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Analysis of Conceptual Solutions of Universal Helical Geared Reducers

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Abstract. Geared reducers are mechanisms designed to reduce the number of revolutions using geared elements and nowadays they present one of the most commonly used types of mechanical transmissions in mechanical engineering. Due to the different shapes of geared elements, there are different types of geared transmissions: helical, bevel, worm, special and combined transmissions. This paper analyses only helical geared transmissions, since there is a great extent of whole this matter. Helical transmissions are analysed only with external helical gearing, since internal geared pairs represent a special and very large group of gears. Within the external helical geared transmissions, only torque transmissions are analysed, while the transmissions of motion are not analysed and they represent another large group of transmissions. Only universal gear reducers with axial, or almost-axial, parallel shafts are considered (two-stage and three-stage transmissions). Although, single-stage gear reducer produced with parallel shafts are not considered by the paper in order to reduce the area of researching. Gear reducers are most commonly delivered to customer with electric motor, known as motor geared reducer, and they are studied here extensively. Gear reducer can be also delivered without motor, only with input shaft. The basic aim of this paper is to present all characteristics and specificities of motor geared reducer in one place.

Introduction

Nowadays, universal motor geared reducers with helical gears have an extremely large application in mechanical engineering. It is only because of their simple construction, high adaptability, high reliability, high power rationality and relatively low production and maintenance costs. Universal geared reducers can be also delivered without electric motor. However, it is a rarely required and only in the case when the customers want to install standard IEC electric motor (Fig.1) or when they want to base the motor separately (if the space is limited and/or the motors are large and heavy) [1].

Universal geared reducers are produced as single-stage, two-stage, three-stage and multistage units. Based on the conducted research of realised solutions of almost all leading producers of universal motor geared reducers with helical gears, it can be concluded that their production program contains universal units of very different conceptual solutions [2].

Most of manufacturers of geared reducers produce single-stage units, although there are some manufacturers which do not produce them since they cover these small gear ratio by belt transmission and there is no need for producing single-stage units (for example companies Rossi [3], Bege [4, 5] etc.). If small gear ratio is required, these manufacturers use two-stage reducers and with their lowest

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gear ratio cover the gear ratio area of single-stage units. With this approach, they simplify and make cheaper their production. However, they certainly lose a part of the market, despite the selling of low-speed two-stage gear reducers at a slightly lower price in order to be competition with manufacturers of single-stage reducers.

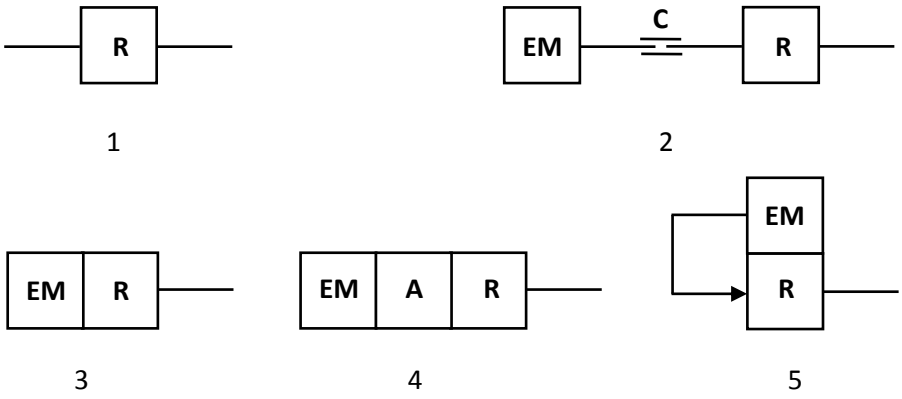

Figure 1. Schematic review of characteristic construction ways of universal geared reducer: 1 – input shaft reducer (R), 2 - input shaft reducer connected by coupling (C) with standard IEC electric motor (EM), 3 – motor geared reducer, 4 - motor geared reducer with adapter (A) which connect IEC motor and reducer and 5 - motor geared reducer where IEC motor is connected by belt transmission with the reducer [1].

Great number of smaller manufacturers produces two-stage geared reducers in special case for two-stage gear unit, while three-stage reducers are built by connecting two-stage and single-stage gear units. Therefore, their three-stage gear units are slightly more expensive then gear reducers built in the universal case for two-stage and three-stage gear reducer. By this approach, they achieve emphasis on two-stage gear reducers and achieve slightly lower production costs then manufacturers who produce two-stage gear units in universal housings for two-stage and three-stage gear reducers. At the same time, manufacturers with high gear ratios of two-stage gear reducer try to capture as much of the customers who are interested for three-stage gear units [1, 6].

