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Design and Execution of a Test Rig for Studying the Vibrations of a Gearbox

The current trend in the construction of gearboxes, regarding the speed increase, favours 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, dynamic contact, noise, vibration*

1. Introduction

Vibrations and noise produced by gearboxes became characteristic indicators for assessing their quality, the requirements in this regard being increased by the actual standards and norms. In their operation, gearboxes are accompanied by vibration and noise, which have negative effects on the operators they serve, as well as on the other machines close by.

The decrease of noise and vibration produced in the gear transmissions became lately a priority, being one of the combat method in the fight against pollution. For this purpose, a test rig for studying the vibrations of a gearbox was designed and developed in the laboratory for Machines and Mechanisms of the "Eftimie Murgu" University of Reșița.

2. Preparation of the gearbox

For carrying out the researches, a gearbox of type 3BH produced by NEPTUN Campina has been choose, being available in the laboratory for Machines and Mechanisms. In order to eliminate the vibration transmission from one stage to another, the gearbox has been transformed in a single stage one, as shown in Figure 1.

In the first phase of the research, for studying the influence of various geometrical factors on the gearbox vibration level, four pairs of gears (pinion + geared wheel) have been manufactured, by keeping the same module (m_n = 4) and gear ratio, but varying the helix angle (β) and thereby all the directly related geometrically sizes : the addendum modification coefficients (x_1, x_2), the contact ratio (ε_α), the overlap ratio (ε_β), the tip diameters (d_{a1}/ d_{a2}), the root diameters (d_{f1}, d_{f2}), the reference diameters (d_1, d_2), respectively the tooth- heights (h_1, h_2).

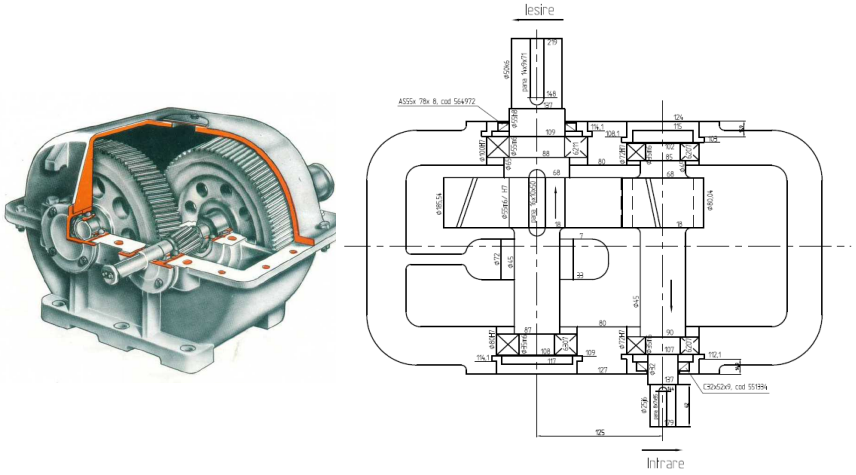

Figure 1. Gearbox: before and after transformation

For the geometric calculation of the gears has been used the ZANEUX program, existent at the gearbox factory Resita Reductoare. The calculation results are presented in table 1.

Table 1.

A= 125 mm b= 50 mm		m_n = 4 α= 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
ε_α/ ε_β	1,34/ 0,62	1,39/ 0,76	1,43/ 0,90	1,48/ 1,03
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
h_1/ h_2	18,31/ 18,38	18,57/ 18,64	18,8/ 18,87	18,96/ 19,03

It is noted that the increase of helix angle has the following influences:
- decrease of the addendum modification coefficients x_1 and x_2;

- increase of the contact ratio (ε_α) and the overlap ratio (ε_β);
- increasing of the tooth- heights h_1 and h_2.

For the second stage of research, after grinding the teeth of the four pairs of pinions and gears, it was planned to analyze the vibration level of the gearbox by using grinded gears, compared with the vibration level by using un-grinded (just milled) gears. The scope of the research is to analyze the influence of the gears precision on the gearbox vibrations level.

