

FORMING OF MODERN MULTI-TURN ELECTRIC DRIVE FOR PIPELINE GATE VALVE OF WEDGE AND SLIDE TYPES

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INTRODUCTION

Fittings with isolation valves of wedge and slide-types, which shut-offs move back and forth, need regulated multi-term reversing drive, where the driven member can turn from some parts of segment to dozens of full or fractional segments, and also stop at any fixed intermediate position. This drive is set directly on the valve as a technological machine, and because of that its output parameters of speed ω_{b_2} and moment T_{b_2} correspond to one type input parameters of damper valve (T_v , ω_v).

Due to the fact that time of the damper valve opening varies from several seconds (8-16) to several minutes (5-7), reducing electrical drives should have rather big gear ratio ($u_{total} = 20...300$). Great diversity of transportation pipes diameters and kinds of substances transported and their pressure, predetermine wide range of the drives' input moments (from 50 N·m to 100 kN·m), output speeds (from 8 to 50 min⁻¹), number of nut turns (from 2 to 50 turns) and the time of cut-off time. The main constructive demand of the drive is the necessity of hollow output spindle, where, according to technical characteristics, moves the stud of locking valve. This demand makes each of such drives unique for each separate damper valve, as well as their construction for a wide range of pipelines according to their diameter and pressure.

Besides, a modern drive has, together with a controlled electrical engine, some elements of control, such as sensor of absolute position of locking body, of input rotation momentum registration, terminal switches, means of visualization and control, which need to be inserted into the body of the device and produced respectfully. The design is also important, it should match the design of the damper valve.

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The goal of the article is to analyze briefly the existing constructions and to consider a new scheme of electrical drive with multi engine quasi differential reducer, allowing discretely change the drive's output parameters in the given dimension due to changeable gears at fast speed level.

THE ANALYSIS OF THE EXISTING DRIVES

The following foreign companies are leading in producing electrical drives: AUMA (Germany), BIFFI (Italy), ROTORK (England), BERNARD, TECOFI (France), ZPA (Check Republic), GREATORK (China), and also some Russian companies: Cheboksarsky electro mechanical equipment works, «Tulaelectroprivod», Tomzel (Tomsk), «Progress» (Michurinsk), etc.

Most companies mentioned above prefer power *worm-type transmissions* [1].

With the capacity up to 2,5 kW their merits are: big gear ratio at one level (usually, from 10 to 60), smoothness and noiselessness of work, relatively high efficiency coefficient, simplicity of construction, compactness and low metal consumption (0,08 – 0,12 kg/N·m), well-developed designing methodology, production and usage. A very big role is played by the simplicity of construction of a hollow output spindle, as well as the possibility of transmission of momentum from the hollow spindle to the input of isolation valves.

Constant growth of pressures and diameters of pipelines led the appearance of combined power transmissions, where the momentum is transmitted from worm-type wheel to the output cone or cylinder transmission with hollow spindle (fig. 1). They allow increasing the drive's power ratio slightly and widen the intervals of changing of output rotational moment and frequency of the drive rotation, but it also has some drawbacks.

When turning to combine drives it is necessary to unload quick worm-type stage and to form torque output in slow stage with hollow output spindle. Dimensions of this slow stage are determined by maximal contact stress in its top cinematic pair. Despite the fact that admissible pressures at steel thermo proof cylinder gear are a little bigger than those of bronze worm wheel, the specific mass of such transmissions and their dimensions generally increase.

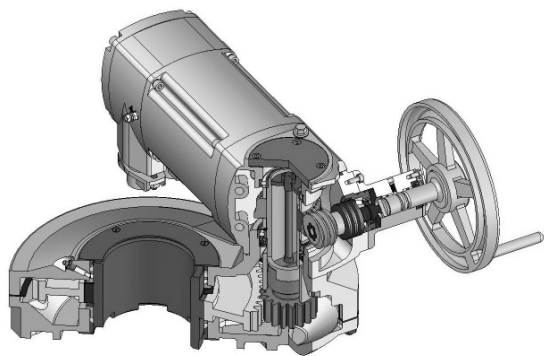


Fig. 1. Overview of multi-turn electrical drive produced by AUMA (Germany) with power transmission of worm-cylinder type and perpendicular arrangement of crossed axes of engine rotor and valve spindle

The construction design of the drive is changed not for the better due to overhanging engine. The drive exterior in respect to the valve is described the following way: 'horizontal overhanging engine at vertical axe of the spindle movements'. The drawbacks of the transmission also include: low efficiency coefficient at high gear ratios, increased ageing and overheating, demand for high quality oiling, strictly fixed position of the input and output spindle rotation axis (90°), heavy axial load on the worm screw; mono threading at power transmission, limited load capacity of the worm gear material, inability of electric wire unification and universalization in the given dimensions and, as a consequence of this – an individual gear for each valve.