Most manufacturers of three-stage gear reducers produce three-stage gear units in universal housing for two-stage and three-stage units. In that case, the emphasis is on three-stage units, which gives them a major advantage in the area of three-stage gear units over the manufacturers who build their three-stage gear units by connecting two-stage and single stage gear reducer. Any weakness of their two-stage gear reducers is compensated by this operation.

Four-stage gear reducers are less demanded by customers. However, manufacturers who make two-stage gear units in a special housing for two-stage gearbox, produce these gear reducers by connecting two units of two-stage gearbox. They certainly have some advantage over manufacturers who produce two-stage reducers in universal housing for two-stage and three-stage gear unit. If it is a case of multi-stage gear reducer, manufacturers who use universal housing for two-stage and three-stage gear units have a great advantage. In that case, using universal housing, they can easily deliver five-stage or six-stage gear units, which the other (unfortunately) cannot, but these gear reducers are rarely required.

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Therefore, each of the manufacturers has an advantage only in a certain segment of the market, but nevertheless they are successfully present and active in the market. Customers, who have wide range of interest in different gear reducers, want to buy all the units from the same producer. Although most manufacturers are not usually able to provide them all, so in such cases, manufacturers try to make slight correction of their gearbox price, in order to retain those customers as well.

It is also evident that all manufacturers strive to increase load capacity and gear ratio values of their gear reducers. Considering today's solutions of universal gear reducers and solutions of twenty years ago, it can be concluded that, within the same axis heights, values of load capacity and gear ratio have increased by 100%, which is certainly an extremely great success of these gearbox manufacturers [1, 6].

Load capacity of modern gear reducers has increased by using output shaft with higher strength, by using the bearings with higher load capacities on all shafts, and especially by increasing the gear ratio of all gear pairs.

Increasing the gear ratio is achieved by increasing the diameter of the driven gears, i.e. increasing the central distance, by expanding the housing (in order to mount large gears), by opening the housing from the top on low-speed and high-speed chamber (in order to mount large gears) and by reducing the diameter of the pinion. So far, it was common practice to mount the pinion on electric motor shaft, i.e. to press it on motor shaft. Today, it is a practice to press the pinion into the motor shaft. Using small pinion gears has affected on abandonment of the concept of axial gear reducers, so today gearboxes are produced as almost axial, with some radial distance between input and output shaft. If small pinion is used, maintaining the same axis height, it is possible to increase the diameter of the driven gear with the reducing of central distance. That will influence the reducing of gear ratio of output gear pair and the "input" of higher torque into the gearbox (since the load capacity of gear unit is defined according to the highest torque of the output shaft - T_{2N}), which could cause higher loadings of all components inside the gear reducer [1, 2, 6]. However, if the concept of axial gearbox is abandoned, this problem will not exist.

It is also evident that some manufacturers abandoned the concept of producing gear units with axis heights distributed according the standard row R20/2 (former R10). In the area of most required reducers, these manufacturers produce gear reducers according the standard row R20 [1, 2]. This expands and increases the production costs, but in a certain segment of torques, it is possible to offer smaller cheaper solutions, which makes the great advantage over the competition.

Therefore, in the development of a new series of universal gear reducers, it should be followed the activities of leading manufacturers of gear units and accepted their axis heights and mounting dimensions, and as much as possible the load capacity and gear ratio.

It follows that single-stage gear reducer should be produced with high gear ratio (up to 15 [1, 7]) in order to cover as large as possible range of gear ratios of two-stage gear unit.

Better solution is that two-stage gear reducers are produced in universal housing for two-stage and three-stage gear reducers with gear ratio values over 50.

