New Design of the Headstock - Generator for Creating Folded Rotary Motion

Ľubomír Šooš, Peter Križan, Miloš Matúš, Juraj Beniak

***Abstract*—**The quality of machine tools or construction elements depends on the accuracy of the operation, the range of operating speed, the maximum rotational speed and the ability to quickly change the specified requirements. The tool or work-piece holder must meet specific demands for maximum speed, rigidity and maximum torque at low speed. This is often not possible to achieve a classic arrangement of the drive kinematic chain. Therefore was idea to create a generator assembled rotary motion. The proposed generator consists in the construction of the spindle, which is doubly stored and powered by two separate engines. This allows the generator to work in four separate modes providing the required sense of rotation up questions and their scope and desired torque at low speed.

***Keywords*—** generator, rotary motion, bearing node, spindle bearing system, machine tool spindle, spindle duplication, stiffness.

I. Introduction

THE decisive criteria of the quality of machining tools are their productivity and working accuracy. One innovated method for improving the technological parameters of manufacturing machines (machine tools) is to optimize the structure of their nodal points and machine components.

Because of the demands on machine tool productivity and accuracy, the spindle-housing system is the heart of the machine tool, [1]. Adequate stiffness and revolving speed of the headstock are necessary conditions for meeting the manufacturing precision quality and machine tool productivity required by industry, [7].

When designing a machine tool headstock, the starting point is the design of the spindle support, as this limits the stability, accuracy and production capacity of the machine by its stiffness and revolving speed. However, the parameters influencing the stiffness and frequency can act in opposition to each other, [6, 8]. The selection of the type of bearing has to take into consideration the optimization of its stiffness and revolving speed characteristics.

The headstock, whether tool or workpiece carrier, has a direct influence on the static and dynamic properties of the cutting process. The spindle-bearing system (SBS) stiffness affects the surface quality, profile, and dimensional accuracy of the parts produced. It also has a direct influence on machine tool productivity because the width of cut influences the initiation of self-induced vibration; it is directly proportional to machine tool stiffness and damping, [8].

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II. Problem Formulation

Classical rotary unit

Conventional rotary motion generators - “classical unit” are constructed either with the drive external kinematic chain, or integrated rotary drive “motor-spindel ”.

The classical unit, where the spindle is driven by a motor through a gearbox, has no control system. The disadvantages of the classical construction are problems with the gears at higher revolving frequencies; actual cutting speeds are not continual because of the discontinuous nature of the gearboxes, large dimensions of complete units.

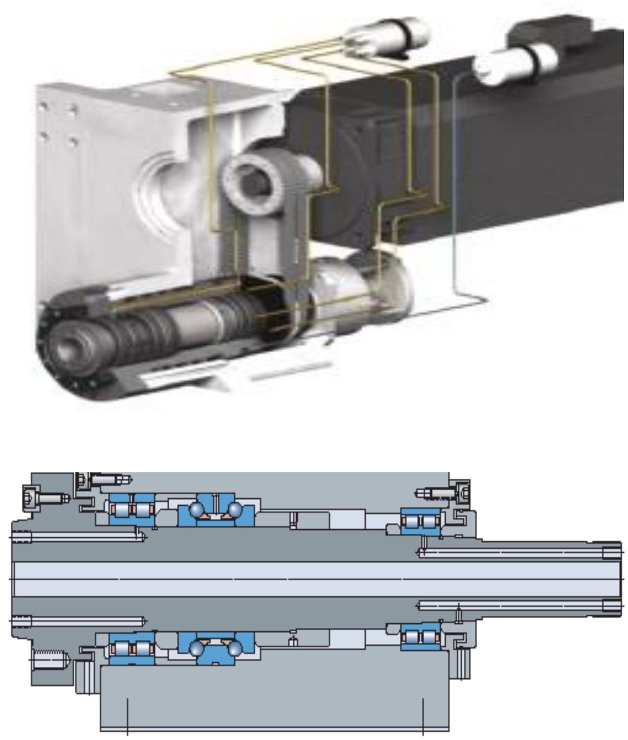


Fig.1 Headstock with external kinematic chain [2]

The number of unit with an integrated motor ”motor-spindel” and machine rotation components supported on ball bearings with angular contact is increasing proportionally with the increasing demands on the quality of the machine tool [2]. This is because these bearings can be arranged in various combinations to create bearing arrangements which can enable the carry of both radial and axial loads. The maximum speed of the bearings node is a function of the maximum speed of the individual bearings, their number, high of the preload magnitude, manufacturing precision, monitoring, the types of lubrication and cooling used. With the growing demand for a maximum of rotational speed, efficiency and accuracy of running are growing number of applications integrated drive generators. But units with an integrated motor are very expensive, Fig.2.

