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National University “Zaporizhzhia Polytechnic”

Methodical instructions
on performance of course project
on the discipline “Applied mechanics”
for students of specialty G3 Electrical engineering
of all forms of learning

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Methodical instructions on performance of course project on the discipline “Applied mechanics” for students of specialty G3 Electrical engineering of all forms of learning / V.G.Shevchenko, S.L.Ryagin, S.O.Shumykin, R.V.Onyshchenko. – Zaporizhzhya: National University “Zaporizhzhia Polytechnic”, 2025. – 15 p.

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GENERAL INFORMATION

Electric drive is one of the most common units. It is an important part of many machines, ensuring their functioning. Designing or selecting an electric drive is a typical task in engineering.

The electric drive consists of a gearbox and an electric motor, which can be connected to each other with or without a coupling. Connection without a coupling is more common in cases where the electric motor is attached directly to the gearbox housing. The electric motor serves as a source of mechanical energy, it gives motion to the rest of the structural elements. The gearbox converts the parameters of mechanical energy: as a rule, it increases the torque moment by reducing the rotation speed. The coupling connects the shafts of the electric motor and gearbox, alignment of which is not ideal, and also reduces ununiformity of a movement. Sometimes a flywheel is additionally used to further reduce ununiformity of a movement.

The gearbox can be cylindrical, bevel, worm, planetary, etc., depending on its characteristic features. It is characterized by power, operating mode, gear ratio, torque moment, maximum rotation speed and some other parameters. The coupling can be flexible, tooth-type, spring, with rubber-bushed studs, etc. The electric motor can be of different types as well. But parameters of the gearbox, coupling and electric motor must correspond to one another.

The electric drive is connected to the actuator via an output shaft. Torque moment is transmitted via a key.

The task is the following in this course project. The angular velocity and power at the output shaft are given. It is necessary to develop an electric drive that provides the specified parameters. It is possible to select a standardized drive that is produced in series.

The course project consists of 2 sheets of drawings and explanatory note. The electric drive in three projections and in axonometry must be shown at the sheets. The explanatory note must contain general information about the electric drive, calculations related to its development or selection, design of the output shaft key, as well as calculation of the drive efficiency. The explanatory note may contain additional information about choice and design of electric motor, coupling, gearbox, etc.

INITIAL DATA

Variant number is appointed to each student by the teacher. A student chooses from Table 1.1 initial data to course project in accordance with his variant number. Here ω – angular velocity of the output shaft, N – output shaft power.

Table 1.1

Variant	ω, rad/s	N, kW
1	16,996	2,88
2	9,603	2,30
3	18,326	6,04
4	12,524	4,88
5	19,981	10,98
6	11,498	8,62
7	18,179	15,45
8	10,482	12,57
9	12,839	24,39
10	6,901	19,32

All additional information must be found independently, using standards, regulatory and reference literature, and other similar sources.

A student must fulfill the course project himself. Usage of AI at fulfillment of the course project is strongly forbidden.

Course project must be performed in accordance with the requirements of the correspondent standards.

Title sheet must be the first sheet of explanatory note. All initial data must be placed at the beginning of explanatory note. Conclusions and literature must be placed at the end of explanatory note. Explanatory note must be handwritten. Drawings can be fulfilled using computer facilities.

The literature must contain sources that were actually used at fulfillment the course project.

Record of calculations must be detailed enough for its check. After check student has to correct all mistakes and to prepare course project for re-check. If there are no mistakes, student has to support the course project.

EXAMPLE

The introduction of the explanatory note must contain general information about the electric drive.

The first part must be devoted to the arrangement or selection of the electric drive and its components. It must begin with the initial data and contain all the necessary calculations.

Let ω=9,069 rad/s and N=4,08 kW for the output shaft according to the task. First of all, it is necessary to calculate the related parameters.

Output shaft rotation speed:

$$n_2' = \frac{30 \cdot \omega}{\pi} = \frac{30 \cdot 9{,}069}{\pi} = 86{,}6\ rpm \qquad (1.1)$$

Output shaft moment:

$$M_2' = \frac{N}{\omega} = \frac{4{,}08 \cdot 10^3}{9{,}069} = 449{,}88\ Nm \qquad (1.2)$$

Using this data, it is possible to select a standard electric drive, for example, the S series shaft-mounted gearmotor from the Table A.1. When choosing, output shaft rotation speed n_2 have to be approximately equal to n'_2. Output shaft moment M_2 have to be approximately equal to M'_2, but slightly more then it.