The main disadvantage of worm gear and its counterparts is the mono threaded mechanical energy transfer from source to consumer.

Spiroid gears, in spite of their advantages over the worm ones due to the multiple contact of two gear wheels, also have a number of disadvantages: low efficiency coefficient at gear ratios over 20, necessity for high manufacturing and mounting accuracy, lack of well-developed and specified regulatory base for designing.

Planetary gearing of one-stage 2k-h or two-stage 3k three-satellite types (according to the classification given by Prof. V.N. Kudryavcev) [2] can also include: low gear ratio and complexity of making tooth gear input spindle and output operating spindle structure hollow.

Mono thread *planetary gears K-H-V* of one-satellite type are much more limited in their usage in gears due to several reasons: low diversity in the number of teeth of carrying wheel and satellite and the impact of this diversity on the gear ratio; complexity of internal gear geometric synthesis, technical difficulty to transfer the momentum from satellite to output element, low efficiency coefficient and other problems.

The main drawback of all types of transmissions mentioned above is inability to provide output parameters in speed and momentum in one given dimension.

Multi-threaded planetary and rolling transmission with intermediate rolling element is worth special attention (Fig. 2). It is used in electro drive EPC-50000 with double-sided muff of rotational moment limitation. The drive is used in isolation valves in pipelines of 'Transneft' Company. The maximal rotation moment at the drive output reaches 50000 N·m at the frequency of output hollow spindle rotation of 8 min⁻¹. Rotation moment range at the output stage amounts to 20000...50000 N·m. The first quick mono-threaded reducer's stage is ordinary cylindrical gearing with gear ratio 5,77.

The second power planetary-roller multi-threaded drive stage with intermediate rollers has eccentric hollow shaft-carrier as an input component and as an output component – girth gear rigidly connected with output hollow drive shaft coaxially mounted with spindle of isolation valve. Gear ratio of slow-speed planetary-roller drive stage $u_{ss} = 32,5$, and overall gear ratio of combination actuator must reach 187,5.

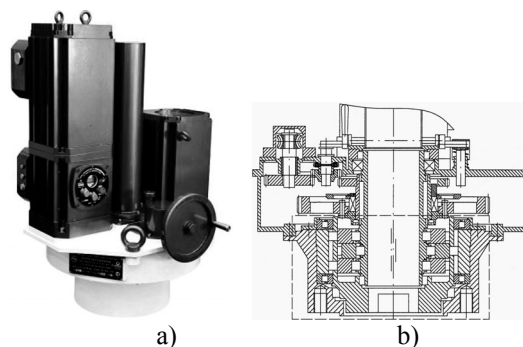


Fig. 2. General view (a) and design arrangement (b) of multi-turn drive with parallel positioned axes of engine rotor and valve spindle produced by "Tomzel" (Russia)

Among disadvantages of EPC-50000 drive there are: absence of parametrical series of output capacities by speed and torque in one preset parameter; rather complex kinematics of gear units of slow-speed drive stage's motion; necessity of high accuracy of manufacturing and assembling; high responsivity to inaccuracies of fabrication due to multiple static indeterminacy; high load on transitory rollers.

Kinematical scheme of combination multi-threaded drive on the basis of quasidifferential gear "3k-2g-h"

Abovementioned disadvantages of drives were eliminated in new double-reduction indivisible multi-threaded gears of quasidifferential type (fig. 3-5).

Kinematical scheme of combination transmission contains new double-reduction quasidifferential gear "3k-2g-h" [3] with input carrier h , output big central wheel b_2 and ordinary cylindrical fast-speed gear " $z_1 - z_2$ " with internal gearing.