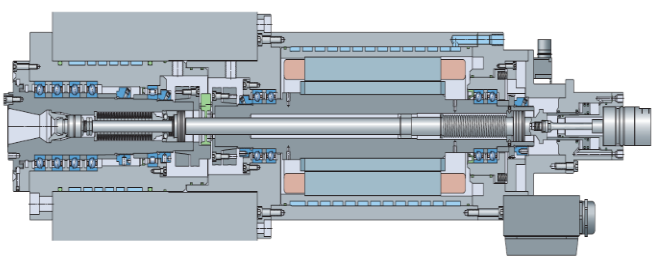


Fig. 2. Unit with an integrated motor [4]

III. Problem Solution

Therefore has been idea to create a generator assembled rotary motion. The proposed Headstock consists in the construction of the spindle, which is doubly stored and powered by two separate engines.

This allows the generator to work in four separate modes which providing the required questions fulfill on maximum speed, sense of rotation and their scope and desired torque moment at low speed.

A. New design of "Unit with duplo-motor“

The “Generator for creating folded rotary motion” has been designed in order to achieve technological parameters comparable to the performance of standard electro-spindles, but at a lower production costs and with higher controllability. This particular headstock is assembled from readily available elements (bearings, single drives). The demands on the other peripheral devices are reduced, as are the costs.

Figure 3 [5] shows the spindle (1), with rotor the internal motor (2) built-in. Spindle (1) is supported by bearings (3), (4). The stator (5) of the internal motor is built-in in internal cylindrical body (6) which is supported on bearings (7), (8). The clutch (9) connects a hollow shaft with an external electro-motor (10). The stator feeding rings (11) are located in the rear part of the shaft. The clutch (12) enabling switching between working modes is located in the front part of the shaft.

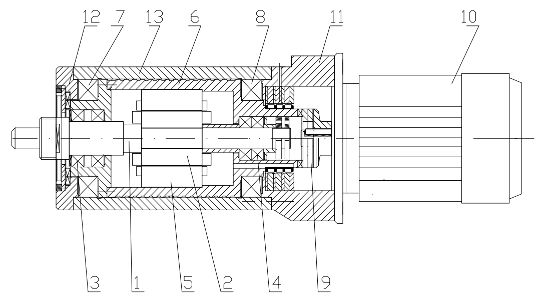


Fig 3. "Unit with duplo-motor“

The advantage of this design, which is already in use, is that the headstock can work in four different modes:

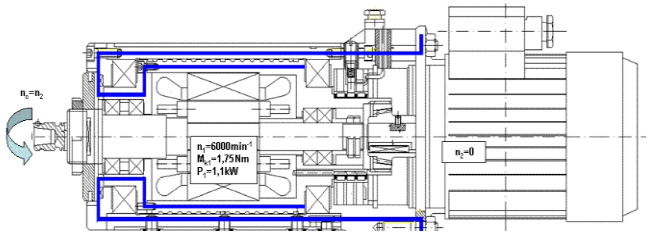
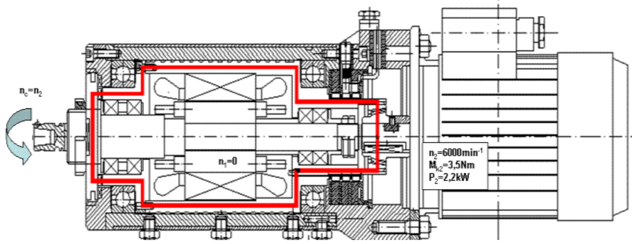
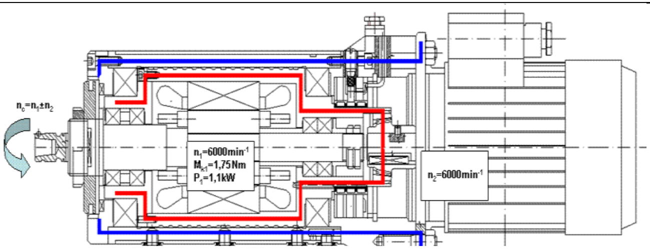
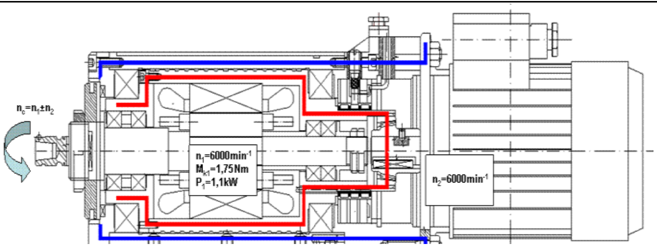
- mode I. - internal cylindrical body (6) is rigidly fixed on the body of the Headstock,
- mode II. - internal cylindrical body (6) is rigidly fixed on the Spindle (1),
- mode III. - no engagement - concurrence sense of rotation,
- mode IV. - no engagement - opposite sense of rotation.

