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Milan Rackov, Zeljko Kanovic, Sinisa Kuzmanovic, Ruzica Trbojevic

Shaft Position Influence on Technical Characteristics of Universal Two-Stages Helical Speed Reducers

Purchasers of speed reducers decide on buying those reducers, that can the most approximately satisfy their demands with much smaller costs. Amount of used material, ie. mass and dimensions of gear unit influences on gear units price. Mass and dimensions of gear unit, besides output torque, gear unit ratio and efficiency, are the most important parameters of technical characteristics of gear units and their quality. Centre distance and position of shafts have significant influence on output torque, gear unit ratio and mass of gear unit through overall dimension of gear unit housing. Thus these characteristics are dependent on each other. This paper deals with analyzing of centre distance and shaft position influence on output torque and ratio of universal two stages gear units.

1. Introduction.

Big gear ratio value of universal speed reducers is one of the most important indicators of their quality, i.e. capability to satisfy as much as possible customers' demands. Pinion diameter is being reduced and axis distance is being increased in order to increase gear ratio. Gear module increasing affects on load capability increasing, but also on gear ratio decreasing. Optimal values of output torque and gear ratio can be achieved by adequate position of shafts with gears on them.
where $n = 2^k$, k being a natural number.

2. Problem description.

In the scope of universal gear units family, it tends to achieve the biggest possible load capability and gear ratio, with applying minimal mass for each shaft height. Gear ratio increasing can be the simplyest achieved by axis distance increasing, however, space limitation and shaft height are limiting factors. Also, speed reducers manufacturers tend to retain symmetrical position of motor between two sides of housing. This problem is particulary emphasized when the gears are positioned in vertical or horizontal plane (Fig. 1), hence appliance of this arrangement is trying to avoid because of nonrational using of housing space.

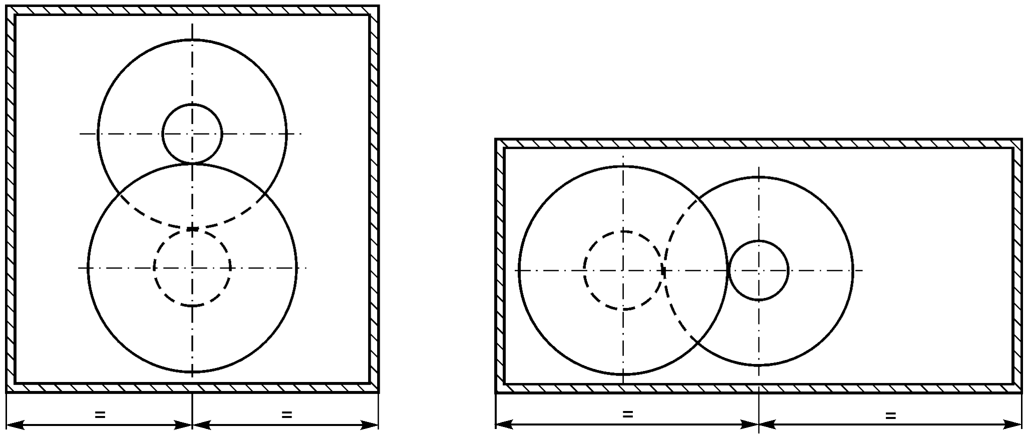

Figure 1. Vertical and horizontal position of gears inside of speed reducer for symmetrical motor position between housing walls

Regarding gear unit housing (Fig. 2), it is obvious that axis distances and driven gears diameters are possible to increase by avoidance the shafts position in vertical plane. Doing this, gear ratio and load capability of reducer are increasing. This operation is fully justifiable for two- and more-stages speed reducers, and all manufacturers are implement it.

