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EVALUATION OF TOOTHED GEAR MESH CONDITION ON THE BASIS OF MEASURMENT OF VIBRATIONS

Summary. The article presents the results of laboratory investigations of "PIOMA-1000" toothed gear, on the basis of which the conclusion has been drawn, that there exists possiblility to determine the mesh state of toothed gear being investigated by use of vibration-accoustic diagnostic. The investigations has been carried out on the stand featuring with electic power flow in clase circuit. The mechanical vibrations of toothed gear housing were the carrier of information about change of mesh state. The results of investigations presented in this elaboration have prooved that the attenuation-frequency analysis of vibrations of toothed gear may be the carrier of information about the mesh state of toothed gear being investigated.

INTRODUCTION

Since many years in Fundamentals of Design and Utilization of Mining Machines Institution of Mining Mechanization Institute of Silesian Polytechnic intensive works are being conducted. Main aim of these works is improvement of design and research methods of toothed gears of mining machines drives. One of these work stages is research of prototype "PIOMA-1000" toothed gear carried out at a stand featuring with electrical flow of power in a closed system [1]. This toothed gear is destined for application within mining industry. It is a two-stage axis-spur gear of power rating N = 55 kW and total gear ratio u = 24,54. The investigations have had to reveal whether the toothed gear and its individual parts meet requirements regarding designed durability at a rated load. As an additional aim of investigations it was assumed that the wear process of teeth and its connection with the vibrations level of toothed gear will be formulated. The authors of this work want to prove that there is a possibility to apply vibration-acoustic diagnostic for determination of mesh state of gears of "PIOMA-1000" toothed gear.

PROCESS OF INVESTIGATIONS

The investigations were conducted at the stand (drg. No. 1) featuring with electrical flow of power in a closed system. The mechanical vibrations of toothed gear generated by the intermating gears were the information corrier of change of mesh state.

When vibration-acoustic problems, very often the information conained in frequency diagram of signal generated by a facility under testing are utilized. These information obtained by use of spectroanalysis usually are clear and allow for direct interpretation. Many technical facilities are investigated with application of spectroanalysis [2]. The vibration spectrum from determined point of facility under testing is to get as an effect of measuring and then after analysis it is possible to determine the energy concentration zones connected with respective vibration-acoustic signal sources. The diagrams of obtained spectrum may be compared with the master spectrum or with that one registered during flawless operation of elements and kinematic pairs of the machine or facility under testing. It should be underlined that the obtained vibrations spectrum of toothed gear case is not allways the carrier of information determining the state of mesh. The investigation undertaken have to prove whether applied method may be suitable for diagnostic evaluation of state of mesh of "PIOMA-1000" toothed gear.

The basis of vibration-acoustic diagnostic of state of mesh is the band-selective character of vibration effects generated during coming the teeth into mesh. These effects constututing a diagnostic signal may be described among others by the vibration signal spectrum. The vibration spectrum depending on the state of mesh constitutes a certain structure which is considered as a mutual connection between the frequency and the energy of measured vibrations. The spectrum structure of vibrations may be the effect of reflection of assembling inaccuracy, mesh performance inaccuracy, deformation of teeth or other elements of toothed gear as well as rezonance effects toothed wheels, shafts and bearings. Beside above specified factors, the spectrum structure may also be influenced by demage or wear of teeth flanks or teeth spalling. The subject of diagnostic evaluation in case are teeth demages.

In case the diagnostic signal is taken from a sensor fastened to the wall of the toothed gear case, then the vibration spectrum structure is influenced by the whole dynamic system of the toothed gear. The measured diagnostic parameters depend on the place of reception of diagnostic signal. One of tasks which are to be solved when carrying out the investigations applying, the vibration-acoustic diagnostic is determination of suitable point on the toothed gear case.