Fig. 4 Stand of "Headstock with duplo-motor”

The "Headstock with duplo-motor“ can be described as a spindle with double supports, driven by two separate motors which can operate independently or together, Table 1.

Connecting such a Headstock with a suitable control system can provide optimal conditions (speed, torque moment, ect…) for various technological and technical operations. The intelligent control system can operate in any one of the working modes and ensure nominal or optimal technological parameters best suited to the machining process, [5]. In the third and fourth mode, the clutch (12) is switched off. In the mode III, the spindle is driven by both motors, providing the maximum speed, which is required, for example, in grinding. In the mode IV are motors opposite sense of rotation. Both motors can rotate at high speed but different (in area with maximum constant torque moment), and the resulting speed is low, but with high torque moment.

Table 1 Different operating modes

Mode	Schema of unit working	Technical parameters
M I. Internal cylindrical body is rigidly fixed on the body of the Headstock		**Speed:** $n_{1max} = 6000$ (min^{-1}) $n_2 = 0$, $n_c = n_1$ **Torque moment:** $M_{kc} = M_{k1} = 1{,}75$ (Nm) by n_{1max} **Power:** $P_c = P_1 = 1{,}1$ (kW)
M II. Internal cylindrical body is rigidly fixed on the Spindle		**Speed:** $n_1 = 0$ $n_{2max} = 6000$ (min^{-1}) $n_c = n_2$ **Torque moment:** $M_{kc} = M_{k2} = 3{,}5$ (Nm) by n_{2max} **Power:** $P_c = P_2 = 3{,}5$ (kW)
M III. Disengaged - concurrence sense of rotation		**Speed:** $n_{1max} = 6000$ (min^{-1}) $n_{2max} = 6000$ (min^{-1}); $n_c = n_1 + n_2$ **Torque moment:** $M_{kc} = M_{k1} = 1{,}75$ (Nm) by n_{1max} **Power:** $P_c = P_1 = 1{,}1$ (kW)
M IV. Disengaged- opposite sense of rotation		**Speed:** $n_{1max} = 6000$ (min^{-1}) $n_{2max} = 6000$ (min^{-1}); $n_c = n_1 - n_2$ **Torque moment:** $M_{kc} = M_{k1} = 1{,}75$ (Nm) by n_{1max} **Power:** $P_c = P_1 = 1{,}1$ (kW)

