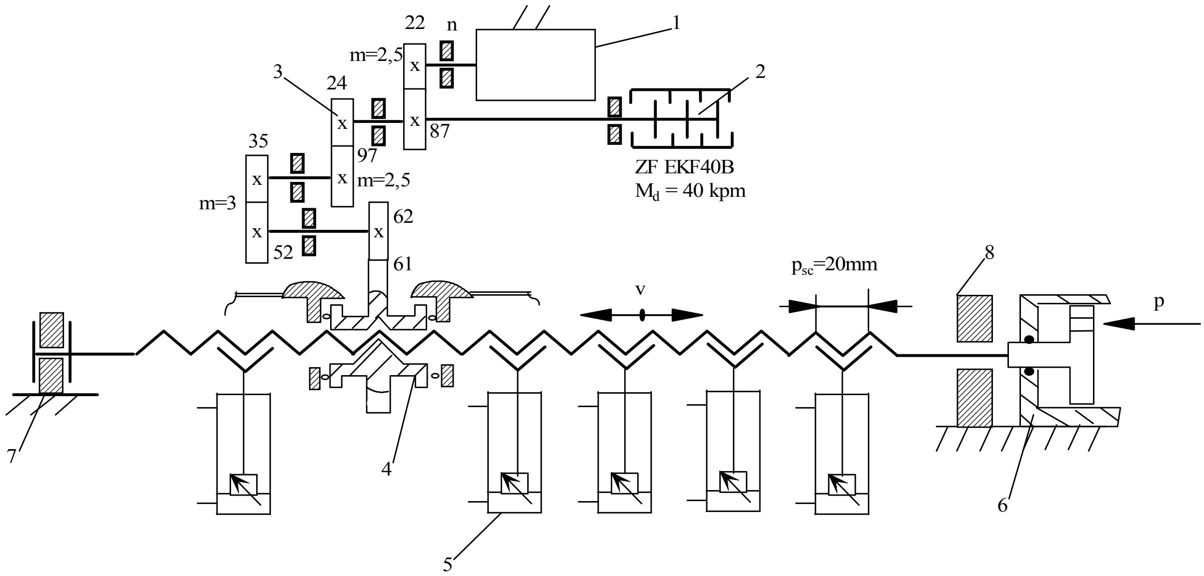

Fig. 2. *The kinetic diagram of the new variant*

The numbers meaning within figure 2 is the following: 1 - feed electric motor with speed adjustment by frequency; 2 – brake; 3 – Z axis gear reducer; 4 – bearing and ball screw; 5 – rest cylinders; 6 – linear hydraulic motor for ball-screw straining; 7 – bearing towards headstock; 8 – bearing towards tailstock.

3. CALCULATION OF REST CYLINDERS

The force and the travel required to annul the deflection and to ensure the proper supporting ware determined by calculating the ball-screw. There were chosen cylinders with 50 mm diameter piston, to work to a pressure of approximate 30 … 40 daN/cm^2.

The equations (1) and (2) describe the working of such a cylinder when ascending:

$$M\frac{d^2x}{dt^2} + bv + Ff = p_1S_1 - \left(p_2S_2\right) \tag{1}$$

$$Q = S_1\frac{dx}{dt} + \frac{V_m}{E}\frac{dp_1}{dt} \tag{2}$$

Within the above equations the lettering represents the following: M - reduced mass, x - travel, t - time, b – linearized coefficient of force losses in proportion to the speed, v - speed, Ff – friction force , p_1 – pressure on the large surface of the piston, S_1- large surface of the piston, p_2 - pressure on the small surface of the piston, S_2 - small surface of the piston, Q - used flow, V_m - average volume of liquid in the large chamber of the cylinder , E – elastic modulus of the used oil.

The term (p_2S_2) appears only during the braking phase and it is considered as being constant. If differentiating relation (1) and replacing $\frac{dp_1}{dt}$ in the relation (2) then relation (3) will be obtained:

$$M\frac{d^3x}{dt^3} + b\frac{d^2x}{dt^2} + S_1{}^2\frac{E}{V_m}\frac{dx}{dt} = QS_1\frac{E}{V_m} \tag{3}$$

Solving the differential equation allows the determination of speed and travel evolution in time. As a result of the calculation a time required to perform the maximum travel which corresponds to the correct supporting of the ball screws has been determined. Its value is 1 … 2 s.

Figure 3 presents a schematic drawing of such type of cylinder and the notation is the following: 1 – rod; 2 – cover with clamping flange; 3 – bushing, 4, 5, 6, 8 – sealing elements (fixed); 7 – body; 9 – cylinder; 10 – braking bushing at end of travel; 11, 12 – movable sealing elements for the piston; 13 – locking system of the piston on the rod.

