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Dynamics and Vibroacoustics of Machines

Study of Loading in Point-Involute Gears

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Abstract

The main limiting factor in high-speed aviation gear systems is contact strength. There are two main ways for reducing contact stresses in gears with involute tooth profile: 1) by using a standard basic rack profile with increased pressure angle; 2) by using a non-standard basic rack profile i.e. increasing the overlap ratio. However, contact stresses can also by reduced by implementing point gearing; Novikov's gears in which the relative radius of curvature is much more larger than it is in involute gears. On the basis of an involute and Novikov's gears, an point-involute gear was created which has a mixed engagement. An attempt was made to apply this design in the spur gear of the central gear box of gas turbine engines. But due to the point nature of the tooth profile, the limiting factor for the gear becomes its bending strength. Hence there was a necessity to conduct comparative tests with the usual spur gear of the central gas turbine engine gear box. A pulsator test bed was created for these tests and comparative tests were carried out.

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*Keywords:*spurgear, strength, fatigue life, pulsator, test, involute;

1. Introduction

The main limiting factor in high-speed aviation high performance gears is contact strength. Hertz's formula for finding the stresses in the area of contact has the following form:

$$\sigma_H = z_M \sqrt{\frac{q}{2\rho_E}} \tag{1}$$

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Nomenclature

q – distributed load along the length of the contact line, N/mm;

ρ_E – mismatch radius of curvature;

z_M – coefficient of mechanical properties of material;

ε_α - overlap ratio

where q – distributed load along the length of the contact line, N/mm;

ρ_E – mismatch radius of curvature;

z_M – coefficient of mechanical properties of material (for steel gears $z_M = 275$ (MPa)^2)

The essence of increasing contract strength of involute gears is in decreasing the distributed load q through increase of overlap ratio. This can be achieved in spur gears by using an instrument with non-standard cutting contour with addendum factor more than one (the achieved overlap ratio is guaranteed to be more than two, $\varepsilon_\alpha > 2$). This increases the load carrying capacity as well as it reduces the level of noise and vibration generated by the gear. The contact stress can be further reduced by using helical gears [1, 2, 3, 4] which gives a positive effect on the strength of the gear system.

The contact stress can be reduced by increasing the mismatch radius of curvature. In involute gears, this can be achieved by increasing the pressure angle to 25..28^0. But this may lead to thinning of the tip of teeth which may in turn decrease the overlap ratio [5, 6]. A more significant reduction of the mismatch radius of curvature can also be achieved by implementing Novikov's gears through little difference in radii of curvature of tooth profiles $|\rho_1 - \rho_2|$.

Then

$$\rho_E = \frac{\rho_1 \cdot \rho_2}{\rho_1 - \rho_2} \quad (2)$$

The main difference of Novikov's gears from involute gears is in that overlap of teeth is achieved along the length and not along the tooth height as is the case with involute gears and the teeth contact is a point and not a line. Novikov's gears have 2..2.5 times less friction loses than conventional involute gears. The advantages of Novikov's gears over involute gears are detailed in researches [7, 8, 9, 10, 11]. These research works show in depth theoretical research as well as results of compared experimental tests. Novitov's gears can be applied not only in spur gears but also in bevel gears [12]. Hence is reasonable to conclude that with the necessary technological improvements for Novikov's gear manufacture, they can replace involute gears in the future.

A reduction gear with Novikov's gears is installed in the helicopter WG-13 Links. The gear has about 40% less number of gear wheels and bearings while the power transmitted is 2.2 times more compared to that a similar gear with involute gears would transmit and this could be theoretically increased to 3.3 times [13].

Implementation of gears wheels with Novikov's mesh is not quite possible for short-tooth gears for gas turbine engine applications. The width of the tooth is required to be more than axial pitch to achieve adequate overlap ratio and this leads to increase of the mass of the gear. Again, another disadvantage of Novikov's gear mesh is high sensitivity to changes of center distance.

A point-involute gear with mixed mesh was created on the basis of involute and Novikov's gear meshes. This was developed under the supervision of Zhuravlev G.A. [14] in the Rostov University. A point-involute gear is a short-tooth gear with length of tooth 0.7 of axial pitch and overlap ratio of two. Thecuttingcontourisshowninfig. 1.