The characteristic frequencies at which the changes of state of mesh caused by the wear or damage should reveal most distinctly may be determined from a following formula:

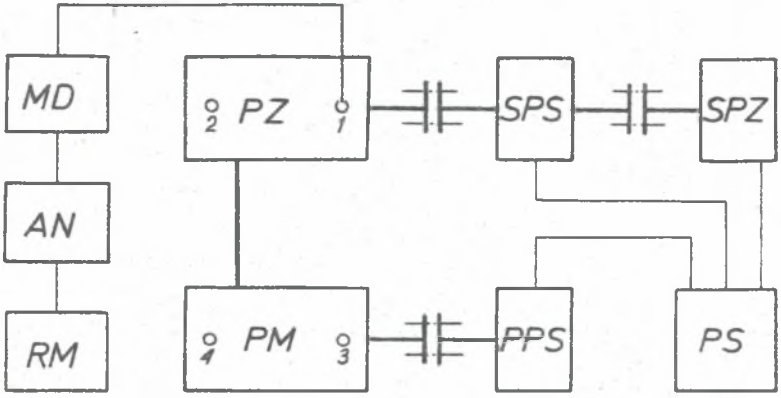
$$f_{zi} = i \frac{n\,z}{60} \quad [Hz]$$

where:

i - integer determining harmonics,
n - rotational speed of toothed wheel [r.p.m.],
z - number of teeth.

The intensity of spectrum components in the characteristic frequencies f_{zi} may be considered as the components of the vector in the multidimensional space. The vibrations acceleration, velocity or displacement may be considered as a phisical quantily under measuring. The root-mean-square value of accelerations of toothed gear case vibrations was the measured quantity in these investigations, whereas the characteristic frequencies were 100 and 350 Hz and their multiples.

The set of apparatus which in form of block diagram is shown in drg. No.1 has been applied for measuring and vibrations analysis. On the toothed gears in special for this purpose prepared places 1, 2, 3 and 4 was fastened special piezoelectric sensor serving for measuring of vibrations accelerations. The signals from the sensor were conducted to the measuring-recording apparatus.



Drg. No. 1. Block diagram of investigation stand and a set of apparatus applied for measuring the accelerations and attenuation-frequency analysis of vibrations toothed gear

PZ - toothed gear under investigation (reducer), PM - multiplying gear, SPS - direct current electric motor, PPS - direct current generator, SPZ - alternating current electric motor, PS - control desk, MD - vibration meter, AN - frequency analyzer, RM - mechanical recorder, 1,2,3,4 - places of application of piezoelectric converters