In the third stage of research has been identified the collaboration possibility with MASTER Bucharest for teeth-surface coverage, studying thereby the influence of the superficial coatings on the level of vibrations and noise. Superficial coverage is provided by a flouropolymer coating done by using material Xylan 1052, produced by Whitford Plastics Company Limited from Great Britain.

This coating has, besides the fact that it reduces significantly the vibration level of the gearbox, following supplementary advantages:

- doubling of the gears lifetime;
- decreasing with about 10° C of the gearbox operating temperature;
- decreasing with about 10% of the power loss;
- increasing the transmission efficiency;
- in case of shocks, the coating is acting as an absorbant, reducing the transmitted energy to the resonant surfaces.

3. The driving motor

In order to attempt the test trials at various speeds, the gearbox drive is done with an electrical motor GC2Pa44a type from the manufacturing range of UME Bucharest, with the technical data in accordance with Table 2.

Table 2.

Item no.	Characteristic	Value
1	Rated power	2,5 kW
2	Nominal voltage	110 V
3	Nominal current	31 A
4	Nominal speed	1500 min^{-1}
5	Direction of drive	right
6	Maximum torque	16 Nm

4. Choosing the break system

In order to enable the varying of the gearbox transmitted load, two alternatives for the break system have been discussed: *a generator*, to which the produced current will be downloaded over a rheostat, or: *a gear pump*, which, through a controlled oil flow, will vary the pressure and, thereby, the power ab-

sorbed by the pump. Finally, the breaking system has been chosen by using an oil pump of type KF 6/ 400 H30B NOB 7DP1, made by KRACHT Werdohl Germany, on the following considerations:

- the originality of the idea, this breaking system being not found in the studied references;
- the pump was available;
- the author of the project has a richer knowledge in the field of calculation and use of gear pumps than the power generators.

5. Supplementary features

Registration of the gearbox transmitted load is done with the help of two torque flanges type T10FS made by HBM, Germany. These devices allow the measurement of torque and speed. Each flange was mounted on the input -, respectively the output shaft of the gearbox, for the data acquisition, three MP 60 modules (two for torques and one for the speed) being used.

In conclusion, the gearbox load variation has been done by mounting a spherical valve on the pressure pipe of the pump, torque an speed measurement being done by the torque flanges. The oil- flow circuit is presented in Figure 2.

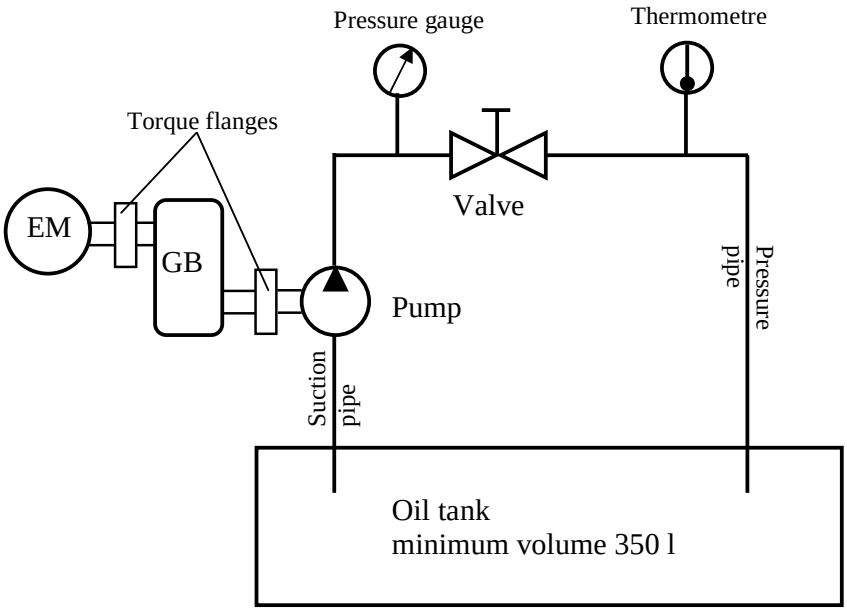

Figure 2. Oil flow circuit

For the dynamic isolation of the gearbox, regarding the possibility of vibration transmission from the electrical motor, respective from the pump, couplings with rubber strips have been chosen as shown in figure 3. These couplings have the advantage of a smooth assembling because they don't require a rigorous alignment of the gearbox with the motor, respectively with the pump.

