

PROGRESS IN QUALITY ASSESSMENT OF CONVEYOR IDLERS

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Abstract: The paper deals with the transformation of term quality according ISO standards into industrial practice. There are given investigations which give background for understanding of noise structure generated by a belt conveyor. It is shown that the role of idlers to generated noise by the belt conveyor is crucial. It has shone that for quality assessment of idlers, parameters connected with vibration has to be taken. The paper gives: general consideration on the quality term, describes dynamic properties of idler/(test rig), idler/(belt conveyor belt structure), presents results of computer simulations, gives the noise nature of the belt conveyor, describes the test rig, shows investigations on vibration generated by an idler, and gives vibration levels for idlers in different quality and condition.

Keywords: Conveyor belts, testing quality, assessment

1 INTRODUCTION

The quality is an inherent or distinguishing attribute-property, degree or grade of excellence. It is definition/concept of the quality given by [1]. Synonyms to quality are property, character, attribute. The problem is how to transform the quality definition into industrial practice. The term quality implies that quality assessment is done by some subjective/objective measures. Subjective measures are for example: customer satisfaction, delighting customers. Objective measures have to be obtained by measurements of characteristics. In [2] are cited the following definitions: fitness for use; compliance with specified requirements; freedom from defects, implications or contamination; degree of excellence; customer satisfaction; delighting customers; the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs. The last definition is according to [3]. To fulfil proper quality of a product several measures have to be undertake which form quality system according to ISO 9000. The presented papers deals with quality assessment of belt conveyor idlers by objective measures given by vibration measurements. The scope of measurements comes from customers expectation of belt conveyors low noise. The quality of idlers is assessed by customers when they are used in belt conveyor systems. The expectation of the customer is low noise, proper reliability low cost of idlers. It may be fulfilled by proper design, quality control, quality assurance. Quality assessment is connected with quality control and quality assurance. Some specified requirements for idlers are given in Polish standard [4]. The scope of quality assessment given in the paper is based on consideration presented in papers [5] to [7]. Measurements given in papers [8] and [9] show that another quality measures ought to be added to fulfil customers satisfaction. Some measures connected with noise and vibration have to be added. The vibration and noise generated by the conveyor idler is not desirable effect which accompany operation of the idler. The level of vibration and noise depends of several factors. The factors may be divided into four groups: design, production, technology, operation, change of condition as it is given for gearboxes in paper [10]. Design factors include specified flexibility/stiffness and shape/dimensions of idler components, specified machining tolerance/errors of components. Production technology factors include deviations from specified design factors given during machining and assembly of an idler. Operational factors include rotational speed of an idler and its load. The consideration on the vibration and noise generated by belt conveyors is given papers [5] to [7]. The noise and vibration effect to environment in which the belt conveyor is used. The belt conveyor idlers have also vital influence to reliability of a belt conveyor. To fulfil the proper reliability and proper low vibration and noise level suitable quality idlers are needed. The proper quality of idlers is fulfilled by quality control of components which give final products/idlers and the quality assessment of final products. Quality control is a system for maintaining proper standards in manufacturing goods, esp. by regular inspection of the products. The final product quality may be tested by investigation of its dynamic behaviour when an idler rotates with its rated rpm. In paper [9] the test rig for quality assessment is described. During the quality assessment of an idler it is rotated with its rated rotation speed - rpm and is loaded and driving by flexible two narrow belts.

2 DYNAMIC PROPERTIES OF IDLER AND RIG, AND CONVEYOR SUPPORTING STRUCTURE

Dynamic properties such systems like: idler – rig, idlers – conveyor supporting structure is obtained by modal analysis. A mode of vibration is a “global” property of a structure. That is, evidence of a mode can be measured from practical any point on a structure. A mode is really the manifestation of energy trapped within the boundaries of a structure that can't be readily dissipated. As this energy travels back and forth within the structure, it causes the structure to deform with various well defined wave-like motions, called “mode shapes”. These mode shapes occur at various natural frequencies of vibration and also will “decay” in amplitude, i.e., become damped out, if external sources of energy are removed from the structure. Each mode of vibration is defined, then by a specific natural frequency, damping factor (damping ratio) and a mode shape. These modal parameters can be determined from a set of frequency response function (FRF) measurements, acquired by exciting the structure and measuring its responses at various points across its surface. The elastic motion of complex mechanical structures like: idler, idler and rig, idlers and conveyor supporting structure can be adequately described by linear differential equations. The equation are a balance between the forces within the structure and the externally applied forces. The internal forces consist of combination of mass (inertial), damping (disipative), and stiffness (elastic restoring) terms. All mechanical structures fall into two categories; either lumped parameter systems or distributed parameter systems. A lumped parameter system is, or can be approximated by, an assemblage of discrete (lumped) masses connected together with linear springs and dampers. The equations of motion of a lumped system are obtained by applying Newton's Second Law to each mass in the system. Each equation is a force balance, that is the sum of the forces acting on the mass is equal to the amount of mass times its acceleration. For n masses there will be n expressions of Newton's Second Law or n equations of motion. The lumped way of description of the mechanical structure (section of belt conveyor) is given in papers [5] and [7]. Dynamic models of distributed systems are typically built (that is, the coefficient matrices are determined) using finite element techniques. Considerations given in paper [7] show that equations of motion are dynamic, static and through damping coupled. In [4] there are given two parameters which have direct influence to dynamic properties of idler and rig or idlers and conveyor supporting structure. That is, unbalance, and a run-out of an outer surface of an idler. The unbalance is specified as $G 40$ according to ISO 1973, the value of a run-out of an outer surface of an idler according to [4] depends of an idler diameter and length.

