12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

HIGH-FREQUENCY VIBRATION ANALYSIS OF PLANETARY REDUCTION GEARMOTOR

Dmitry Litvinov
Riga Technical University
1 Kalku Street, LV-1658, Riga
Latvia

ABSTRACT
In this article the analysis of signals from vibration sensors in a high-frequency range is presented, and also conclusions about advantages of high-frequency vibration analysis at vibration diagnostics of planetary reduction gearmotors are done.
Keywords: vibration, envelope spectrum, sensor

1. INTRODUCTION
Due to wide kinematics possibilities, economy, reliability, small size, low noise level, planetary reduction gearmotors are found wide application in machine-building. Also planetary reduction gearmotors have transmission of large power possibility at small sizes and small loading on gear cogs and on supports.
The all above enumerated advantages will be in use only in case, when planetary reduction gearmotors work smoothly. For this purpose it is necessary to carry out the vibration monitoring and diagnostics of these gearmotors timely. The special attention must be attending the analysis of high-frequency vibration, because only at the signal analysis in a high-frequency range it is possible to find out the incipient defects.

2. NATURE OF VIBRATION ORIGIN IN PLANETATY REDUCTION GEARMOTOR
There are general regularities to the law of acoustic signal change character at violations in work of gearing mechanism, caused the defects of making, assembling and maintenance, being information sources at the estimation of the planetary reduction gearmotors technical state. Thus the changes of vibroacoustic processes develop on a background of the perturbing forces action, accompanying normal functioning of gearing and determining interferences level at diagnostics.
Noise and vibration of gearing arise up as a result of variable forces influence, conditioned a change in time of toothing parameters. It means that even the ideal gearing can not work noiselessly [1].

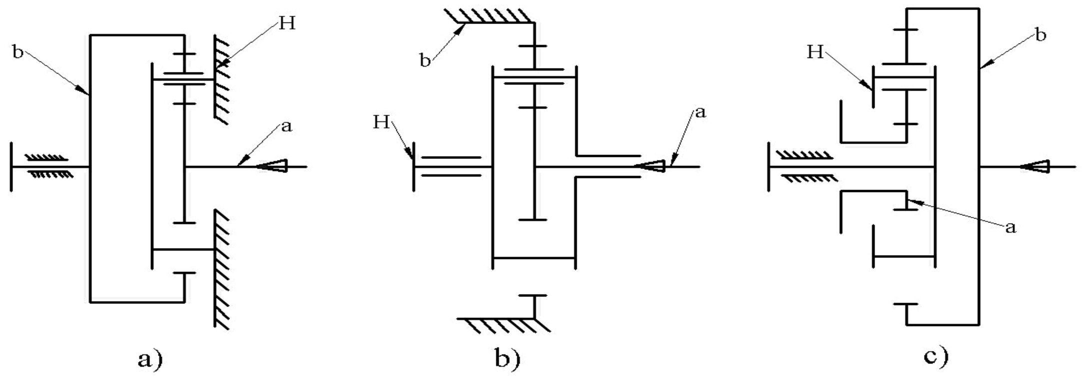

Figure.1. Kinematics of planetary reduction gearboxes on the basis of one stage planetary gearing:
***a**– with immobile rein **H**; **b** – with immobile epicycle (a crown) **b**; **c** – with an immobile leading gear **a** (a sun)*

The harmonic constituents of oscillation forces in planetary reduction gearboxes have a kinematics and parametritic origins. Frequencies of oscillation forces are determined by schemes of reduction gearboxes *Fig.1* which are very various, especially in the cases, when multi-stage reduction gearboxes and gearboxes with all rotating units (a sun, crown, rein) are utilized. Gearboxes with single satellites can have immobile either crown either rein or a sun.

2.1. Basic diagnostistic parameters of planetary reduction gearmotor defects.

Rotation frequencies of gearbox gears with immobile rein $f_H = 0$ *Fig.1*, ***a*** and, accordingly, vibration frequencies of basic components accounts also, as well as in usual double stage reduction gearbox, that is, rotation frequency of satellites f_g is related to rotation frequency of a sun [2]:

$$f_g = f_a \frac{Z_1}{Z_2} \tag{1}$$

Where $Z_1; Z_2$ - amount of teeth on a sun and satellite
Rotation frequency of crown is equal accordingly:

$$f_b = f_a \frac{Z_1}{Z_3} = f_g \frac{Z_2}{Z_3} \tag{2}$$

Where Z_3 - amount of teeth on a crown.
Toothed frequency, identical for “sun - satellite” and “satellite - crown” gearings, is determined by expression:

$$f_z = f_a \cdot Z_1 = f_g \cdot Z_2 = f_b \cdot Z_3 \tag{3}$$

Rotation frequencies rein and satellites in an ideal reduction gearbox with an immobile crown *Fig.1* ***b***, in which the number of crown teeth is equal to the sum of a sun teeth number and satellite teeth doubled number, determined as follows:

$$f_H = \frac{1}{2} f_a \frac{Z_1}{Z_1 + Z_2}, \tag{4}$$

$$f_g = (f_a - f_H) \frac{Z_1}{Z_2} \tag{5}$$

Toothed frequency is determined by expressions:

$$f_z = (f_a - f_H) Z_1 = f_g Z_2 = f_H Z_3 \tag{6}$$

In the real gearboxes through technological reasons at the teeth angular correction the amount of crown teeth is increased on one – two, that results in rotation frequency of rein small increasing, toothed frequencies and satellite rotation frequencies. More exactly these frequencies can be defined:

$$f_H = \frac{f_a \cdot Z^*}{Z^* + 2Z_3} \tag{7}$$

$$f_g = \frac{f_H Z_3}{Z_2} \tag{8}$$

$$f_z = f_H Z_3 \tag{9}$$

Where $Z^* = Z_1 + 2Z_2 + Z_3$.

Planetary reduction gearboxes with an immobile sun gear *Fig. 1* ***c*** are utilized much rarer. Rein and crown rotation frequencies in such gearboxes are determined by correlation:

$$f_H = \frac{2 f_b \cdot Z^*}{Z^* + 2Z_3} \tag{10}$$

Toothed frequency and satellite rotation frequency is equal:

$$f_z = \frac{2 f_b \cdot Z_1 \cdot Z_3}{Z^* + 2Z_3} \tag{11}$$

$$f_g = \frac{f_z}{Z_2} = \frac{2 \cdot f_b \cdot Z_1 \cdot Z_3}{Z_2 \left(Z^* + 2Z_3\right)} \tag{12}$$

3. HIGH-FREQUENCY VIBRATION ANALYSIS OF PLANETARY REDUCTION GEARMOTORS

The defects of shafts, influencing on the vibration of planetary gearing, unite in one group, urgent usually the oscillation of shafts. This group of defects influence on a vibration is determined the shafts geometrical axis lack of coincidence and cog-wheel planted on it with the axis of its rotation, which results in appearance of kinematics vibrating forces, operating with rotation frequency of imperfect shaft on a defectless shaft through the toothing. In addition, imperfect shaft rotation frequency modulating vibration, both defectless shaft and cog-wheel, see *Fig.2*.

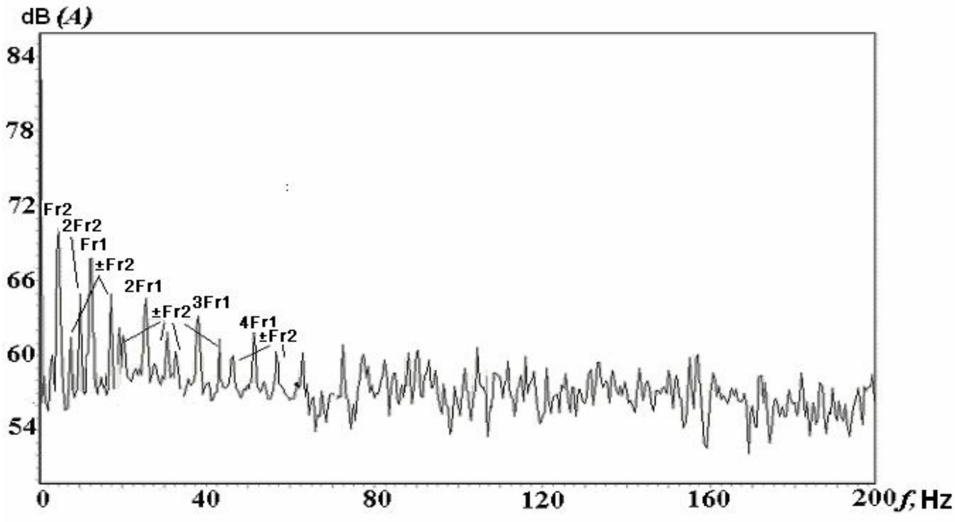

Figure 2. High-frequency vibration envelope spectrum of planetary gearing with the primary oscillation of the following shaft