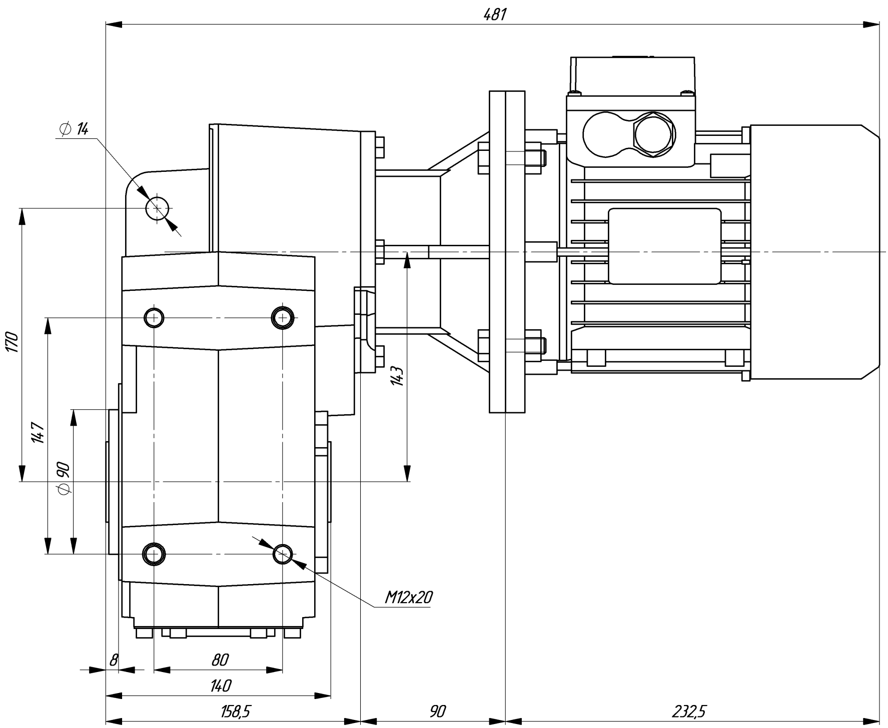
It is appropriate to choose the electric drive of standard size 062 with gear ratio i=16,16 from the Table A.1 for the values (1.1) and (1.2). Output shaft moment M_2=450 Nm, electric motor power N_1=4,25 kW, output shaft rotation speed n_2=86,6 rpm for this electric drive. These values are in excellent agreement with the values M'_2 and n'_2.

The electric drive is shown in three projections in the correspondent pictures 1.1, 1.2 and 1.3 as an example. In the course project, these drawings must be placed on sheet 1, observing the projection relationship.

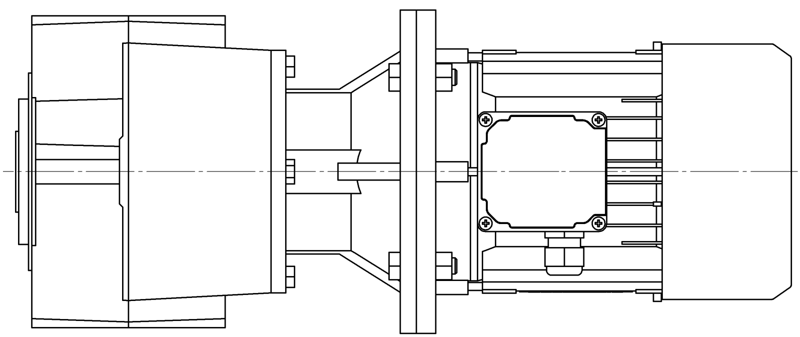
The electric drive is shown in axonometry in the picture 1.4 as an example. In the course project, this drawing must be placed on sheet 2.

All requirements of current standards must be met when preparing drawings.

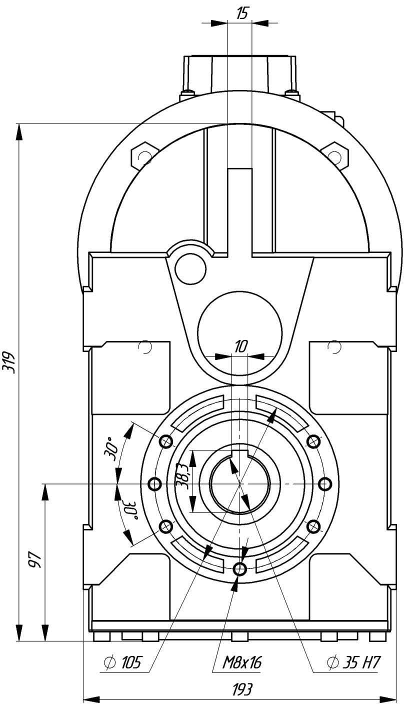
It is necessary to describe all characteristic features of the chosen electric drive at the same part of explanatory note.