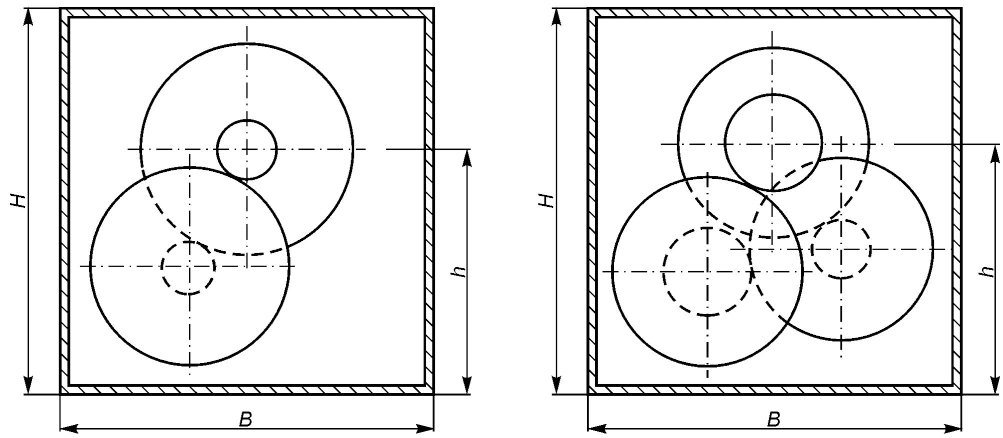

Figure 2. Two-stages and three-stages speed reducer in the same housing

This paper analyses several possible shaft positions of two-stages reducer for the concrete shaft height h = 140 mm and its values of technical characteristics for each position. Housing width and height are B = 235 mm and H = 224 mm.

As the first, reference, position is analysing the case when the shafts are placed in the same vertical plane with equal axis distance (Fig. 3). This shaft arrangement is unfavourable because of small utilization of housing interior, as well as small gear ratios and load capability. The biggest gear ratio of two-stages combination of this gear unit is 39.15, and maximum load capability on output is 26.27 Nm.

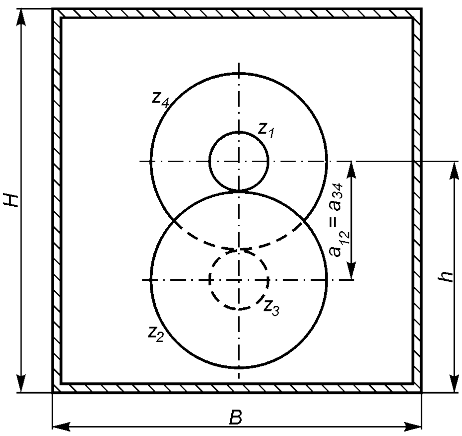

Figure 3. Variant 1 – position of gears with shafts in one vertical plane

The second variant represents the case when the geared shaft is shifted for some angle in regard to axis of input and output gear, without changing distance from a ground (Fig. 4). Axis distances of two pairs remain equal, but they are bigger than axis distances in the first variant. Diameters of gears z_2 and z_3 don't change the values, but the dimensions of gears z_1 and z_4 are increased. Shaft shifting and angle that axes direction describes with vertical are limited by housing width, and for this case that angle has maximum value 33.9°. Increasing diameter of gear z_1, gear ratio of the first pair is getting smaller, while increasing diameter of gear z_4, gear ratio of the second pair is increasing. However, overall gear ratio is reduced regards to the first variant and it is 15.95, so this shaft arrangement is worse than in the first case, although load capability of reducer is much bigger and amounts 59.18 Nm.

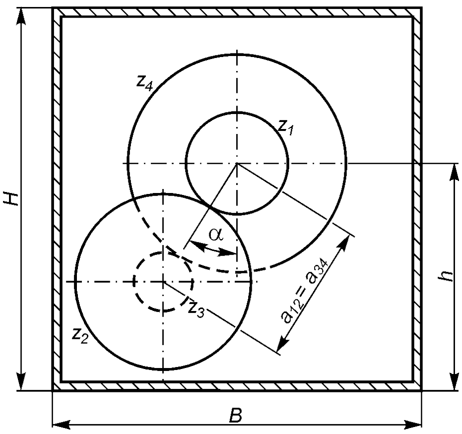

Figure 4. Variant 2 – maximum limited gear position for shifted axes, when the axis distances are equal and teeth numbers of gears z_2 and z_3 don't change

In the third variant of shafts position, gear z_2 is located in limited position for the biggest possible diameter of gears z_2 and z_4 (Fig. 5). Increasing of these dimensions influences positively on increasing of overall gear ratio. Since position of gears is limited because of housing dimensions, the largest angle, between axes direction and vertical, amounts 32.67° and for that position gear ratio is the biggest and amounts 45.57. For these dimensions and gears position, two-stages gear reducer can carry the load of 41.32 Nm on output.

