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INFLUENCE OF GEAR HELIX ANGLE ON AXIAL LOADING CAPACITY OF OUTPUT SHAFT OF HELICAL GEAR UNITS

RACKOV Milan, TRBOJEVIC Ruzica, KUZMANOVIC Sinisa

FACULTY OF TECHNICAL SCIENCES, NOVI SAD,
SERBIA & MONTENEGRO

SUMMARY
The problem of axial loading capacity of output shaft free end of universal helical gear units is analyzed in this paper. This problem is analyzed with a particular attention on influence of a helix angle of gear that is mounted on the output shaft. The analysis is especially interesting today when manufacturers of gear units increase helix angle in order to obtain bigger loading capacity and more silent functioning of gear units.

1. INTRODUCTION

In certain cases gear unit size selection depends on axial loading capacity of output shaft. This is the case when the working element is directly mounted on output shaft of gear unit (e. g. huge mixers and fans), as well as the case when helical gear, bevel gear or worm gear is mounted on output shaft end of gear unit.

Axial loading capacity is defined by load carrying ability of shaft, bearings, retaining rings (which support the bearings), and, eventually, screw (which fixes element mounted on shaft. Axial force from the gear on the shaft has also certain influence on axial loading capacity (just for the helical gears, of course).

In this paper it will be analyzed just influence of gear helix angle on axial loading capacity of output shaft end through calculation of operating life of bearing that is subjected to axial force.

2. PROBLEM DESCRIPTION

Output shaft of gear units may be subjected to active radial and axial loads, besides forces on gear. Magnitude of radial load, its direction (α) and the point at which radial load is applied (x) depend on conditions of exploitation, as well as magnitude of axial load, its direction (toward or from gear unit), distance (R) and position (γ) of applied load (fig. 1). Just the case when $R = 0$ will be analyzed in this paper.

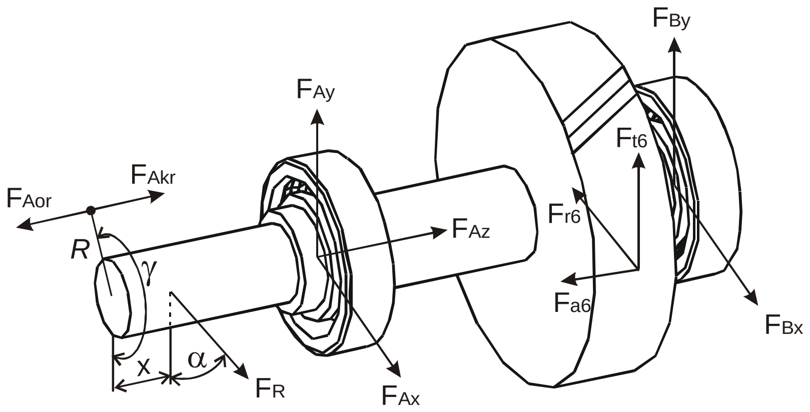

Fig. 1 Shematic review of loading of gear unit output shaft

In the process of gear unit adoption these conditions have to be satisfied:

$$T_N \geq T_i \cdot f_B \quad \left(f_{BD} \geq f_B\right)$$

$$F_{Rdoz} \geq F_R \cdot f_B$$

$$F_{Adoz} \geq F_A \cdot f_B$$

$$P_Q \geq P$$

where:

- T_N – nominal torque,
- T_i – output torque,
- f_B – driving factor,
- f_{BD} – admissible value of driving factor,
- F_{Rdoz} – admissible radial force,
- F_R – actual radial force,
- F_{Adoz}– admissible axial force,
- F_A – actual axial force,
- P_Q – thermal capacity (the biggest power which can be transmited by gear unit without overflow of maximal permitted temperature, at normal temperature of ambient air),
- P – power that is being transmited by gear unit.

On the basis of these facts, the obvious aim is that admissible axial force has much bigger value. With that as bigger as possible axial load we have to adopt as smaller as possible gear unit in order to achieve the cheapest solution.

3. PROBLEM ANALYSIS

In the case that gear unit output shaft is subjected to outer axial load, that axial force loads the bearing more additionly and it depends on direction of applied load.