Picture 1.1 – Frontal projection of the electric drive



Picture 1.2 – Horizontal projection of the electric drive

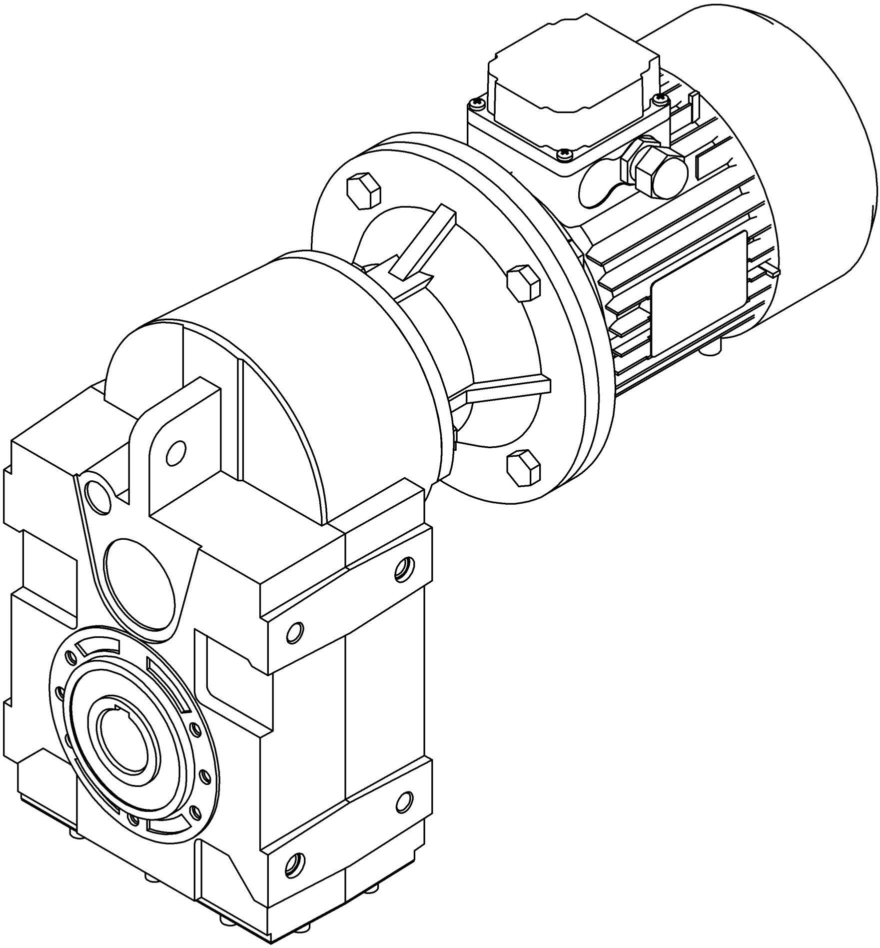


Picture 1.3 – Profile projection of the electric drive

In particular, the S series shaft-mounted gearmotors are available with a cast iron housing in sizes from 050 to 125. They provide a wide range of gear ratios with maximum efficiency under any operating conditions. These gearboxes are specifically designed for use in systems with conveyors or augers. They are also suitable for a variety of industrial applications. [1] This is just the case where the electric motor is attached directly to the gearbox housing without a coupling.

Here have to be placed calculation of the drive efficiency as well. The drive efficiency η can be calculated by the following formulas:

$$\omega_2 = \frac{\pi \cdot n_2}{30} = \frac{\pi \cdot 86{,}6}{30} = 9{,}069\, rad/s \qquad (1.3)$$



Picture 1.4 – Axonometry of the electric drive

$$\eta = \frac{\omega_2 \cdot M_2}{N_1} = \frac{9{,}069 \cdot 450}{4{,}25 \cdot 10^3} = 0{,}96 \qquad (1.4)$$

The value 0,96 in formula (1.4) is really rather high even for such type of gearmotors, and it confirms high efficiency of the electric drive.

The second part of the explanatory note must contain strength calculations for the electric drive components.

In particular, the calculation of the output shaft key must be given here. First, it is necessary to determine the output shaft diameter *D* and key width *b*. In this example, these values can be taken from the drawing Picture 1.3: *D*=35 mm, *b*=10 mm. Shear force *Q* can be determined by the formula:

$$Q = \frac{2 \cdot M_2}{D} = \frac{2 \cdot 450}{0{,}035} = 25714 N \quad (1.5)$$

The key length *l* is a standardized value. It can be selected from the Table B.1 (Appendix B) or from reference books. It is advisable to select key length in such a way that shear stress τ_k in it would be not less than half of the admissible one. It is taken prismatic key with length *l*=40 mm in this example.

The value of admissible stress [τ] can also be taken from reference literature. It is taken [τ]=80 MPa in this example. Now it is possible to check the fulfillment of the strength condition:

$$\tau_k = \frac{Q}{b \cdot l} = \frac{25714}{10 \cdot 40} = 64{,}29\, MPa \le [\tau] = 80\, MPa \quad (1.6)$$

It is clear from the formula (1.6) that the strength condition is met. Consequently, reliability of the key joint is ensured.