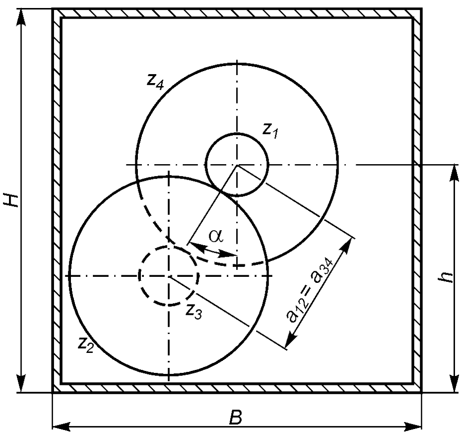

Figure 5. Variant 3 – maximum limited gear position for shifted axes, when the axis distances are equal and teeth numbers of gears z_1 and z_3 don't change

Beside this, some manufacturers of speed reducers made a step forward and abandoned the concept of equal axis distances, i.e. concept of coaxial input and output shafts. On this way, it enables to utilise housing space more rationally, for particular shaft height and to reduce gear dimensions and mass of reducer.

The fourth variant analyses technical characteristics of two-stages gear unit when the axis distances aren't equal and diameter of gear z_4 is increasing. Axis distances are different now and they describe different angles with vertical (Fig. 6). Reducer housing is further symmetrical, so axes of input and output gears are also in same vertical plane. Vertical distance between input and output shaft axis depends on position of gear z_2. For maximum limited position of gear z_2, overall gear ratio of reducer is the biggest and it amounts 47.85. Angle that direction of gears z_1 and z_2 describes, in this case, is 42.23°, and direction of gears z_3 and z_4 with vertical is 33.9°. For this shaft position, load capability of two-stages reducer is 44.34 Nm.

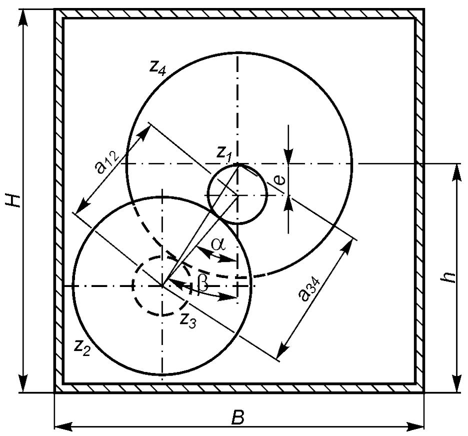

Figure 6. Variant 4 – maximum limited gear position for shifted axes, when the axis distances are different, and teeth numbers of gears z_1, z_2 and z_3 don't change

The fifth variant analyses the values of gear ratio and nominal torque for the position when the space housing is more rationally used, i.e. when diameters of gears z_2 and z_4 are the biggest possible, and diameters of gears z_1 and z_3 are the same (Fig. 7).

It is interesting that diameter of gear z_2 is reduced, in order to gear z_4 become the biggest possible. Overall gear ratio, in this case, is approximate to gear ratio in the previous variant and amounts 46.98, and load capability is 63.77 Nm. Angle, that direction of gears z_1 and z_2 describes with vertical, is 48.23°, and direction of gears z_3 and z_4 with vertical is 34.42°.

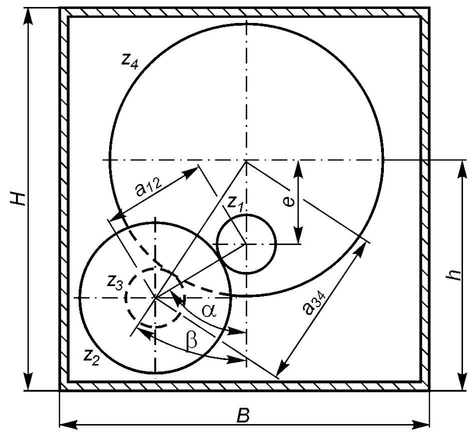

Figure 7. Variant 5 – maximum limited gear position for shifted axes, when the axis distances are different, and teeth numbers of gears z_1 and z_3 don't change

The mass of reducer depends mainly on masses of gears because the same housing is used. If the mass is included in this analysis, comparision of main technical characteristics of reducer can be made for all mention variants of shaft position.

