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Development of an Epicyclic Gearbox for Reduced Sub-Synchronous Vibrations in Gas Turbo-Generator Sets

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American Gear Manufacturers Association



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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Vibrations are present practically in all types of gearboxes. In general, vibrations at gear tooth mesh frequencies and their harmonics are of concern to a gear designer. In star epicyclic gearboxes, low frequency sub-synchronous (below turbine speed) vibrations are also quite predominant. Regular turbo-generator package testing shows that these low frequency vibrations may arise even when the rotating components are balanced precisely. This is attributed to the dynamic eccentricity of rotating parts such as ring gear and splined coupling. In star epicyclic gearboxes of stoekicht design, splined couplings between the ring gears and output shaft usually are preferred to make the ring gears fully floating for equal load sharing. The sub-synchronous vibrations that arise from such components finally get transmitted along with the mesh frequency vibrations to the turbine rotor bearings.

Although low frequency sub-synchronous vibrations do not cause any damage to gear life, they seem to deteriorate the life of the turbine rotor bearings which preferably are babitted sleeve bearings of tilt-pad design. When the amplitude levels of these vibrations and their harmonics exceed a certain limit, the life of these bearings, which are designed for a minimum service life of 100,000 hours is significantly reduced. To reduce the level of such vibrations, an improvement is made to the design of star epicyclic gearbox that limits the dynamic eccentricity of ring gears and splined couplings. Gearboxes manufactured and tested to the new design were found to induce a very low level of sub-synchronous vibrations. The improved gearboxes not only allowed the service life of the turbine rotor bearings to be maintained, but also increased the success rate of package testing the first time.

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DEVELOPMENT OF AN EPICYCLIC GEARBOX FOR REDUCED SUBSYNCHRONOUS VIBRATIONS IN GAS TURBOGENERATOR SETS

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Introduction :

In gas turbine driven generators, the power turbine speed is reduced to the desired generator rotor speed with a suitable gear speed reducer. For medium range (5000 to 25,000 hp) gas turbines, power turbine speeds usually vary from 8000 to 20,000 rpm. On the other hand, the most common 4-pole generator rotor speed is either 1800 rpm (60 cps) or 1500 rpm (50 cps). Thus, for 4-pole generators the speed reduction ratios may vary from 5.33 to 13.33.

Of the various gear speed reducer arrangements used in gas turbine applications, a simple star epicyclic gearbox of Stoeckicht design offers the optimum design for reduction ratios as high as 10:1. For higher ratios, compound star epicyclics are preferred. Figure 1 illustrates the principle components of a simple and a compound star arrangements. In the present investigation, a simple star epicyclic gearbox was used to reduce the turbine speed of 8625 rpm to the generator rotor speed of 1500 rpm. Figure 2 shows a sectional view of this gearbox.

In contrast to a Stoeckicht design, the arrangement as depicted in Figure 2 was developed by Allen Gears Ltd [1] of England in which the radial and axial forces generated at the gear teeth are balanced by the reaction forces. The toroidal couple is balanced by the tooth separating forces acting on each internal ring gear, thus eliminating any deformation of teeth. Figure 3 illustrates the basic difference

between an ideal Stoeckicht and the alternate design by Allen Gears. Testing carried out [1] showed the Allen design offers lower face load distribution in the ring gear teeth. Also, contrary to the Stoeckicht design, the face load distribution factor was not found to be dependent on the transmitted torque. At full load, the face load distribution factor of 1.13 was obtained with the Allen design of star epicyclic gearboxes compared to 1.47 with the Stoeckicht design.

Nevertheless, in gas turbogenerator applications, gearboxes with either Allen or Stoeckicht design seem to induce, besides mesh frequency vibrations, some low frequency vibrations known as subsynchronous vibrations (SSV), the synchronous ones being at the turbine rotor frequency. In turbomachinery, when these low frequency vibrations get transmitted to the turbine rotor bearings, they cause severe damage that reduces their expected life of 100,000 hours. The present investigation was directed, first, to determine the causes of these undesirable SSV and, then to develop an improved gearbox for reduced levels of these vibrations at the turbine rotor bearings.

Gearbox Vibrations and Life of Turbine Rotor Bearings :

In a gearbox, vibrations can occur at many different frequencies. The most common of these vibrations are found at the gear teeth mesh frequencies and their harmonics. These are known to be caused by the transmission error of gear teeth.

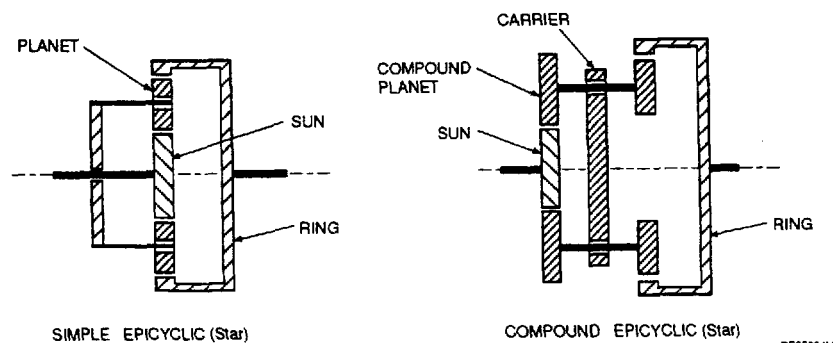


Figure 1: Epicyclic Gearbox - Star Arrangements