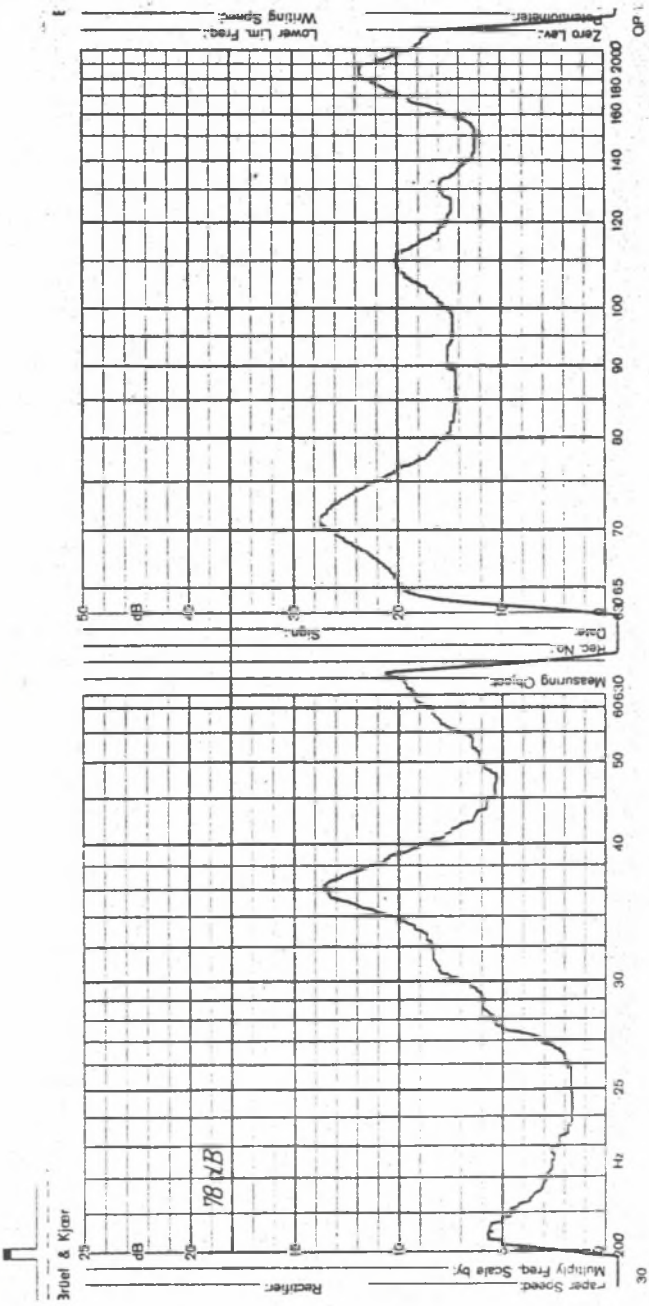
Prior to measurement the toothed gear worked during eight hours without load and then during twenty five hours under the load of 20 kW and thirty one hours under the load of 55 kW. After running in period the visual ispection of toothed wheels has been carried out; it was found that there is very good matching of toothed wheels of second stage and the proper trace of matching on the first stage (bevel gearing). The attenuation-frequency analysis has been carried out in range of 20 Hz to 20 kHz using analyzer of constant transmitting bandwidth amounting to 6% of central frequency. The measuring system has been calibrated using a MET-1 vibration table for this purpose. The measurements of vibrations of toothed gear has been carried out in the determined points after running in and then after every 100 working hours of toothed gear.

EFFECTS OF INVESTIGATIONS

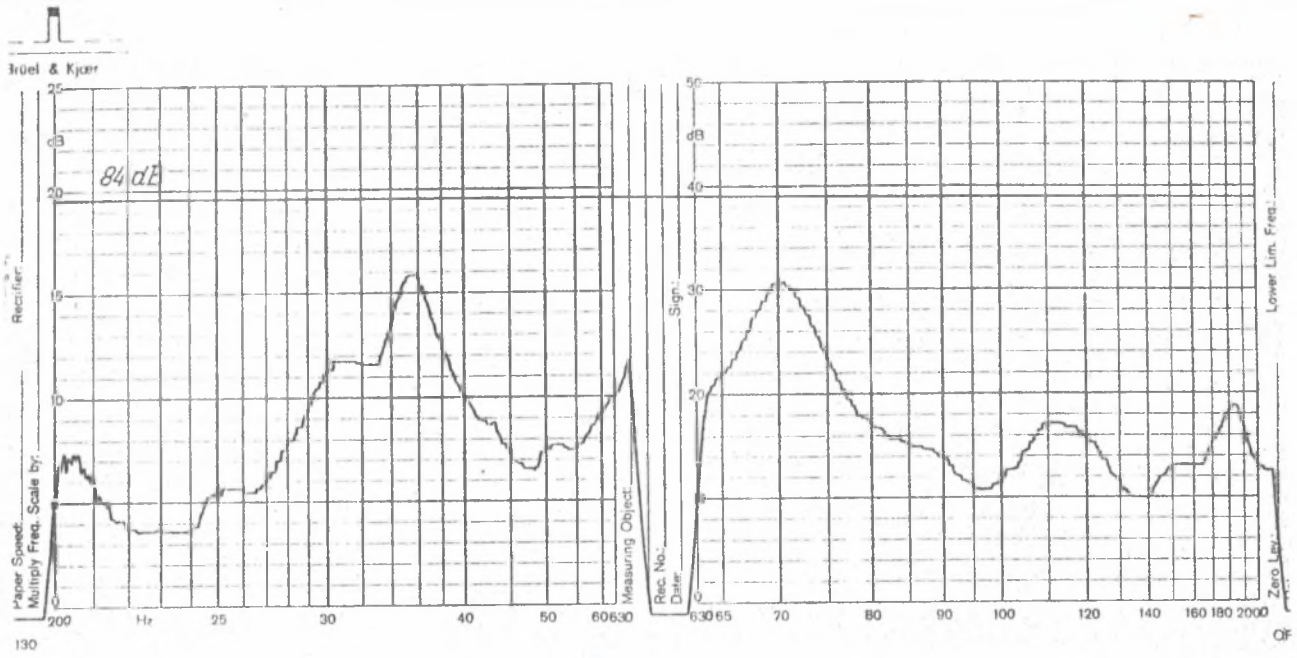
As the effect of measurements the series of spectra determining the energy quantities contained in the individual frequency bands has been obtained. These courses are wholly presented in the work [1]. In this eleboration the presentation of effects has been confined to that characteristic (Drg. No. 2, 3) comprising the band from 200 Hz to 2 kHz documenting the formulated final conclusions satisfactorily.