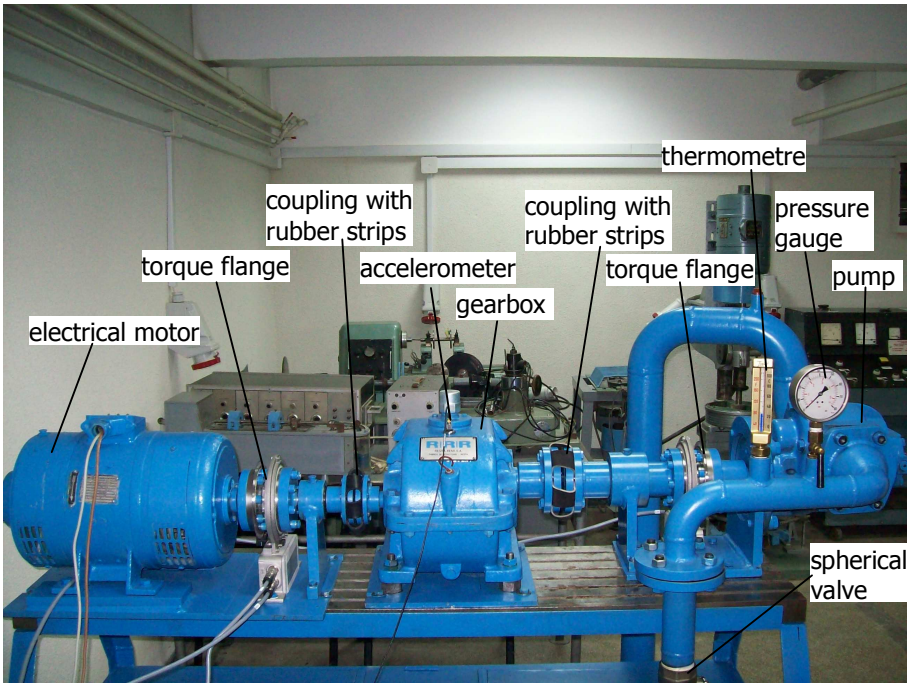

Figure 3. General view of the test rig

For the vibration monitoring, a PULSE 11 platform, purchased from Bruel & Kjaer is used, consisting of:

4524 B type piezoelectric accelerometers (see figure 4)

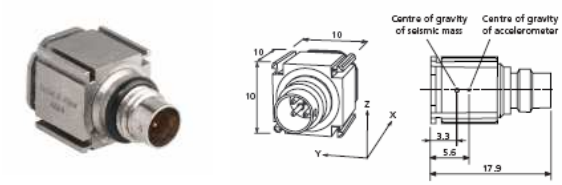

Figure 4. Piezoelectric accelerometer

Type 4524B is a lightweight triaxial piezoelectric accelerometer, with three independent outputs for simultaneous measurements in three mutually perpendicular directions. The clip mounting facility combined with the ability to mount the transducer on five of its six surfaces makes mounting on structures very flexible and quick and thus ideal for structural and modal analysis measurements. The light compact construction is an improved design covered by the OrthoShear® patent.

AO 0526 D 100 type cables (see figure 5) for measurement setup and electrical supply of the accelerometers.

Figure 5. Connection cable

Data acquisition front-end type 3560B-020 (see figure 6)

Figure 6. Data acquisition front-end: general view and connection to PC

Type 3560 B is a compact data acquisition system with five input and one output channel which handles the communication with the PC through an USB cable type AO 1449 (see figure 6).

5. Conclusions

For studying the influence of various factors of the gear geometry on the vibration level of a gearbox a special test rig has been designed and constructed. The original idea was to use an oil pump for the break system of the transmission.

The test rig is also used for studying the influence of the superficial flouro-polymer coatings on the level of vibrations and noise.

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