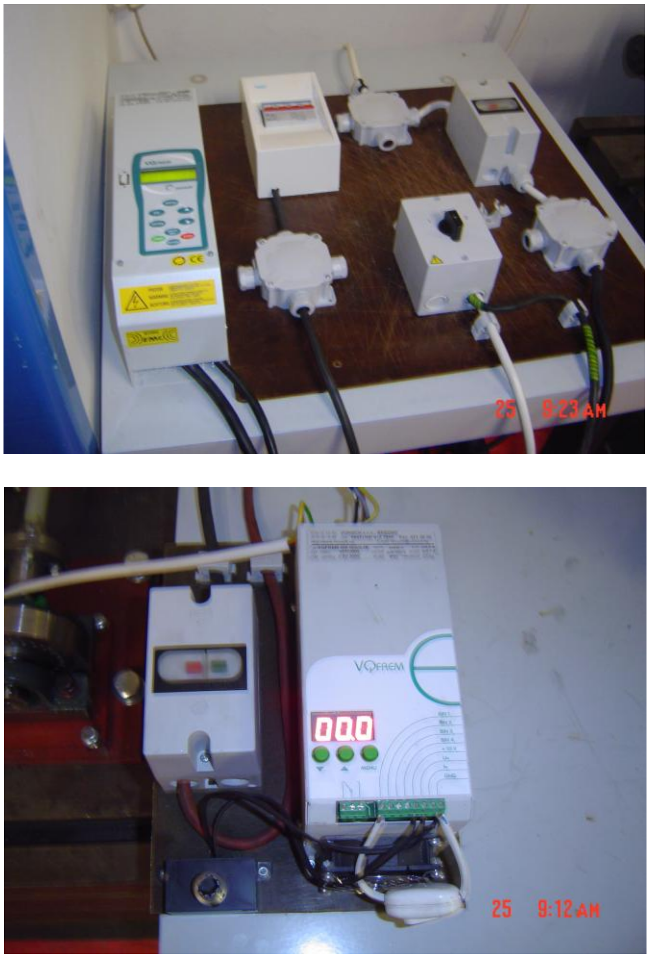


Fig. 5 Inverters for motors control

B. Progress tests

Currently we test on a prototype, which is shown in Fig. 4. Motors control for the individual modes is currently hand through the inverters shown in Fig. 5. Motor wiring shown in the Fig. 8 individual modes is currently hand through the inverters shown in Fig. 5. Motor wiring shown in the Fig. 6. There are ongoing measurement precision operation, (Fig.7) and measurement of performance new generator (Fig. 8). After the completion and evaluation of measurements we will know definitively describe the advantages and disadvantages of the proposed solution Headstock for different range of applications.

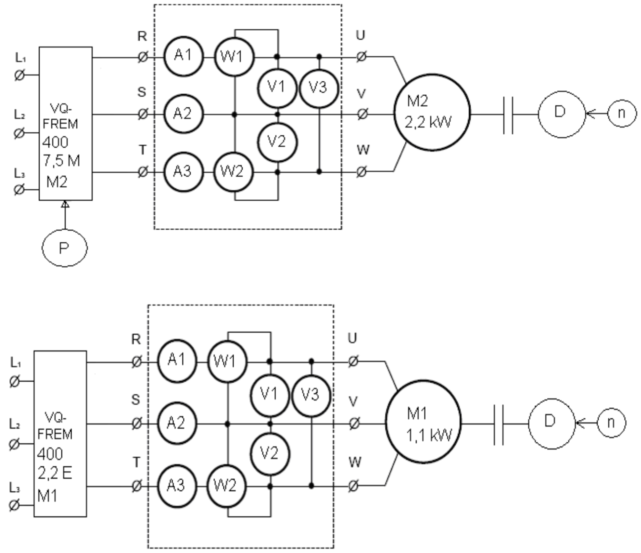
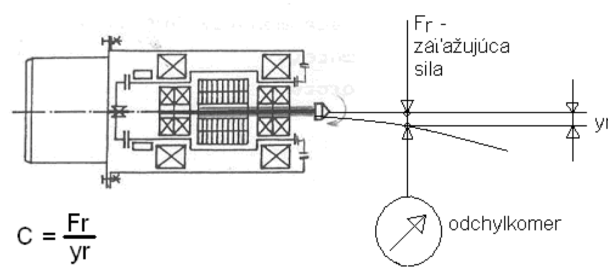
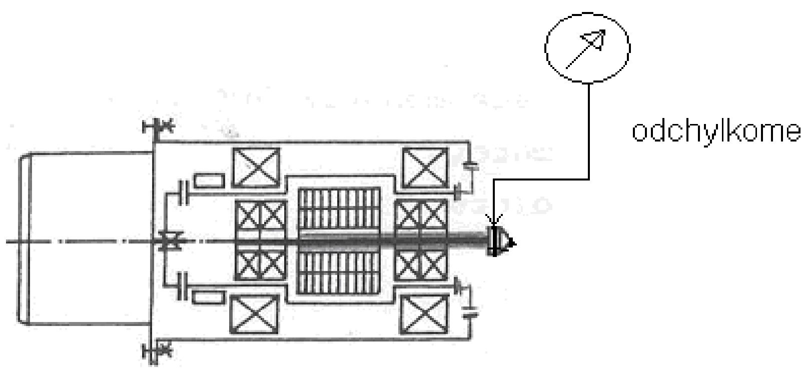