It is adopted that applied load is positive ($+F_A$) when its direction is toward gear unit, and it is negative ($-F_A$), when its direction is from gear unit. For shaft rotating direction on the right we get one gear force direction, and for the rotating on the left we get contrary.

$$F_{AL} = | \pm F_A \pm F_{A6} |.$$

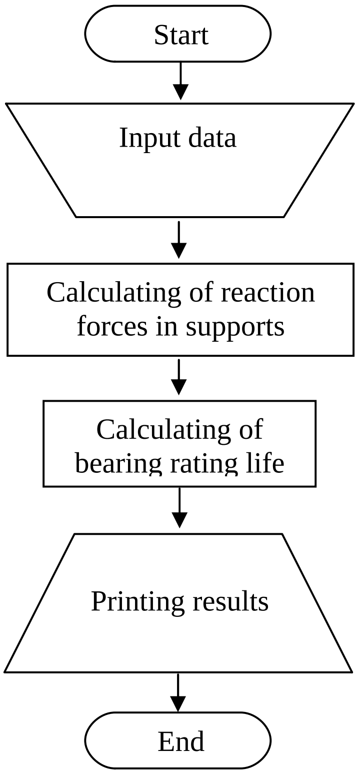

Fig. 2 *Algorithm of program procedure*

Gear axial force value depends on actual torque T, speed ratio (gears dimension) and values of gear helix angle - $\beta_{5/6}$. Its value can be calculated as follows:

$$F_{A6} = \frac{2T}{d_6} \cdot tg\beta_{5/6} .$$

The magnitude of the equivalent radial load (F) for radial and angular contact ball (roller) bearings, under combined constant radial and constant thrust loads is given by the formula:

$$F = X F_r + Y F_a$$

where:

X – radial load factor,
Y – axial load factor,
F_r – the applied radial load,
F_a – the applied axial load.

Bearing rating life is calculated on the basis of the equivalent radial load:

$$L_{6A} = \frac{10^6}{60 \cdot n_6} \cdot \left(\frac{C}{F} \right)^{\alpha}$$

where:

n_6 – revolution number of output shaft (R.P.M.),
C – basic dinamical load rating in newtons,
F – equivalent radial load in newtons,
α – exponent (α = 3 for ball bearings).

A computer program is used for analyzing gear helix angle influence on magnitude of gear axial load and overall load of bearing. Program's algorithm is shown in fig.2.

Diagrams of gear helix angle influence on bearing rating life are obtained on the basis of calculated results (fig.3-8). They obviously show that influence of gear helix angle is significant. We can see that bearing rating life has remarkably different values for the certain values of gear helix angle. From this analysis and on the basis of obtained results it can be noted that bearing rating life has favorable values for gear helix angle range 0-15°. With further increasing of gear helix angle, bearing rating life is significantly reducing, which means reducing axial loading capacity of output shaft of gear unit.

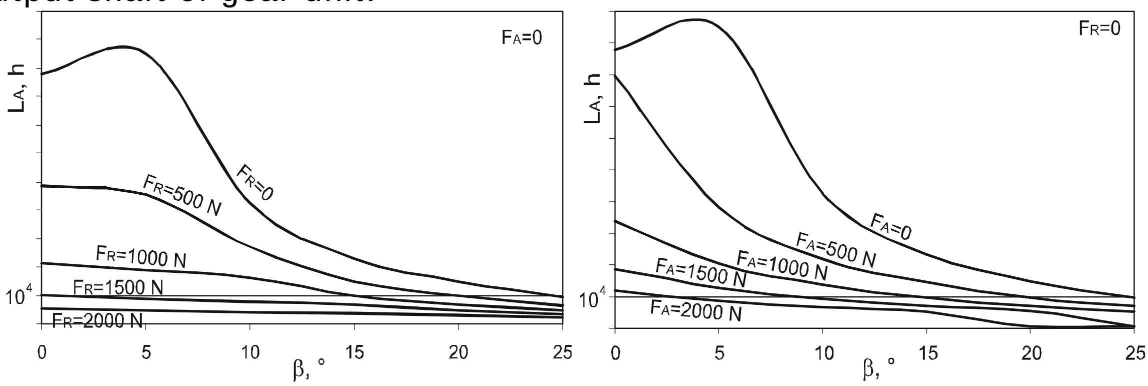

Fig. 3 *Gear helix angle influence with shaft rotating direction on the right and applied load toward gear unit*