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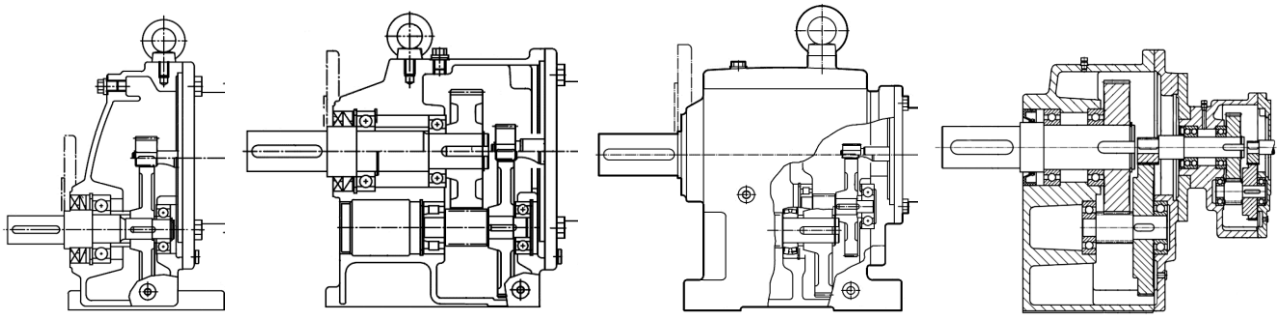
Three-stage gear reducer is better to be assembled in universal housing for two-stage and three-stage reducer, i.e. the emphasis should be given to three-stage units. Three-stage gear reducers should be built with large gear ratio (above 300) [1, 2].

Additionally, it should take care that intermediate sizes of gear unit are offered to customers in the area of the most required gear ratio values (axis heights). Also, two pairs of gears could be offered in the same area: with small load capacity and high gear ratio, and large load capacity and low gear ratios. Such approach would certainly provide a competitive product. In order to survive in the market, competition acts in a different ways. In the case that leading manufacturer put the emphasis on large load capacity and small gear ratios, the competition will do the opposite and put the emphasis on small load capacities and high gear ratios, i.e. the emphasis will be on this solution which leading manufacturers do not offer. If this approach is used, the competition could be eliminated with producing two sets of gears and having higher production costs.

1. Problem Description

Helical gear reducer can be produced in different variants as: single-stage, two-stage, three-stage or multi-stage gear unit; also as reducer with parallel or axial (almost axial) input and output shafts. There are reducers with input and output shafts in horizontal plane, or in vertical plane, or with free shaft arrangement; also there are reducers with one or two parts housing; there are gear units with axial, radial and radial-axial way of mounting. This large number of variants, i.e. conceptual solutions is a consequence of high universality, smaller production costs, simplify assembly and making distinction from competition to avoid the possibility of copying someone else's solution.

Characteristic solutions of single-stage, two-stage, three-stage and multi-stage gear reducers are shown in Fig. 2. Depending on the size of gear ratio, the number of gear stages is determined, where lower stage reducer should be always adopted since it represents cheaper solution due to smaller number of gear pairs [4, 5, 8].



1 2 3 4

Figure 2. Characteristic solutions of (1) single-stage (Nord), (2) two-stage (Nord), (3) three-stage (Nord) and (4) multi-stage universal gear reducer (Bege).

Solutions of characteristic gear reducers with parallel, axial, or almost-axial shafts are shown in Fig. 3. Parallel shaft solutions are used in places where greater rigidity is required, where there are no

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constraints in space and where higher powers are used. Gear reducers with axial (or almost-axial) shafts are used where available space is limited and where compact construction is required [1, 4, 5].

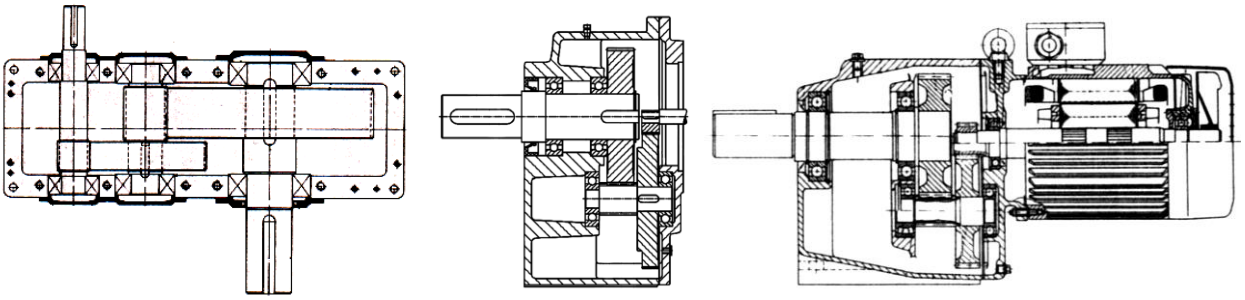

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Figure 3. Characteristic solutions of (1) gear reducer with parallel shaft (Santasalo), (2) axial shaft (Bege) and (3) almost-axial shafts (KEB).

Characteristic solutions of gear reducers with horizontal, vertical and free shaft arrangement are shown in Fig.4. Each solution has certain advantages. Horizontal shaft arrangement can increase the stiffness of the reducer construction. Vertical shaft position saves the space and the free shaft arrangement provides the simply assembling [1, 8].

