Analysis of housing models of modern single-stage universal gear reducers

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Abstract. Universal gear reducers are quite simple products, so today there are many manufacturers around the world that produce this kind of reducers. Their connecting dimensions and shape are not defined by the standard, so there is a large number of solutions. The most of manufacturers produce gear reducers with connecting dimensions and axis height, usually the same like the biggest manufacturers do (mainly company SEW), because they want to provide interchangeability of their gear reducers. It is interesting to note that most manufacturers are trying to adopt such a form of reducer that will be different from competing solutions in order to avoid an accusation of coping with someone else’s solution, although manufacturers have almost identical shape and competing (copied) solutions. The paper presents, due to the volume of matter, only the analysis of forms of the housing of modern single-stage universal gear reducers in order to point out the expected directions of their further development.

1. Introduction

Universal gear reducers can be divided in different ways. Nowadays, the basic division is made according to the size of backlash into the industrial reducers, which are most commonly encountered in practice (power transmissions) and low backlash reducers, with an backlash size less than 10 angular minutes, which are used only in precision mechanics (movement transmissions) [1,2]. The further division is done according to the position of the gears on the ordinary reducers and planetary reducers. In this paper, only industrial gear reducers will be considered, although today planetary reducers are increasingly used in places where at a slightly higher price it is possible to achieve large transmission ratios and small dimensions [3,4]. The ordinary reducers can be divided to reducers with parallel and coaxial, or almost coaxial shafts. In this paper only single-stage reducers will be considered, which can be made only as parallel shaft reducers. The further division of these gear reducers can be made according to the mounting method with radial, axial and radi-axial mounting. According to the number of stages reducers can be single, two, three and multi-stage. According to the way of connection between the reducer and the electric motor, recucers can be delivered with classic intup shaft, reducers with an adapter for IEC motors, when customer mounting electric motor or when reducers is delivered with IEC motor. Geared motors can be delivered with special reducer electric motor or with standard IEC motor. Depending on the size of the reducer, there are small (usually with axis height h < 100 mm), medium (100 < h < 500 mm) and large reducers (h > 500 mm), so that the size of the gear reducer can also have a certain impact on the final shape of the reducer, or its housing, although it is intended that all housings within one reducer family are identical to each other. In this paper only medium-sized gears are considered.
2. Problem description

Universal medium-sized reducers can be manufactured in a special housing for single, two, three and multi-stage reducers, which is the best but also the most expensive solution, justified in large series and such an approach is less common in practice. Single-stage reducers are exclusively manufactured in single-stage housings, although there are manufacturers who do not produce single-stage units at all. In order to reduce production costs, since single-stage reducers are not relatively demanded and, if required, two-stage reducers with lower transmission ratio are offered instead. Two-stage gear drives are often produced in a special housing for two-stage units, and three-stage reducers are designed by connecting the single-stage reducer housing to the two-stage gear unit. In this case, two-stage reducers are cheaper, while the three-stage reducers are a bit expensive. Four-stage gear drives are manufactured by connecting two-stage reducer with a smaller two-stage gear drive. There are manufacturers who produce universal housing for two and three-stage reducers, so their two-stage reducers are more expensive than two-stage units built in a special case for two-stage reducers. However, their three-stage gear drives are cheaper than three-stage reducers made with a combination of two-stage and single-stage reducer. Four-stage and multi-stage reducers are built by connecting two two-stage, three-stage and two-stage or two three-stage reducers. What concept will be adopted depends on which particular segment of the gear ratios (revolution number) is interested for the company. The most demanded are two-stage reducers with high gear ratios, or three-stage reducers with lower gear ratios. Therefore, some companies produce only this type of reducers. Smaller manufacturers tend to the opposite area than the major competitors, but there are manufacturers who have both types of reducers in their product line.

2.1 Single-stage reducers

The shape of the housing of the single-stage reducer depends on the position of the shaft and the way of the installation. Regarding the position of the shaft, there are the reducers with horizontal (Figure 1) and vertical shaft positions (Figure 2).

![Figure 1. Characteristic solutions of single-stage reducers with horizontal arrangement of shafts as foot-mounted variant, company solution (a) Kissling [5], (b) Flender [6], (c) Hansen [7], (d) Rossi [8] and (e) Hansen [9].](image)

Reducers with horizontal shaft position are usually made with radial mounting and they have experienced extremely intensive development of shape. From the usual, obsolete shape, today they have a very interesting modern shape (Figure 1d). For the older solutions, the functionality and the consumption of material were the most important factors, while today the basic attention is paid to aesthetics (Figure 1d). Modern solutions are characterized by simple and appealing shape, mild transitions and slightly higher material consumption.

