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Influence of the Tooth Helix Angle on the Vibrations of a Cylindrical Gearbox

The current trend in the construction of gearboxes, regarding the speed increase, favors the increase of the dynamic loads which are accompanying the operation of these kinds of machines. The phenomena of dynamic contact like frictions, collisions and shocks which are taking place in cinematic couples, engines and mechanisms during their movement, are generating vibrations in a wide range of frequencies.

Keywords: *gearbox, vibration, gears, helix angle*

1. Introduction

Vibrations produced by gearboxes became characteristically indicators for assessing their quality. Therefore, the decrease of vibrations produced in the gear transmissions became lately a priority, being one of the combat method in the fight against pollution.

2. Researches regarding noise reduction of cylindrical gearboxes by modifying the helix angle of the gears

Experimental tests were done on the test rig described in [1], on four pairs of gears (pinion & idler) whose teeth were machined with different helix angles: β= 9°, 11°, 13° and 15°.

The main geometric data of the gears are presented in table 1. The mentioned data have following specification:
A- centre distance;
m_n – module;
z_1, z_1– teeth number (1 for pinion, 2 for mating gear);
b- tooth width;
α_n– normal pressure angle;

β- helix angle;
x_1, x_2-- addendum modification coefficients (1 for pinion, 2 for mating gear);
d_{a1}, d_{a2}-tip diameters of pinion (1), respective mating gear (2);
d_1, d_2- reference diameters of pinion (1), respective mating gear (2);
d_{f1}, d_{f2}- root diameters of pinion (1), respective mating gear (2).

Table 1.

A= 125 mm b= 50 mm		m_n = 4 α_n= 20°		z_1 / z_2 = 17/ 43 (i= 2,529) back-lash: 0,15- 0,27 mm
	β= 9°	β= 11°	β = 13°	β= 15°
x_1/ x_2	0,48452/ 0,47656	0,39876/ 0,34228	0,30296/ 0,18148	0,20311/ -0,00731
d_{a1}/ d_{a2}	80,04/ 185,28	80,04/ 185,54	80,02/ 185,79	79,99/ 185,98
d_1/ d_2	68,85/ 174,14	69,27/ 175,22	69,79/ 176,52	70,40/ 178,07
d_{f1}/ d_{f2}	61,73/ 166,90	61,47/ 166,90	61,22/ 166,92	61,03/ 166,95

For vibration measurements, there were used Bruell & Kjaer accelerometers of type 4524B, mounted on special prepared surfaces on the housing, as shown in Figure 1

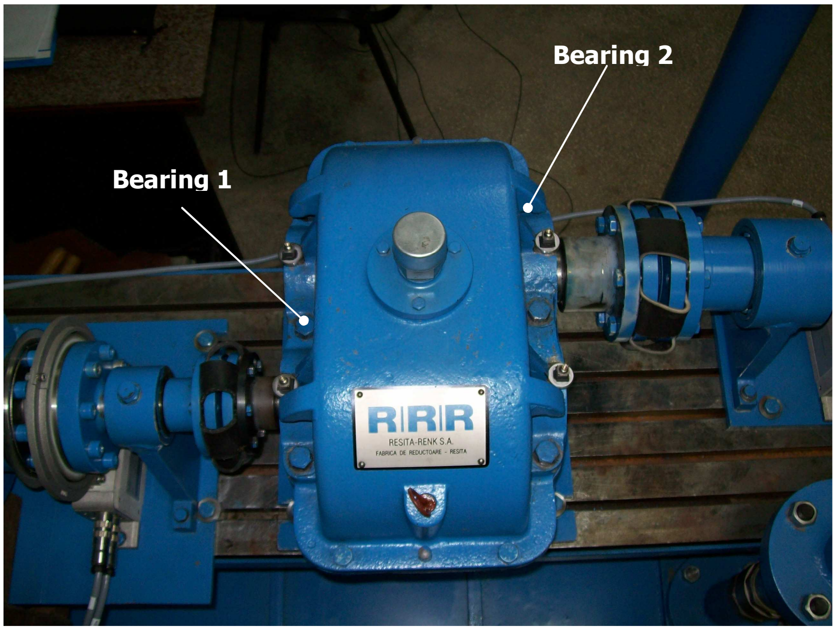

Figure 1. Vibration measuring points on the gearbox housing

Measurements were made on six steps of motor speed (n_1= 1.000, 1.100, 1.200, 1.300, 1.400 și 1500 rpm), respective on eight steps of torque loading (T_2= 16, 19, 22, 26, 29,5, 32,5, 35,5, 38,5 Nm).