Solutions of characteristic gear reducer with one-piece housing (monoblock) and with two-parts housing are shown in Fig. 5. Monoblock housings are newer solutions and they are designed to simplify manufacturing, but with a more complicate assembly. Two-parts housings are older solutions suitable for simply assembly with a complicated production way. Gear reducer housings can be provided for radial, radial and axial, and axial assembly. Two-parts housing has supporting faces that should treated and drill the holes for connecting screws. After that, two halves of the housing should be joined, drill the holes for the centring nuts, insert the nuts and continue manufacturing. This is certainly a rather complicated manufacturing process [1, 3, 9].

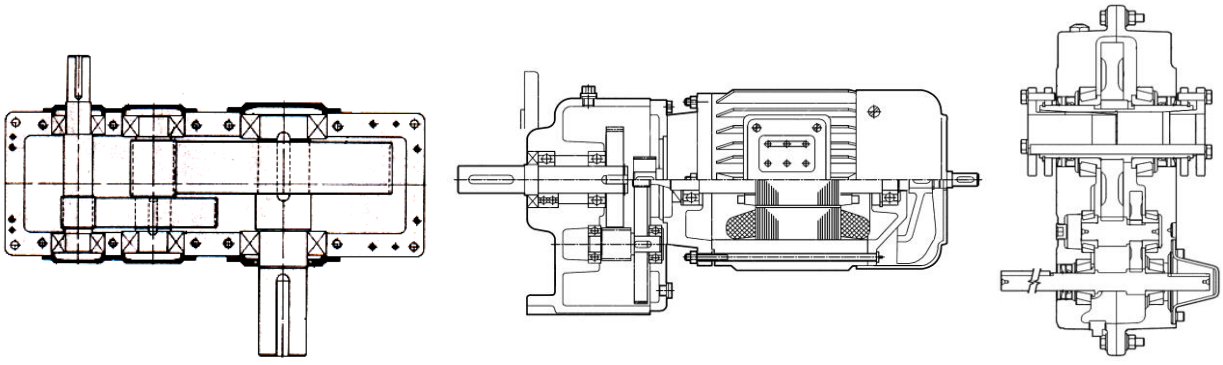

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Figure 4. Characteristic arrangement ways of input and output shafts for universal gear reducers: (1) in horizontal plane (Santasalo), (2) in vertical plane (Nord) and (3) free arrangement of shaft position (Dodge).

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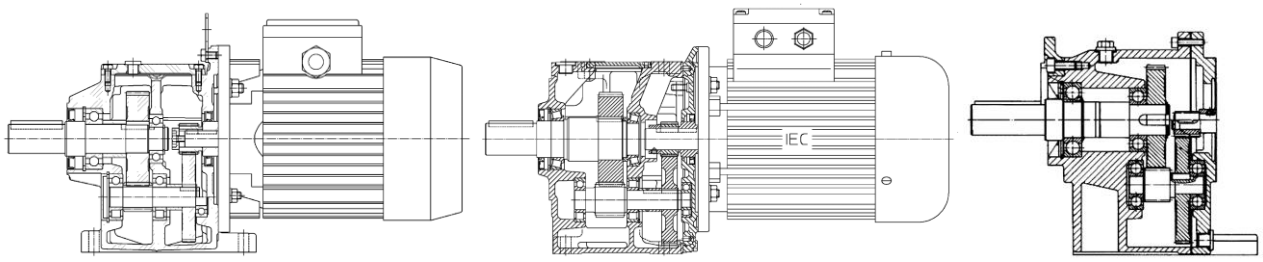
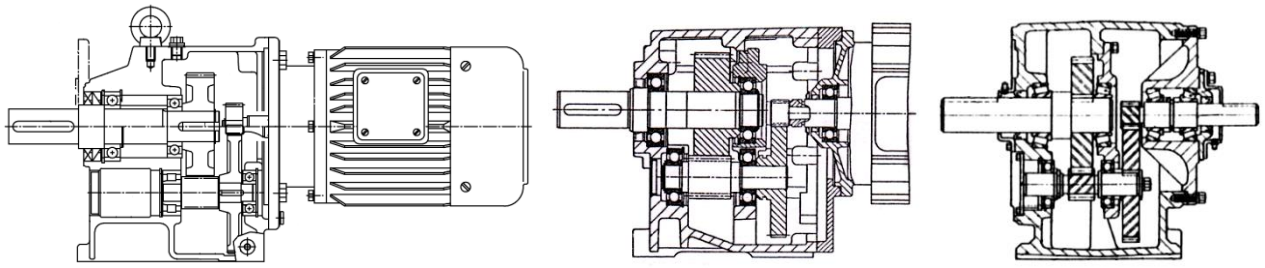