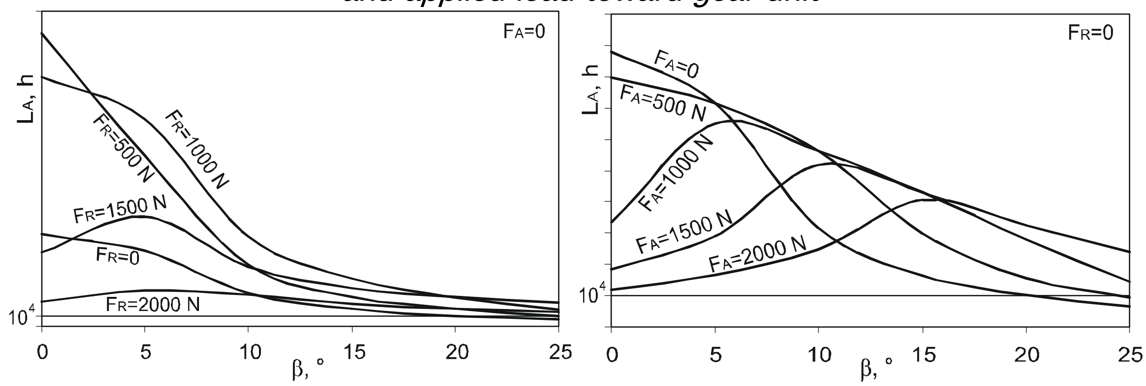

Fig. 4 *Gear helix angle influence with shaft rotating direction on the left and applied load toward gear unit*

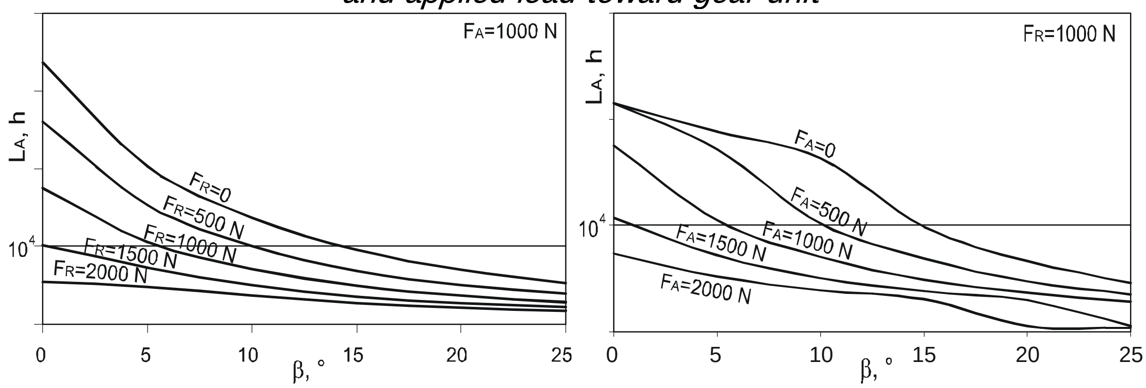

Fig. 5 *Gear helix angle influence with shaft rotating direction on the right and applied load toward gear unit*