Drawing No. 2 presents the spectrum obtained from the sensor fastened in point "1" (Drg. No. 1) taken at the begining of investigations (after running in), whereas in drawing No. 2 the spectrum obtained also from a converter fastened in point "1" but after about five hundred working hours of the toothed gear. The solid line at the top of each diagram determines the whole level which value is given at the beginnign of the diagram. It is easy to notice that after five hundred working hours of toothed gear (Drg. No. 3) the whole level is higher by 6 dB than the initial level (Drg. No. 2). There is visible increasing of vibration level within the band 720 Hz by about 5 dB. These frequencies coincide with the first and second frequency harmonic of mesh of first stage teeth. After visual inspection it has been ascertained that the bevel gearing of the toothed gear with No. 1 measuring point had broken teeth (Drg. No. 4). The spectra taken from other measuring points did not show essential differences. The followings were the diagnosis factors of toothed gear under investigation:

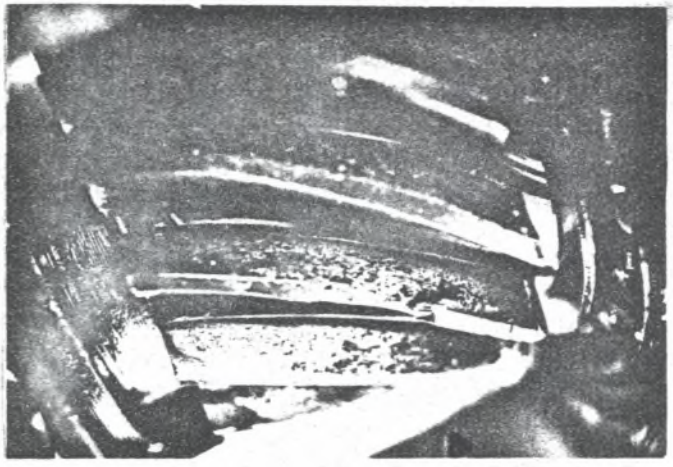
- values of vibration amplitudes in a characteristic frequency bands,
- values of general vibration level,
- dimensionless proportions of above specified values.