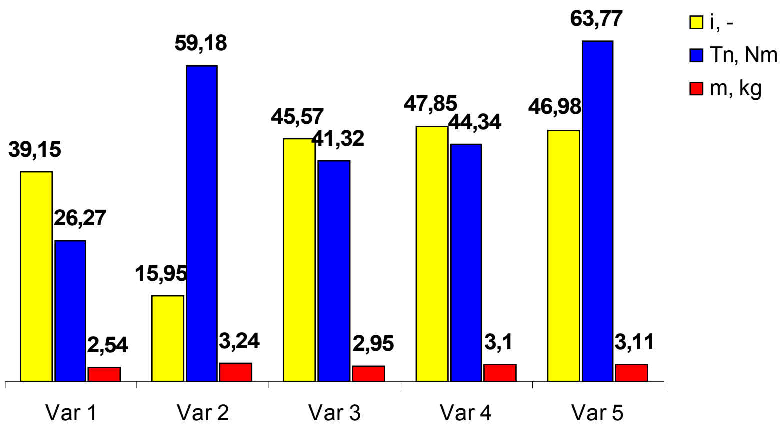

Figure 8. Comparision of technical characteristics of two-stages gear reducers for particular variants of shaft position

If these technical characteristics is analysed regarding to the mass for each variant, more realistic efficiency review will be obtained by their comparision (Fig. 9). Hence, it can be concluded that variants 3 and 4 are approximately same, and, although variants 4 gives some bigger load capability, its mass of gear is also bigger. Though variant 5 has the biggest mass of reducer, it is the most effective because it gives the best ratio of output characteristics.

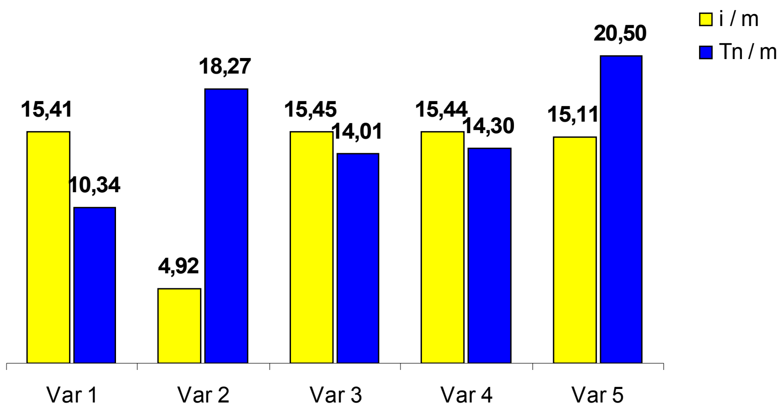

Figure 9. Comparision of technical characteristics of two-stages gear reducers regarding to the mass for particular variants of shaft position

Technical characteristics of gear units can be further improve by enlarging housing walls, i.e. by making bulges on walls where gears are located. Hence, diameter of gears can be bigger, so reducer can obtain bigger gear ratio. The same effect can be achieved with more quality production of housing walls and with reducing their thickness.

4. Conclusion

Based on carried out analysis, it can be concluded that implementation of reducer with paralel shafts, instead of coaxial, enables increasing of overall gear ratio for cca 20% and load capability for 140%. Namely, increasing of overall gear ratio, in some cases, enables offering two-stages speed reducer instead three-stages reducer, or three-stages speed reducer instead four-stages, etc. It is important to mention that abandonment of coaxial reducers enables reducing of axis distance of input gear pair, which also enables manufacturing of smaller first gear pairs and increasing axis distance of output pair, that results with bigger gear ratios and load capabilities and reducing production costs. Abandonment of concept of reducers with coaxial shafts doesn't have big influence on their appliance and possibility of mounting, as well as the largest number of speed reducer without mounted motor, so this operation regarding to the mounting can be fully carried out.

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Address:

- Prof. Ph.D Sinisa Kuzmanovic Faculty of Technical Sciences, Department of Machine Elements, Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia & Montenegro, racmil@uns.ns.ac.yu