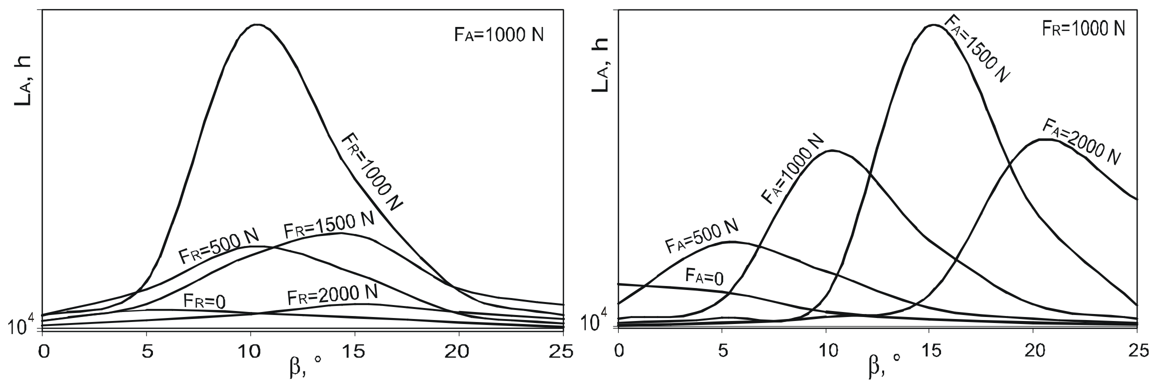

Fig. 6 *Gear helix angle influence with shaft rotating direction on the left and applied load toward gear unit*

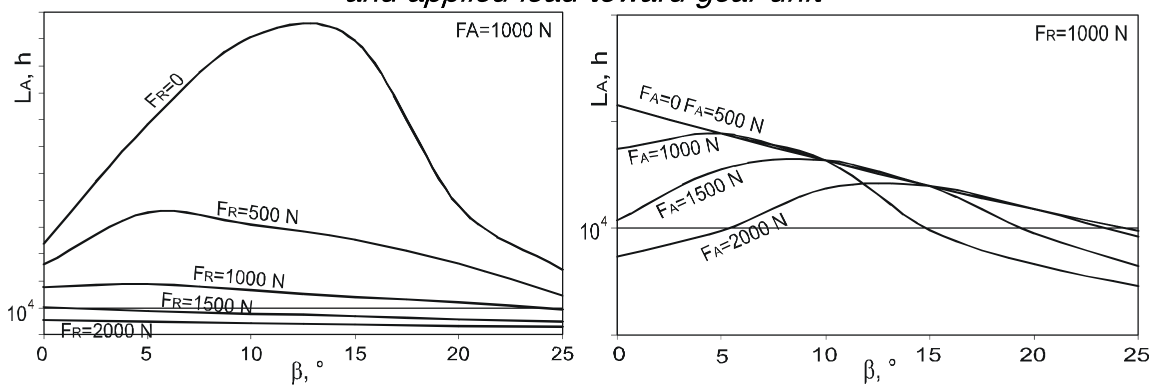

Fig. 7 *Gear helix angle influence with shaft rotating direction on the right and applied load from gear unit*

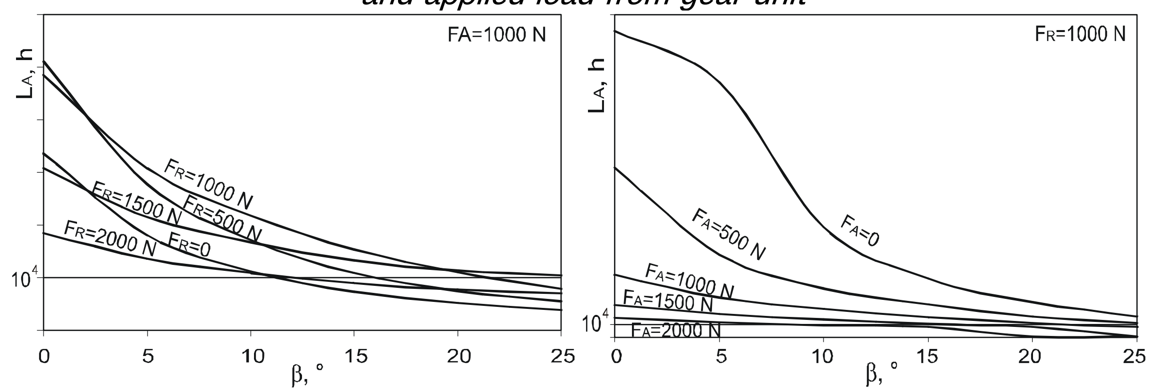

Fig. 8 *Gear helix angle influence with shaft rotating direction on the left and applied load from gear unit*

4. CONCLUSION

On the basis of implemented analysis we obtained the result that it is reasonable to increase gear helix angle to cca 15°. This increasing hasn't much influence on decreasing of bearing rating life and it provide more regular functioning of gear units with smaller gear noise.

Beside that, gear helix angle increasing enables bigger loadings of gear and bearings, and this certainly has favorable influence on quality of gear unit.

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