Drg. No. 2. Attenuation-frequency diagram of vibration signal (measuring point No. 1) recorded after running in of the toothed gear, rated load - 55 kW



Drg. No. 3. Attenuation-frequency diagram of vibration signal (measuring point No. 1) recorded after five hundred of working hours of toothed gear, rated load - 55 kW



Drg. No. 4. Visible defects of teeth of first gear pinion of the toothed gear (reducer)

NOTES AND FINAL CONCLUSIONS

According to opinion of authors, the toothed gears destined for application in driving systems of mining machines should be subjected to the vibration acoustic diagnosis during technical acceptance and exploatation. To this end it is necessary to establish:

- acceptance standards determining permissible vibration state of toothed gear taking the performance accuracy into consideration,
- exploitation standards determining permissible vibration state of toothed gear taking the changes occuring as an effect of wear of its parts into consideration.

Observing these set standarts it would be possible to eliminate the faulty toothed gears just in the manufacturing sphere and to facilitate the forecasting the overhauling the toothed gears being exploited. Therefore it is necessary for a serics of types of toothed gears intended to be manufactured in lots to carry out the diagnostic investigations which enable to establish the relation between the shape of vibration-acoustic signal and the state of toothed gear considered as good (master toothed gear). The "master spectrum" defined in this way should be used as an reference point during technical acceptance newly manufactured toothed gear. Similarly the "master spectrum" should be established for the toothed gears being exploited which may be utilized by qualification them for overhauling. The vibration-acoustic processes (vibrations) associated with exploitation of machines have a random character. There-

fore it is necessary to investigate so many toothed gears, that the obtained effects constitute the basis for application of statistic methods. The conclusions drawn on the basis of investigation of one type of toothed gear not allways are confirmed during investigation of other type of toothed gear. Practically it is necessary to carry out the investigations of each type of toothed gear seperately.

The effects of investigations presented in this elaboration proved that the attenuation-frequency analysis of vibration of toothed gear may be the information carrier about the state of mesh of the toothed gear and at the same time the thesis assumed by the authors has been confirmed.

The authors certify that after preparation of proper material the vibration-acoustic diagnostic may be used for evaluation of mechanical properties of "PIOMA-1000" toothed gears both during technical acceptance and during exploitation.

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[2] Cempel Cz., Motylewski J.: Podstawowe problemy diagnostyki wibroakustycznej. Diagnostyka urządzeń mechanicznych. Wydawnictwo PAN, Wrocław 1977. "Fundamental problems of vibration-acoustic diagnostic. Diagnostic of mechanical systems".

Recenzent: Doc. dr hab. Janusz Szopa

DIAGNOSTYKA PRZEKŁADNI ZĘBATYCH NA PODSTAWIE POMIARÓW WIBRACJI

S t r e s z c z e n i e

W artykule przedstawiono wyniki badań laboratoryjnych przekładni zębatej "PIOMA-1000", na podstawie których wysunięto wniosek, że istnieje możliwość określenia stanu zazębienia badanej przekładni, stosując do tego celu diagnostykę wibroakustyczną. Badania przeprowadzano na stanowisku o elektrycznym przepływie mocy w układzie zamkniętym. Nośnikiem informacji o zmianie stanu zazębienia były drgania mechaniczne skrzyni przekładni. Wyniki badań przedstawione w opracowaniu wykazały, że analiza amplitudowo-częstotliwościowa drgań skrzyni przekładni może być nośnikiem informacji o stanie zazębienia kół.

ДИАГНОСТИКА ЗУБЧАТЫХ ПЕРЕДАЧ ПО ОСНОВАНИИ ИЗМЕРЕНИЯ ВИБРАЦИИ

Р е з ю м е

В статье представлено результаты лабораторных испытаний зубчатой передачи "ПИОМА-1000", на основании которых сделано вывод, что существует возможность определения состояния зацепления испытуемой передачи, применяя для этой цели виброакустическую диагностику. Испытания были проведены на рабочем месте с электрическим переплывом мощности в закрытой системе. Носителем информации о изменении состояния зацепления были механические колебания ящика передачи. Резулбтаты испытаний представленные в разработке поквзали, что амплитудно-частотный анализ колебаний ящика передачи может быть носителем информации о состоянии зацепления колес.