If the wear of one tooth is so great, that at entered in meshing loading on it is very small or absents, the impulsive loading on the remaining indents of gearing has two jumps (at an entrance and exit from imperfect tooth meshing) with the fixed time domain between jumps, equal $3/f_{rot}Z$, where f_{rot} is imperfect cog-wheel rotation frequency, Z is an amount of indents of the cog-wheel, and by the fixed period, equal $1/f_{rot}$. Thus in the vibration spectrum of gearing will be revealed not only impulsive modulated cogging component vibrations with lateral harmonics, different on frequencies of kf_{rot} but also groups of components on the rotation frequency harmonics of cog-wheel with multipleness, near to the row of $kZ/3$, see *Fig.3*. Sometimes these components examine as subharmonicss of cogging vibration [3].

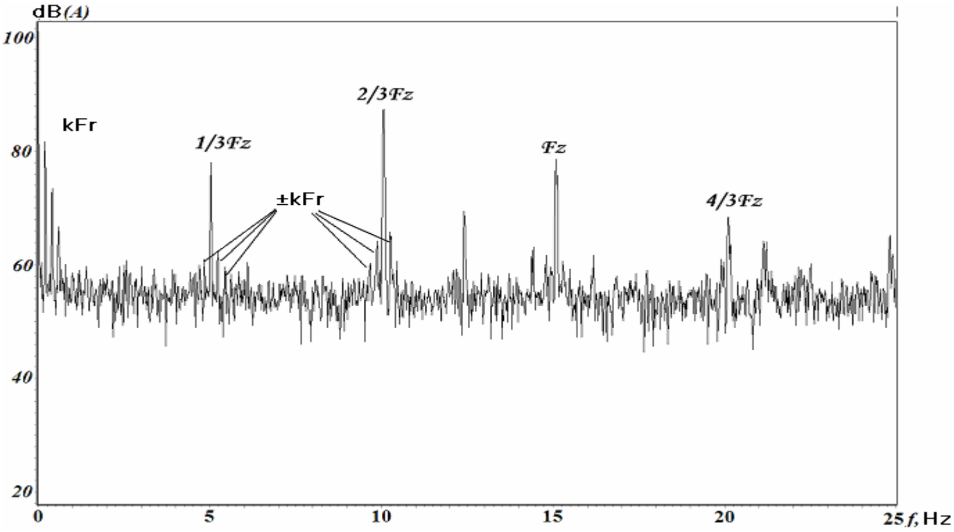

Figure 3. High-frequency vibration envelope spectrum of planetary gearing with the strong wear of tooth

Thus conducting the analysis of high-frequency vibration envelope spectrum it is possible to define condition of cog-wheels and rolling bearings of planetary reduction gearmotor in the early stage of their origin.

5. CONCLUSIONS

It is possible to make a conclusion coming from all above-stated that in spite of planetary reduction gearmotor labouriousness of vibration diagnostics process, especially rolling bearings of satellite gears, application of permanent vibration diagnostics and monitoring gives considerable effectiveness of costs due to repairs which are conducted on the equipment actual state. The presence of permanent and operative information about the state of reduction gearmotors base allows also opportunely planning the purchase of repair parts, or new reduction gearmotors. Also the modern methods of diagnostics application allow taking the losses of the finished product and equipment downtime to the minimum, and also allow considerably promoting quality of the finished product.

6. ACKNOWLEDGEMENTS

This work has been partly supported by European Social Fund within the National Programme “Support for the carrying out doctoral study program’s and post-doctoral researches” project “Support for the development of doctoral studies at Riga Technical University”

7. REFERENCES

[1] Неразрушающий контроль. Справочник в 7 томах под редакцией чл.-корр. РАН В.В. Клюева. Том 7. Машиностроение, Москва, 2005. 830 с.

[2] Барков А.В., Баркова Н.А., Азовцев А.Ю. Мониторинг и диагностика роторных машин по вибрации. Санкт-Петербург, Издательство СПбГМТУ, 2000. 162 с.

[3] Барков А.В., Баркова Н.А., Борисов А.А. Диагностика механических передач. Санкт-Петербург, Издательство СПбГМТУ, 2005. 51 с.