1 2 3

Figure 5. Characteristic solutions of universal gear reducer with (1) monoblock housing (Rossi), (2) with two-part housing intended for radial mounting (Rossi) and (3) with two-part housing intended for axial mounting (Rehfuss) [5]. Note: Monoblock housing is every housing that has all shaft supports inside the housing as one element. If any shaft support is located on the front or back cover, than it is considered as two-part housing.

2. Problem analysis

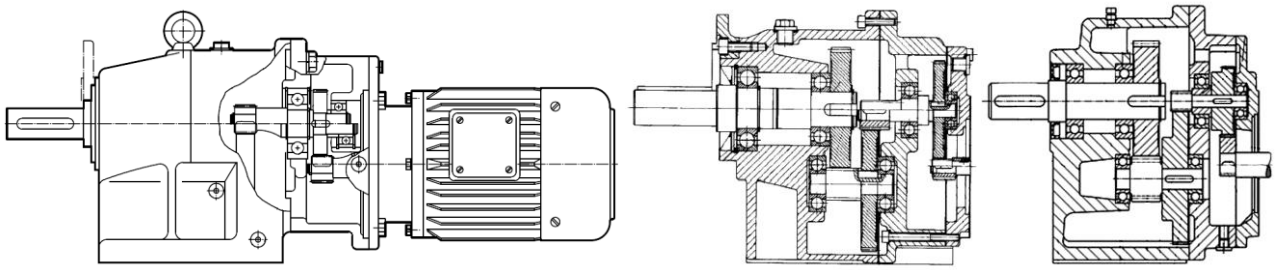
If only two-stage gear units are considered, with axial or almost-axial shafts, it is evident that housings with axial mounting are most commonly used today (Fig. 6). This approach provides relatively simple mounting with a slightly more complicate manufacturing, since it is sometimes necessary to provide that supports for bearings are aligned with shafts in the case the bearings are in housing cover [1, 8, 10].



1 2 3

Figure 6. Characteristic solutions of two-stage universal gear reducers: (1) Nord, (2) Lenze and (3) Winsmith.

If only three-stage gear reducers are considered, with axial or almost-axial shafts, manufactured by connecting two-stage and single-stage gear unit, it is also evident that housings with axial mounting are most commonly used today (Fig.7) [4, 5, 8, 9].



1 2 3

Figure 7. Characteristic solutions of three-stage universal gear reducers obtained by connecting two-stage and single-stage gear unit: (1) Nord, (2) Rehfuss and (3) Bege.

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Considering two-stage gear reducers, with axial or almost-axial shafts, manufactured in universal housing for two-stage and three-stage gearbox, it is evident that housings with both radial and axial mounting are most commonly used today (Fig.8).

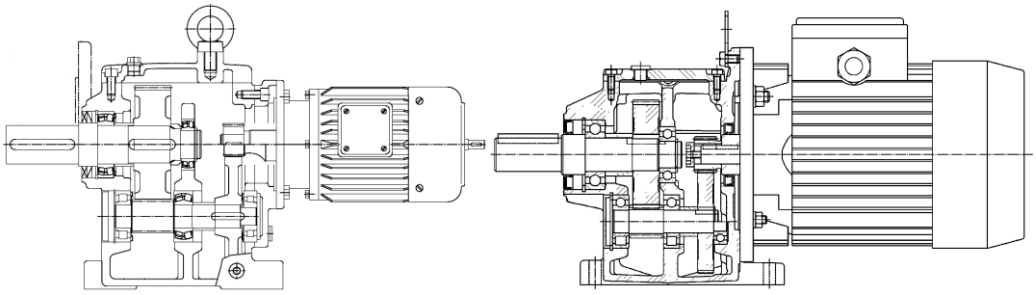

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Figure 8. Characteristic solutions of two-stage universal gear reducers manufactured in universal housing for two-stage and three-stage gearbox: (1) Nord and (2) Rossi.

If three-stage gear reducers are considered, with axial or almost-axial shafts, manufactured in universal housing for two-stage and three-stage gearbox, it is also evident that housings with both radial and axial mounting are most commonly adopted (Fig.9) [3, 8].