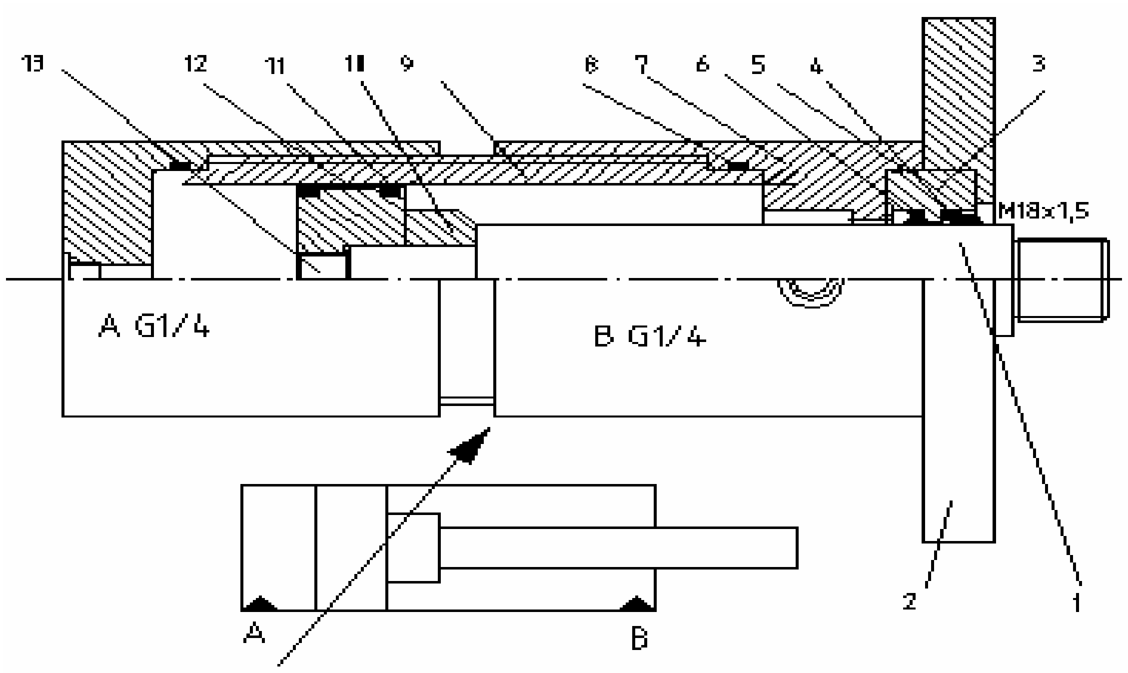

Fig. 3. *A schematic drawing of the cylinder*

Such a cylinder is the one in the figure 4.

Fig. 4. *The cylinder*

The calculation does not take into consideration the brake and the compression the liquid endures along the pipes. When dimensioning the control cams of the cylinders it was estimated the time required for lifting was 6 s. Under these circumstances, a control anticipation of 0.6 m results for a rapid traverse of 6 m/min. In order to prevent accidents the control for descending is double, from the cam and the Z axis transducer as well. Inductive microswitches confirm the positions of the cylinders. In case of power failure the hydraulic locks block the cylinders. A pneumatic-hydraulic accumulator is provided to avoid oil heating and to shorten the actuating time. Figure 5 shows a cylinder mounted on the bed.

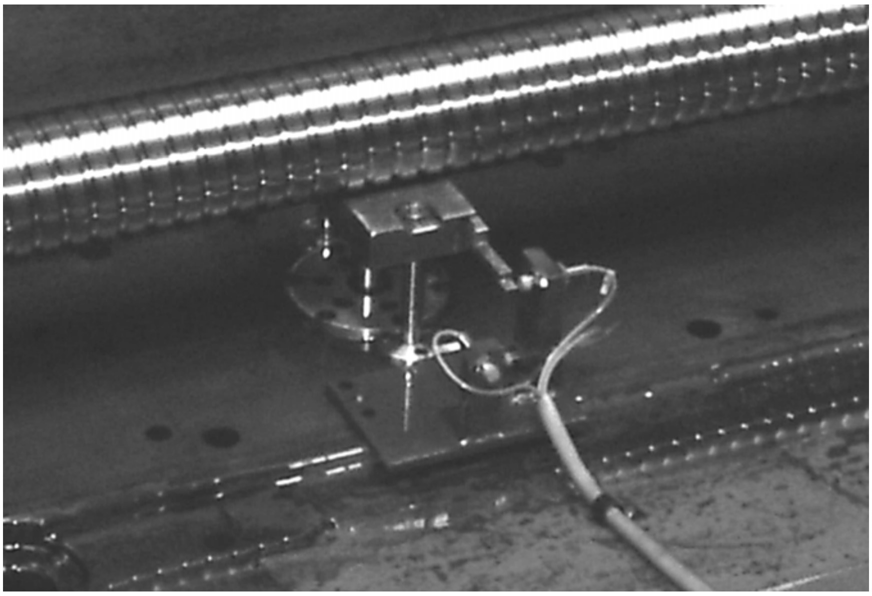

Fig. 5. *The cylinder mounted on the bed*

4. CONCLUSIONS

Modernizing the machine presented hereinbefore has led to the following conclusions:

- Ball-screws longer than 6 - 8 m can be used on condition that additional rests are provided;
- Rests (linear hydraulic motors) will be actuated by means of the specialized hydraulic equipment, according to the position of the slide being moved;
- Each rest is adjusted during assembling so as the compensation of the deflection to be real;
- The entire system must be provided with safety elements to prevent defective running and to avoid bumping with the slide.

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