Because it was intended to study only the vibrations caused by the gears, it was performed a FFT analyze (Fast Fourier Transformation) and it have been recorded the peeks of the vibration speed, measured at the teeth frequency or its harmonics.

Based on the results of measurements, there was possible to draw up the charts shown in Figures 2 and 3.

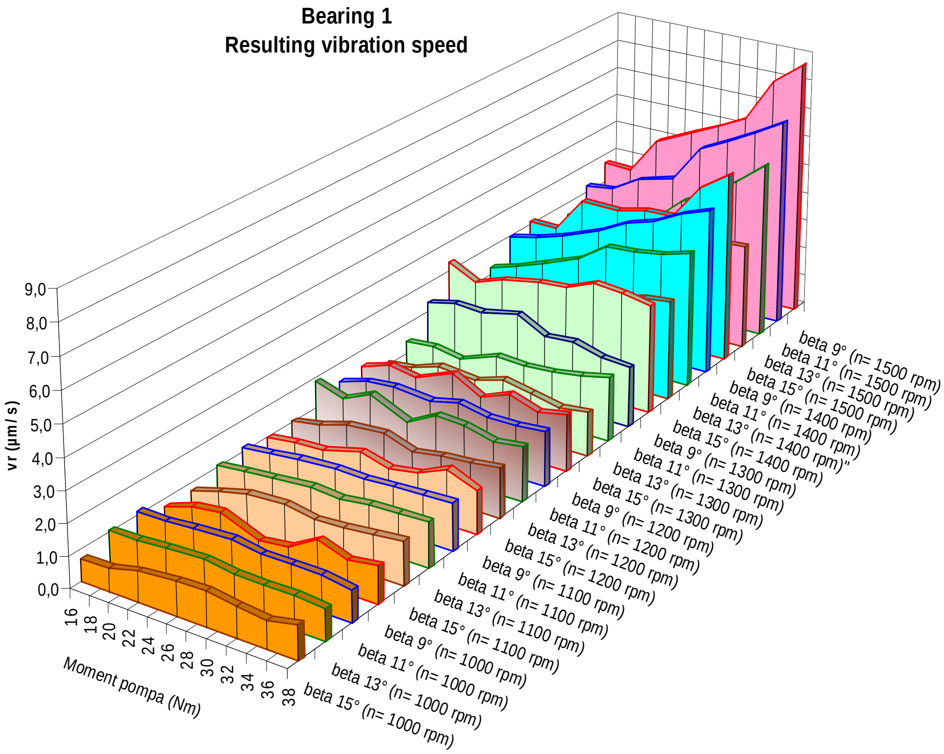

Figure 2. Resulting vibration speed measured on bearing 1

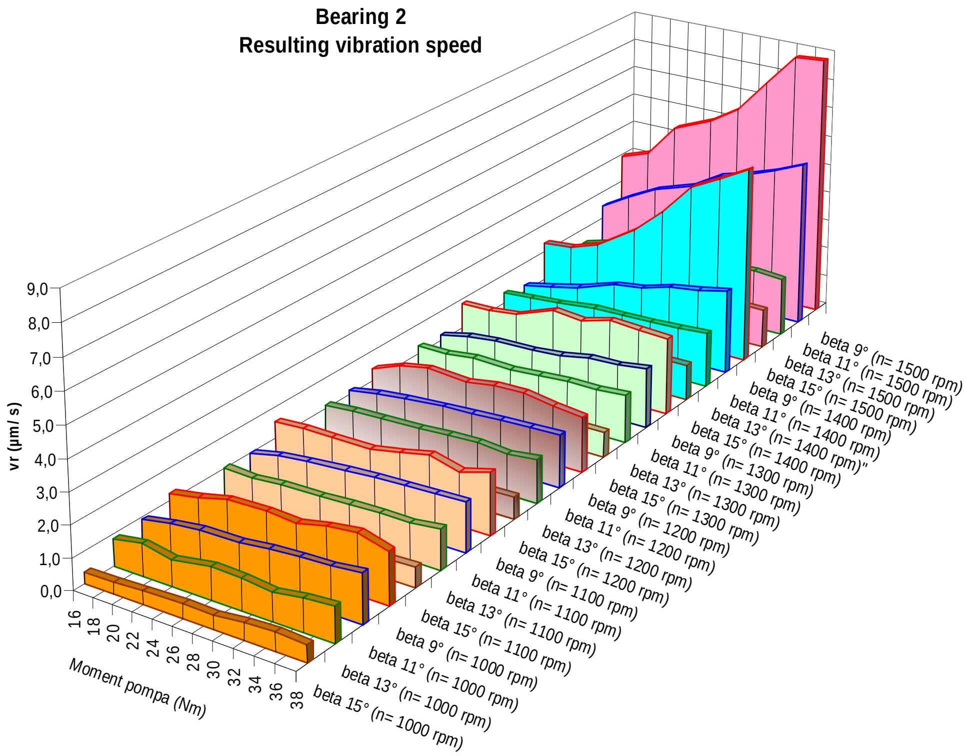

Figure 3. Resulting vibration speed measured on bearing 2

Based on the information contained in the previous shown figures, following comments can be made:

- in the lower speed range (1.000 – 1.200 rpm), the helix angle variation has no visibly influence on the amplitudes of the measured vibration speed;

- in the upper range of speeds (1.300 – 1.500 rpm), the increase of the helix angle decrease the amplitudes of the measured vibration speed;

- analyzing the trend of the curves drawn, it can be concluded that the increase of the helix angle decreases the amplitudes of the measured vibration speed.

This last conclusion is also supported by the following theoretical fact: by increasing the helix angle, in terms of keeping constant the other geometrical elements (module, teeth no, centre distance), the addendum modification coefficients are lowering. This has as an effect the decreasing of the radius of the teeth curvature and consequentially, the lowering of the rolling friction of the mating gears. As the friction between the teeth flanks is one of the main factors which are generation gear vibrations, this friction lowering leads to the decrease of the measured vibrations.

