Vibroacoustical diagnosis of planetary precessional kinematical transmission

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Abstract. An ideal dynamical system should not generate any vibrations, because vibrations mean a loss of energy. Vibration in planetary precessional gear box occurs at bearings, gear wheels, misaligned shafts, imbalance rotating parts, couplings. If damage occurs, not only the dynamic processes change, but also the forces that act on system components. Regarding this aspects, sound level was measured by using Brüel & Kjær Sound Level Meter Type 2250 Light that has everything needed to perform high-precision, Class 1 measurement tasks in environmental, occupational and industrial application areas. Obtained and measured results were presented in diagrams and tables to be compared with German standard VDI-2058 Limit value for vibration severity and noise level.

1. Introduction
The paper regarding vibroacoustical research on planetary precessional kinematical gear box with transmission ratio $u = -72.3$, see figure 1 [1, 2, 4, 6].

![Planetary precessional gear box](image)

**Figure 1.** Planetary precessional kinematical gear box: (a) Satellite wheel made of plastic material type Hostaform C2091 (b) Satellite wheel made of powders material type Жгр7.

Acoustical analysis on planetary precessional kinematical transmission was made regarding analysis over a frequency range, here, a special analysis (FFT – Fast Fourier Transformation). In practice the simple amplitude measurement of the vibration speed signal is often used for evaluation of the balance condition. The vibration speed signal is a direct measure of the out-of-balance condition, since the balance quality is specified as the speed of the center of gravity of the rotor. An increase in amplitude over time may indicate increasing damage.
2. Constructive and technological solution to reduce vibration and noise in kinematical PPT

In practice we can use various methods to minimize vibration and noise levels in dynamic systems. Mechanical transmissions used in various machines and installations are sources of high frequency vibration and noise. The most effective, but also the most expensive way to get quieter transmission, is the method of execution of machine parts with very high precision or method of static and dynamic balancing of moving parts. For kinematical PPT we recommend correct choice of materials for gearwheels in terms of shock and vibration damping. One of the main advantages of PPT is the multiplicity meshing (up to 100% pairs of gearing teeth). For kinematical PPT satellite block can be made of plastic materials with damping properties (absorption) of gear shock. For this purpose has been developed kinematic precessional reducer (figure 2), with satellite block made of plastic materials type Hostaform C9021, and satellite wheel made of powders material type Жгр7 [3, 4], see figure 2.

![Figure 2. Planetary precesional kinematical gear box: (a) Satellite wheel made of plastic material type Hostaform C2091 (b) Satellite wheel made of powders material type Жгр7.](image)

3. Standards for assessing the sound pressure level.

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Experimental result was compared with limits for vibration amplitude ($v_{eff}$ in mm/s) in general engineering in line with VDI directive 2056 [5, 7]. Regarding this directive table 1, mechanical systems were divided into four main groups K (small machines), M (medium machines), G (large machines) and T (turbo machines).

| Sound pressure [dB] | Vibration amplitude $v_{eff}$ [mm/s] | Group K (Small machines (< 15 kW)) | Group M (Medium machines (15kW–75kW)) | Group G (Large machines (> 75 kW)) | Group T (Turbo machines (> 75 kW)) |
|--------------------|------------------------------------|----------------------------------|---------------------------------|----------------------------------|----------------------------------|
| 133                | 45,0                               | Unacceptable                     | Unacceptable                    | Unacceptable                     | Unacceptable                     |
| 125                | 18,0                               |                                   | Acceptable                      | Acceptable                       |                                   |
| 121                | 11,2                               |                                   |                                 | Usable                           |                                   |
| 117                | 7,1                                |                                   | Acceptable                      |                                 | Usable                           |
| 113                | 4,5                                | Acceptable                       | Usable                          |                                 | Good                             |
| 109                | 2,8                                |                                   |                                 |                                  |                                   |
| 105                | 1,8                                | Usable                           |                                 | Good                             |                                   |
| 101                | 1,12                               | Good                             |                                 |                                  |                                   |
| 97                 | 0,71                               | Good                             |                                 |                                  |                                   |
Tested kinematical PPT see figure 1 and figure 2 regarding VDI directive 2056 belong to group K for small machines like individual propulsion components of engines and machines whose operating condition is linked to that of the entire machine, in particular series manufactured electric motors up to around 15 kW [7].