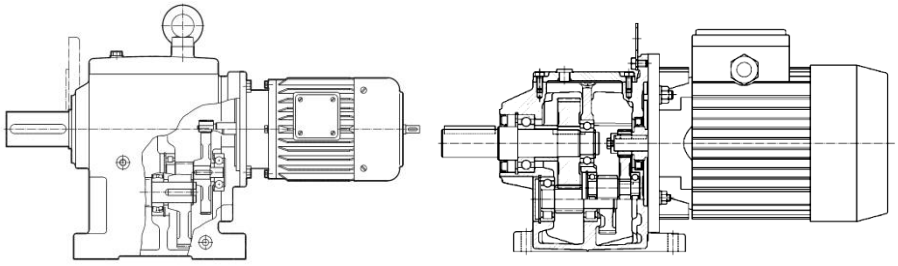

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Figure 9. Characteristic solutions of three-stage universal gear reducers manufactured in universal housing for two-stage and three-stage gearbox: (1) Nord and (2) Rossi.

In order to reduce production costs, some manufacturers additionally practice to produce only one (universal) housing with feet and flange (Fig.10-1) or they install feet or/and flange (Fig.10-2). With this approach, they reduce amount of large and complex castings, but they increase the extent of manufacturing, and sometimes they reduce the stiffness of the housing (Fig.10-2) [3, 11].

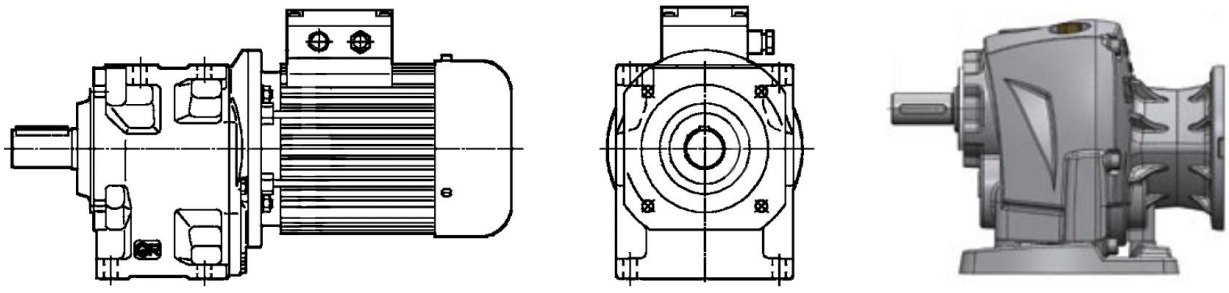

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Figure 10. Characteristic solutions of three-stage universal gear reducers manufactured in universal housing for two-stage and three-stage gearbox, provided in variant with feet and/or flange: (1) Rossi and (2) Robus.

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3. Selection the most successful gearbox solutions

From many successful realized solutions of universal gear reducers manufactured in special housing for two-stage gearbox, the solutions of companies Sesame, Bege and Aokman (Fig.11) can be especially emphasized [1, 3]. Within many realized gear reducers assembled in universal housing for two-stage and three-stage gearbox, it can be emphasized solutions of companies Siemens, PGR and Lenze (Fig.12) [1, 10].

1 2 3

Figure 11. Successful realized solutions of two-stage universal gear reducers manufactured in special housing for two-stage gearbox: (1) Sesame, (2) Bege and (3) Aokman.

1 2 3

Figure 12. Successful realized solutions of two-stage universal gear reducers manufactured in universal housing for two-stage and three-stage gearbox: (1) Siemens, (2) PGR and (3) Lenze.

4. Conclusion

Based on the given analysis, it is evident that modern solutions of gear units are made in different variants in order to ensure providing as simple and low cost as possible manufacturing and assembling. Gear reducers with special housing for two-stages gear units and gear reducers with universal housing for two-stage and three-stage gear unit are almost equally exploited. Today, one-piece housings are required almost in all cases in order that manufacturing become easy, no matter the assembly will be more complex. One-piece housing makes possible ideal axial consistecy of bearings and so far the providing of regular and proper gearing. This is very important for long-lasting and reliable operation of gear reducers. Additionaly, one-piece housings provide greater rigidity of the unit, which also has beneficial effect for the gear reducer lifetime. One-piece housings are also better hermetically closed, which is also important for gear units. Of course, radial mounting allows the

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mounting of large gears, with a slightly more complex assembling, i.e. certain subassemblies are not possible to assemble outside of the reducer and to be then mounted into the housing.

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