Strength calculation of the output shaft must be given here as well. The only load on the output shaft just for the shaft-mounted gearmotor is torque moment M_2. Accordingly, a check for shear stress will be sufficient.

Shaft cross-section modulus W_ρ can be calculated by the following formula:

$$W_\rho = \frac{\pi \cdot D^3}{16} = \frac{\pi \cdot 0{,}035^3}{16} = 8{,}42 \cdot 10^{-6}\ m^3 \quad (1.7)$$

The estimation of shear stress value τ_s without taking into account the concentration can be performed as follows to check the fulfillment of the strength condition:

$$\tau_s = \frac{M_2}{W_\rho} = \frac{450}{8{,}42 \cdot 10^{-6}} = 53{,}44\, MPa \leq [\tau] = 80\, MPa \qquad (1.8)$$

It is clear from the formula (1.8) that the strength condition is met. Consequently, reliability of the output shaft is ensured. Additionally, the following condition is satisfied:

$$\tau_s = 53{,}44\, MPa \leq \tau_k = 64{,}29\, MPa \qquad (1.9)$$

This means that in case of an abnormal overload, the relatively inexpensive key will be damaged, but the shaft will remain functional. Thus, the key performs its protective function.

LITERATURE

1. Shaft mounted gear reducers – S Series. – URL: https://www.motovario.com/eng/products/shaft-mounted-gear-reducers--s-series

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4. Targ, S. Theoretical Mechanics. A Short Course. – M.: Mir, 1976. – 526 p.

5. Meshchersky, I.V. Collection of Problems in Theoretical Mechanics. – M.: High School, 1967. – 320 p.

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Appendix A
Example of electric drive parameters

Designations:
i – gear ratio;
M_2 – output shaft moment;
N_1 – electric motor power;
n_2 – output shaft rotation speed.

Table A.1 – Parameters of the S series shaft-mounted gearmotors [1]

Standard size	*i*	M_2, Nm	N_1, kW	n_2, rpm
1	2	3	4	5
052	8,63	170	3,01	162,3
	11,14	190	2,60	125,7
	12,00	200	2,55	116,7
	13,66	210	2,35	102,5
	15,27	240	2,40	91,7
	16,29	240	2,25	86,0
	18,63	240	1,97	75,1
	19,73	240	1,86	71,0
	21,04	260	1,89	66,5
	21,53	260	1,84	65,0
	24,07	260	1,65	58,2
062	8,00	330	6,30	175,0
	8,92	330	5,65	156,9
	9,55	360	5,76	146,7
	10,65	360	5,16	131,5
	11,71	390	5,09	119,6
	13,06	420	4,90	107,2
	13,36	420	4,80	104,8
	15,94	450	4,31	87,8
	16,16	450	4,25	86,6
	19,29	450	3,56	72,6
	19,55	460	3,59	71,6
	23,18	470	3,10	60,4

Continuation of the Table A.1

1	2	3	4	5
082	7,34	550	11,44	190,8
	8,06	600	11,36	173,6
	9,94	650	9,98	140,8
	11,61	700	9,21	120,6
	12,75	750	8,98	109,8
	14,04	760	8,26	99,7
	15,43	770	7,62	90,7
	15,73	770	7,48	89,0
	17,29	770	6,80	81,0
	19,03	770	6,18	73,6
	20,14	770	5,84	69,5
102	8,06	850	16,10	173,6
	8,85	900	15,54	158,3
	10,88	950	13,33	128,6
	12,75	1000	11,98	109,8
	13,99	1200	13,10	100,1
	15,43	1250	12,37	90,7
	17,21	1300	11,53	81,3
	19,00	1400	11,25	73,7
	20,83	1400	10,26	67,2
122	8,48	1500	27,00	165,1
	9,30	1700	27,92	150,6
	10,24	1700	25,36	136,7
	11,42	1900	25,41	122,6
	12,63	2200	26,61	110,9
	13,84	2400	26,48	101,2
	16,99	2600	23,36	82,4
	21,25	2800	20,12	65,9

Appendix B
Recommended lengths of prismatic keys

Designations:
b – key width;
l – key lenth.

Table B.1 – Some recommended lengths of prismatic keys

b, mm	*l*, mm
8	18, 20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 70, 80, 90
10	22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 70, 80, 90, 100, 110
12	28, 32, 36, 40, 45, 50, 56, 63, 70, 80, 90, 100, 110, 125, 140
14	36, 40, 45, 50, 56, 63, 70, 80, 90, 100, 110, 125, 140, 160
16	45, 50, 56, 63, 70, 80, 90, 100, 110, 125, 140, 160, 180
18	50, 56, 63, 70, 80, 90, 100, 110, 125, 140, 160, 180
20	56, 63, 70, 80, 90, 100, 110, 125, 140, 160, 180