4. Research on experimental stand.
Experiments were carried out in a closed laboratory room with rigid floor on the GUNT laboratory trolley type PT500.01 provided with a T-shaped channel. In these channels, we fix all components (figure 3): drive unit with three phase motor (P=0,36 kW), kinematical PPT gear box with satellite block from plastic materials and GUNT brake/ load unit type PT500.05. Precise axial alignment of the shafts was achieved using claw couplings. Figure 4 represent typical measurements of noise level. In figure 5 is shown Bruel & Kjaer Sound level meter Type 2250 which was used for measuring noise levels that have everything needed to perform high-precision, Class 1 measurement tasks in environmental, occupational and industrial application areas.

Sound level meter Type-2250 is a highly versatile, cloud enabled modular platform with many optional application modules such as frequency analysis, FFT, advanced logging (profiling) and sound recording [8].

![Figure 3. Research on the test bench [2].](image1)

![Figure 4. Measurements of noise level.](image2)

![Figure 5. Sound Level Meter – Type 2250.](image3)
5. Data measurements and results.
In table 2 is showed noise analysis at various work speeds, with and without load: the noise level is within the range 32-58 dB for the satellite executed from plastic (figure 2a) and 38 dB - 64 dB when the satellite wheel is made by powder metal (figure 2b) [2].

Relatively low levels of noise can be explained by the multiplicity meshing of teeth (up to 100%) and the second factor which led to decrease noise level is represent by use of the plastic wheel (satellite) that have a greater capacity to damping shocks and vibrations and emitted noise level.

| Speed | Plastic satellite | Powder satellite | Plastic satellite | Powder satellite | Plastic satellite | Powder satellite | Plastic satellite | Powder satellite |
|-------|------------------|-----------------|------------------|-----------------|------------------|-----------------|------------------|-----------------|
| 600 min⁻¹ | 35 dB | 33 dB | 32 dB | 32 dB | 32 dB | 32 dB | 32 dB | 32 dB |
|       | 41 dB | 39 dB | 38 dB | 38 dB | 38 dB | 38 dB | 38 dB | 38 dB |
| 1200 min⁻¹ | 46 dB | 40 dB | 44 dB | 44 dB | 44 dB | 44 dB | 44 dB | 44 dB |
|       | 49 dB | 48 dB | 46 dB | 46 dB | 46 dB | 46 dB | 46 dB | 46 dB |
| 1800 min⁻¹ | 48 dB | 47 dB | 46 dB | 46 dB | 46 dB | 46 dB | 46 dB | 46 dB |
|       | 53 dB | 50 dB | 49 dB | 49 dB | 49 dB | 49 dB | 49 dB | 49 dB |
| 2400 min⁻¹ | 53 dB | 50 dB | 51 dB | 51 dB | 51 dB | 51 dB | 51 dB | 51 dB |
|       | 58 dB | 56 dB | 55 dB | 55 dB | 55 dB | 55 dB | 55 dB | 55 dB |
| 3000 min⁻¹ | 58 dB | 56 dB | 56 dB | 56 dB | 56 dB | 56 dB | 56 dB | 56 dB |
|       | 64 dB | 63 dB | 62 dB | 62 dB | 62 dB | 62 dB | 62 dB | 62 dB |

In conclusion we can mention that assessment of measured values (table 2) in line with VDI directive 2056 (table 1) demonstrated good acoustical behavior of kinematical PPT gear box [1, 2].

6. References
[1] Malcoci Iu and Bodnariuc I 2015 Vibroacoustical Diagnosis of Planetary Precessional Kinematical Transmission (Part I) Innovative Manufacturing Engineering International Conference IManE pp 593-597
[2] Malcoci Iu 2015 Vibro acoustic research of planetary precessional transmissions, PhD thesis (Chișinău: Technical University of Moldova)
[3] Malcoci Iu 2013 Precessional transmission sound research Meridian Ingineresc Chișinău 4 pp 64-69
[4] Bostan I, Dulgheru V, Țopa M, Bodnariuc I, Dicusară I, Trifan N, Ciobanu R, Ciobanu O, Odainăi V and Malcoci Iu 2011 Transmissii planetare precesionale cinematice Antologia invențiilor Chișinău Bons Offices 4 pp 179-226
[5] Abraham D, Boxhamer J and Mittash P 11/2011 Instruction manual. PT500 –Machinery Diagnostic. PT500.04 – Computerised Vibration Analyser (Barsbütel Germany: G.U.N.T. Gerätebeu GmbH)
[6] Bodnariuc I 2010 Contributions to the elaboration and research on the kinematic planetary precessional transmissions, PhD thesis (Chișinău: Technical University of Moldova)
[7] Institution of German Engs. (VDI), Directive 2056 Guideline for evaluating mechanical vibrations from machinery, Verlag, Düsseldorf (FRG), 10/1964
[8] http://www.bksv.com/Products/handheld-instruments/sound-level-meters/sound-level-meters/type-2250.aspx