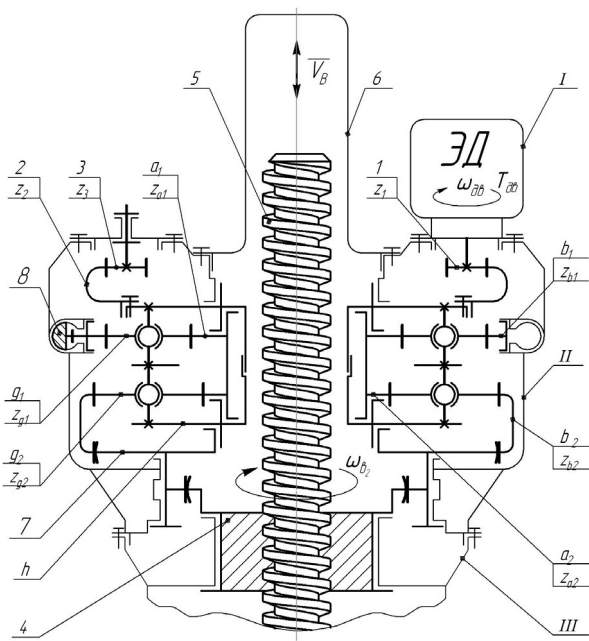


Fig. 3. Kinematical scheme of a new multi-turn electric drive of isolation valve of pipeline transport with multi-threaded power transmission and parallel positioned axes of engine rotor and valve spindle:

I – drive motor; II – multi-threaded power transmission; III – isolation valve on the basis of a screw mechanism; 1, 2, 3 – gear units of kinematical chain which connects electric drive, multi-threaded reducing gear and controlling unit; 4 – driving pin;

5 – valve spindle; 6 – protective structure;

7 – output shaft; 8 – registration sensor of support moment

The last one is needed because of engine that isn't situated coaxially but in parallel to axis of reducing gear and valve spindle in order to provide its passing through the drive.

Turndown of gear ratio u in such kind of transmissions is situated within the most frequently demanded extended limits: $15 \leq u \leq 150$ for driving equipment, while the most loaded elements are internal operating gearings " $b_1 - g_{1i}$ " on the input of a group and gearing " $g_{2i} - b_2$ " on the output of the gear. Besides satellite gears g_{1i} function as big tooth gears in the inner gearings " $b_1 - g_{1i}$ " (overdrive gears) and satellite gears g_{2i} as small tooth gears in the inner gearings " $g_{2i} - b_2$ " (reduction gears).

The drive provides: convex-concave contact in the most loaded gearings of a transmission; high contact ratio that provides gearing smoothness; high multi-threading provided by multipair contacts by phase imbalance of gearing in kinematical fluxes; offloading of conjugate profiles both in internal " $b - g_i$ " and in outside " $a - g_i$ " operating gearings.

Power transfer from input to output implemented on intake velocity ω_h , and changing of power flow parameters (velocity ω_{b_2} and moment T_{b_2}) is implemented on output tooth gear ($T_{b_2} \omega_{b_2}$) as provided by concept of multithreading energy input [3, 5] under which it's rational to transfer power flow on increased velocity on input and to change its parameters on output of transmission.

In accordance with Willis formula gear ratio of drive u is determined by formula

$$u = u_{12} u_{hb_2}^{b_1} = \frac{u_{12}}{u_{b_2h}^{b_1}} = \frac{u_{12}}{1 - u_{b_2b_1}^h} = \frac{z_2}{z_1} \frac{z_{b_2} z_{a_1}}{z_{b_2} z_{a_1} - z_{b_1} z_{a_2}}$$

In case of an equality of the sums of teeth number of central wheels $z_{a_1} + z_{b_1} = z_{a_2} + z_{b_2} = const$ given in one dimension and situated in two motion planes, the angles in all operating gearings equal and settled out of interval $18^\circ \leq \alpha_{w_{a_1g_1}} = \alpha_{w_{g_1b_1}} = \alpha_{w_{a_2g_2}} = \alpha_{w_{g_2b_2}} \leq 30^\circ$.

Gear works on the basis of quasidifferential approach of distribution and summation of energy. This approach isn't applied in any other contemporary transmission. The transmission works as organic unity due to interlocking of lever-gearing chains in flows.

Because of unusually big teeth number of a little central wheel ($z_{a_1} = 60 \dots 120$) and size of rims, transmission's carrier always performed by triple web of modular construction. Loads' locking on the main gear units of transmission permits to unload its props maximally, and subdue issues of selection and designing of props to design and technological concerns. External dimensions of transmission's body frame are defined by gearing modulus and sum of teeth number of operating gearing "satellite gear-output central wheel". If electric drive situated in parallel its dimension in such constructional design depends on size of electric drive. If gear ratio implements $u_{hb_2}^{b_1} \leq 45$, output torque $T_{b_2} \leq 3500 \text{ N} \cdot \text{m}$ and power $P_{\text{дв}} = 2,0 \text{ kW}$ than diametrical dimension of reducing gear is no more than $250 \dots 300 \text{ mm}$.

On the figure 4 there is a visualization of operating gearings of the second planetary drive stage. In distinction from well-known schemes of planetary mechanisms central wheels have almost the same size which permits installation of five satellite gears (or more). In a customary planetary gear $2k-h$ it leads to decreasing of gear ratio. It won't take place in a new gear " $3k-2g-h$ ".