For supporting the upper mentioned argument the formulas for calculating the tooth curvature radius are available:

$$\rho_{C1(2)} = 0{,}5 \cdot d_{w1(2)} \cdot \sin\alpha_{wt} \cdot \cos\beta_b \qquad (1)$$

ρ_C- tooth curvature radius;
d_w- pitch diameter;
α_{wt}- pressure angle at pitch diametre;
β_{wt}- helix angle measured on base cylinder;
1- subscript for pinion;
2- subscript for gear.

$$d_{w1(2)} = \frac{2 \cdot a \cdot z_{1(2)}}{z_1 + z_2} \qquad (2)$$

where:
a- centre distance;
z- number of teeth.

$$\cos\alpha_{wt} = \frac{m_n \cdot (z_1 + z_2)}{2a \cdot \cos\beta} \cdot \cos\alpha_t \qquad (3)$$

where:
m_n- normal module;
β- helix angle (on reference cylinder);
α_t- pressure angle in front plane

$$tg\alpha_t = \frac{tg\alpha_n}{\cos\beta} \qquad (4)$$

where:
α_n- normal pressure angle (20°)

$$\sin\beta_b = \sin\beta \cdot \cos\alpha_n \qquad (5)$$

Making the calculations for the four gear pairs, by using the formulas (1) to (5), Table 2 shows the variation of the teeth curvature in relation to the helix angle.

Table 2.

β	9°	11°	13°	15°
ρ_{C1} [mm]	14,368	13,900	13,323	12,624
ρ_{C2} [mm]	36,344	35,160	33,700	31,932

3. Conclusions

The researches which were done are leading to following conclusions:

- by increasing the helix angle of a cylindrical gear transmission, the amplitudes of the measured vibration velocity are decreasing;
- the increasing of the helix angle, as a measure of lowering the vibration level of a gearbox, is applicable as long as the higher axial force can be supported by the bearings of the gearbox, while maintaining an acceptable lifetime.

References

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[3] http://www.bksv.com

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