The vertical arrangement of the shaft is more commonly found in practice. For this arrangement, there are reducers as foot-mounted (Figure 2a), flanges-mounted (Figure 2b), foot and flange-mounted variant (Figure 2c) and shaft mounted reducers (Figure 2d). The shape of each housing is adapted to certain installation requirements.

This kind of gear drives belongs to universal type of reducer, which is adapted for different shapes and mounting positions and therefore they are more complex than special reducers that are designed...
for a specific purpose. Manufacturers of reducers do not know the exact purpose of their products, and they need to adapt it to almost all purposes, i.e. the shapes and positions of the installation.

Within certain solutions, two conceptions of the reducers can be noticed, when the driven gear is overhang (Figure 3a) and when the driven gear is between the bearings (Figure 3b). The solution with the output gear between the bearings allows more compact construction and greater stiffness of the shaft, and thus a better fitting of the gears, but the installation of these reducers is more complicated.

3. Analysis of the solutions

As for the width of the reducer assortment, i.e. the difference in the form of installation, one of the smaller manufacturers of gear reducer, NRW, has the most complete single-stage reducer assortment (Figures 4 and 5). It is one of the few manufacturers that produce single-stage reducers with foot with output shaft positioned on the top or at the bottom.

The output shaft is rarely raised upwards from the foot, as this often prevents the installation of larger electric motors, or it does not allow the installation of a motor gear unit on a flat surface. Additionally, this manufacturer produces single-stage reducers with foot and flange (with three different sizes of flanges), which is rarely required, and also produces reducers with flanges with different sizes that are connected by bolts with the flange of reducer housing. This manufacturer produces all conventional flanges with an adapter for IEC motors with flanges B5 and B14. The shape of the housing is rather complicated, taking into account material savings as well as reinforcement of the housing.
Figure 4. NRW company single-stage reducer solutions [15].

Concerning the input of gear drive, this manufacturer produces motor gear units, conventional reducers and reducers with an adapter for IEC engines, shorter with one bearing and longer with two bearings. The shape of the housing is very simple and elegant. The color of the housing is red and, on a special request, there may be other colors. The shape of the housing is very simple, but it is slightly larger than the previous manufacturer, which enables better heat dissipation and easier maintenance (cleaning), which also improves heat dissipation and, consequently, the correct operation of the reducer.
Figure 5. NRW company single-stage reducer solutions [15].

Similar reducers are manufactured by PGR company (Figure 6), which produces only reducers with an output shaft positioned at the bottom with foot and a flange that is casted together with the housing. SEW company (Figure 7) produces only reducers as foot- or flange-mounted variant, because other forms of installation are extremely rarely required and it left this market segment to smaller manufacturers. Their housings have simple design, but with the lateral waviness of the surface. In this way the area is increased, due to better cooling, and due to the increased rigidity and strength of the housing.
Figure 6. PGR company single-stage reducer solutions [16].
Figure 7. SEW company single-stage reducer solutions [10].
In the similar way as SEW, the company NORD (Figure 8) produces only reducers with foot or flange, as they are most sought after within single-stage reducers and it is not justified (according to their opinion) to have a wider product family.

4. Expected directions for further development
Based on the analyzed solutions made by the world’s leading manufacturers of single-stage reducers, it follows that further development of single-stage reducers can be expected in only the basic two types of installation with foot and flange (Figure 9). Other forms are less demanded and can be expected to be produced from smaller gear reducer manufacturers, which are based on the segment of market that is not covered by major manufacturers.

Figure 8. NORD company single-stage reducer solutions [13].

Figure 9. Characteristic shapes of single-stage reducers, company PGR (a-d) [16], NORD (e) [13] and BONFIGLIOLI (f) [17].
5. Conclusion

It is evident that modern housing solutions, in addition to functional requirements, place aesthetic requirements in the first place, regardless of the material's consumption and the weight of construction, because the design of the reducer increasingly plays a fundamental role in the selection, and although the reducers are installed in the machine and are often not in direct visible field of observer. Today, reducers are in quality, technical characteristics and prices are fairly uniform, the design of the reducer must be paid special attention, because the beautiful reducer attract the attention of the customer and makes a decision on the purchase based on it. This conclusion can be achieved by observing the solutions implemented by the world's leading reducer manufacturers.

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