The specificity of the reducing gear is in fact that fine pitch satellite gears are the smallest units ($z_{g_1} = z_{\text{min}} = 25 \dots 50$) especially within the range of gear ratio $8 \leq u_{hb_2}^{b_1} \leq 45$. Therefore dimensions of gearing are defined just by satellite gears and input central wheel.

Herewith teeth number of all four central wheels a_1 ; a_2 ; b_1 and b_2 adopt a value whereby constructively easy to implement requirement of its placement on a hollow shafts which permit free placement of spindle of isolation valve. Teeth number of satellite gears is settled from the condition of its placement in gear rim of double-rowed, spherical, ball or roller bearing of a necessary capacity.

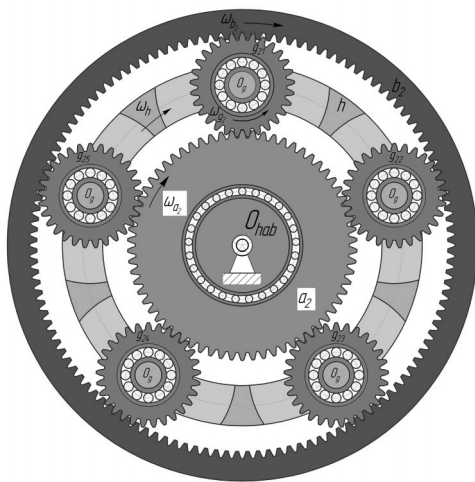


Fig. 4. The visualization of gears "a₂ – g_{2i}" and "g_{2i} – b₂" of the second planetary drive stage of nine-threading gear according to the scheme on the fig. 3

The most advanced construction is the drive on the basis of transmission "3k-2g-h" with an input on the small central wheel and installation of electric motor coaxially towards valve and reducing gear (fig. 5). Herewith it doesn't require additional teeth drive stage and for a pass of screw, special electric drive with hollow rotor [6] for arrangement and movement of spindle of isolation valve and informational shaft of its positional sensor (shown for clarity) is used for pass of screw.

CONCLUSION

In the modern period, Russian and foreign single-threaded drives (cylindrical, conical, worm-type, hypoid, spiroid) which are used in pipeline transport almost used up all possibilities of its development.

The usage of quasidifferential multi-threading planetary reducing gear as a base design of multi-turn electric drive permits to extend range of its gear ratio and use internal gearings of satellite gears with big central wheel which have highest load capacity in the most loaded units of the drive.

In this case dimensions of the drive are defined only by the size of satellite gears and output central wheel. Reducing gear is more compact and has low specific gravity. Structurally it's easy to place hollow shaft within a reducing gear for a free arrangement and movement of isolation valve's spindle and informational shaft for its positional sensor. Simultaneously it's easy to link

together other components: hand drive, pressure sensors, positional sensors, etc.

Coaxial compact look of electric drive defines it as a drive with improved contemporary weight-dimensions characteristics.

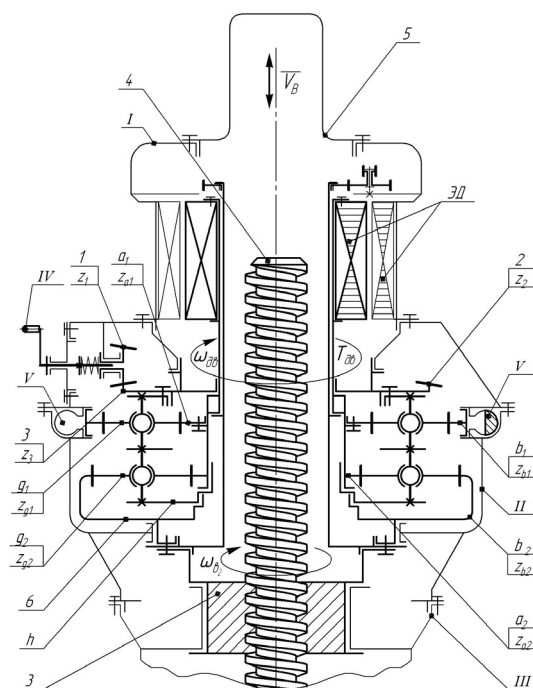


Fig. 5. Kinematic scheme of multi-turn and multi-threading electric drive with an input on small central wheel and coaxially positioned towards axis of rotation of motor rotor, input and output shafts of reducing gears with axis of movement of valve spindle

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