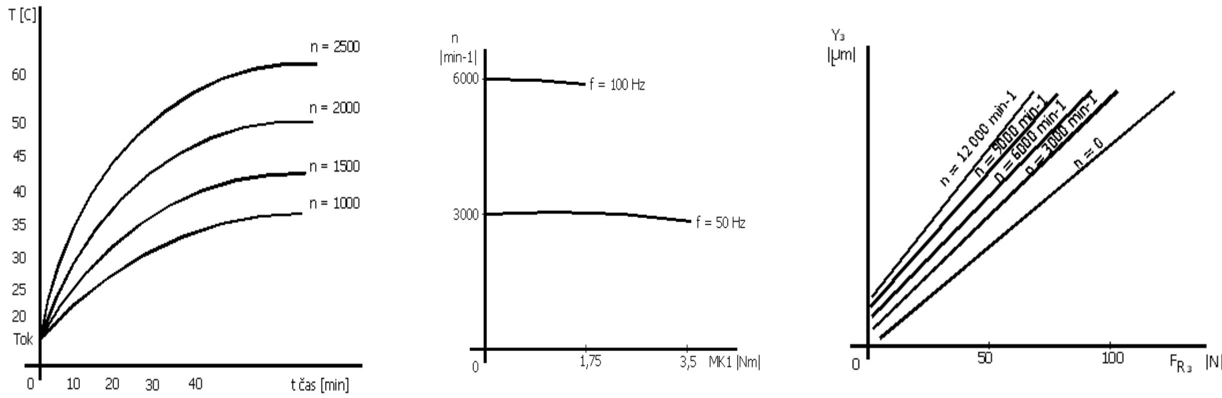
Fig. 6 Wiring engine (VQ-FREM – Inverters; A1, A2, A3 – Ammeters; W1, W2 – Wattmeter; V1, V2, V3 – Voltmeters; n – Speedometer; M1 - Internal motor; M2 – External motor; T1, T2 – Thermometers; P - 90 potentiometer)



a) measurement of radial stiffness



b) measurement of precision radial run
Fig. 7 Measurement accuracy generator



a) The measurement of the temperature T versus time at different frequencies of

b) The dependence of the total speed n_c torque Mk_1, at different frequencies source

c) The dependence of the deflection y_3 radial force FR_3 at different frequencies of

Fig. 8 Measurement of performance

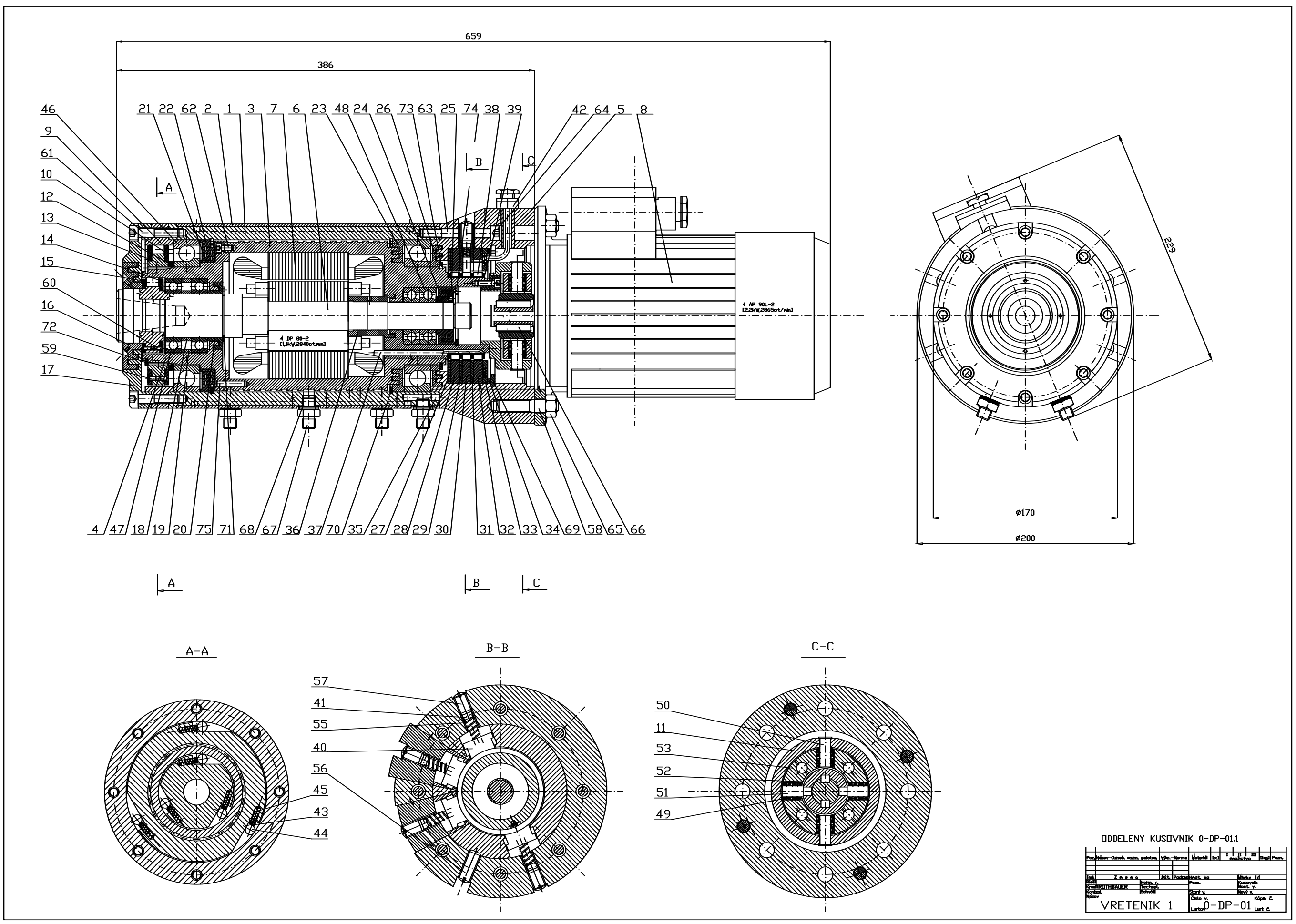
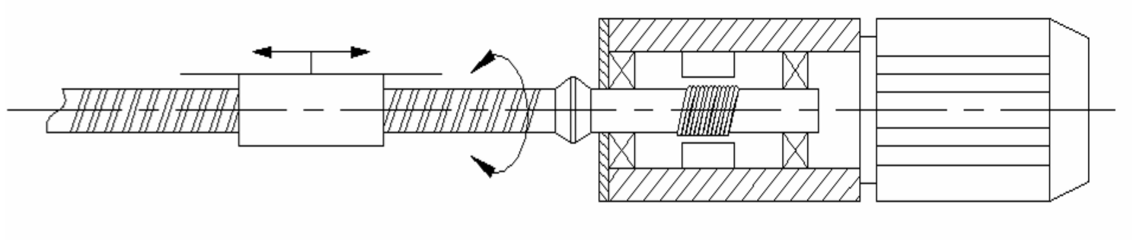
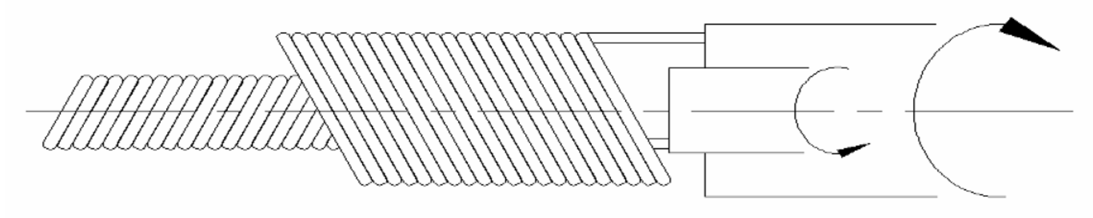


Fig. 9 Real design of the Headstock



a) Transmission of feeding mechanisms



b) Reeling cables

Fig. 10 Measurement of performance

IV. Conclusion

The paper presents in a very concise form summary of our results in research of new design of the generator for creating folded rotary motion with application for spindle-housing system. Special attention is paid to two designs of headstock namely classical headstock and headstock with an integrated drive unit. Description of these two versions is introduced. The paper also presents the function model based on the patent as well as the real Headstock according to the patent [5], Fig. 9. The design of the generator of movements can also be used for other industrial applications in practice [5] for example for Transmission of feeding mechanisms (Fig. 10a) or for reeling cables (Fig. 10b).

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