3 SOME RESULTES OBTAINED FROM COMPUTER SIMULATIONS

Form the signal obtained by computer simulations, using the model described in [5] and [7] vibration spectrums are presented in Fig.1 and Fig.2. Possibilities of using of the proposed mathematical model are given by presentation of computer simulation results. The results gives influence of design factors to the signals. Simulations are taking for belt velocity 5.75 m/s, idlers upper and lower run-out 0.9 and 1.6 mm, shift of the idlers gravity centre 0.8 mm. Fig.1 and Fig.2 gives the velocity of variables: y_8 m/s, y_{10} m/s, y_{26} m/s, y_{30} ; y_8 describes vertical velocity of motion of the mass between two upper idlers, y_{10} describes velocity of motion of the structure supported the upper idler, y_{26} describes velocity of motion of the structure supported the lower idler, y_{30} describes velocity of motion of a central point in lower part of a conveyor belt. The peaks in vibration spectrums are caused by: unbalance and run out of an idler approximately - 9.5Hz, Fig.1a and b; vibration of a mass between idlers upper part of conveyor belt - 5Hz, Fig.1a and b; Vibration of a upper part structure approximately - 50Hz, Fig.1a and b; Fig.2 gives vibration components of a conveyor belt lower part: a component of approximately 32Hz is interpreted as vibration caused by a lower structure support; 2.5, 10 and 15Hz is thought that they are caused by modal components of a lower part of a conveyor belt.

4 NOISE OF BELT CONVEYOR

A belt conveyor noise, as it shows Fig.3, consist of many components. It is caused by the nature of excitation (operation factors) and the nature of the structure (design factors). Excitation forces come from unbalance of idlers, run-out of outer surface of an idler (design or technology factors). They gave cyclic excitation with frequency of an idler rotation (operation factor) and its harmonics. This excitation cause that the idler and supporting structure vibrate and cause noise. This statement is inferred on the base of computer simulations given in chapter 3 of the paper. Convoyed mass (bulk material) by a belt conveyor is not homogenous (especially it is caused by different dimension stones). These stones may cause impulse like excitation and cause vibration of idlers and the supporting structure. Depending of intensity of the excitation impulse and its duration (operation factor) it may cause to vibrate the idlers and supporting structure with its natural frequencies (depends of design factors). The impulse like excitation may cause wide band modulation. That cause that in the spectrum one can

found many, very difficult for identification, components. This effect was examined in [11] and [12] for a case of gearboxes. For components identification further investigations were undertaken and given in following chapters of the paper.

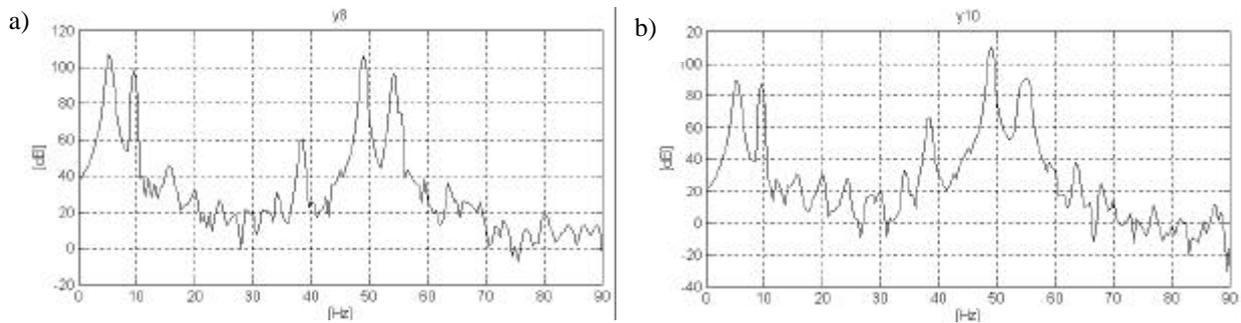


Fig.1a) Velocity vibration spectrum of conveyed mass and belt at central position, y_8 , upper part of belt; b) Velocity vibration spectrum of upper part of structure, y_{10} , upper part of structure

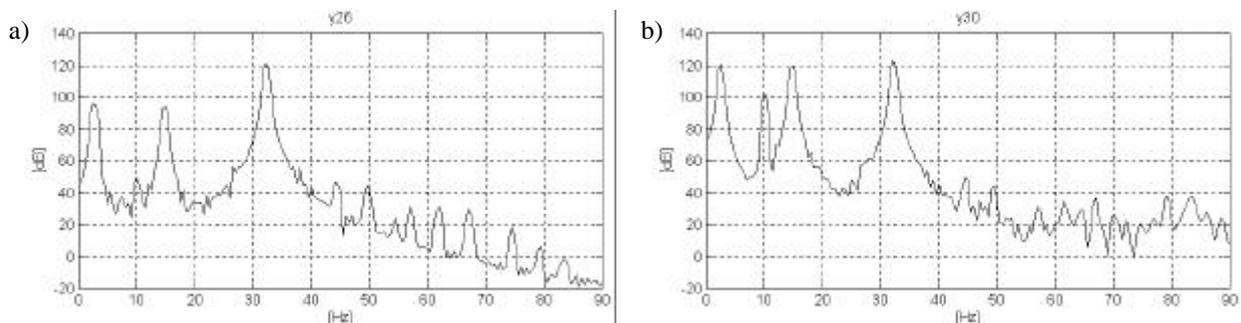


Fig.2) a) Velocity vibration spectrum of lower part of structure, y_{26} , b) Velocity vibration spectrum of belt at central position, y_{30} , lower part of belt;

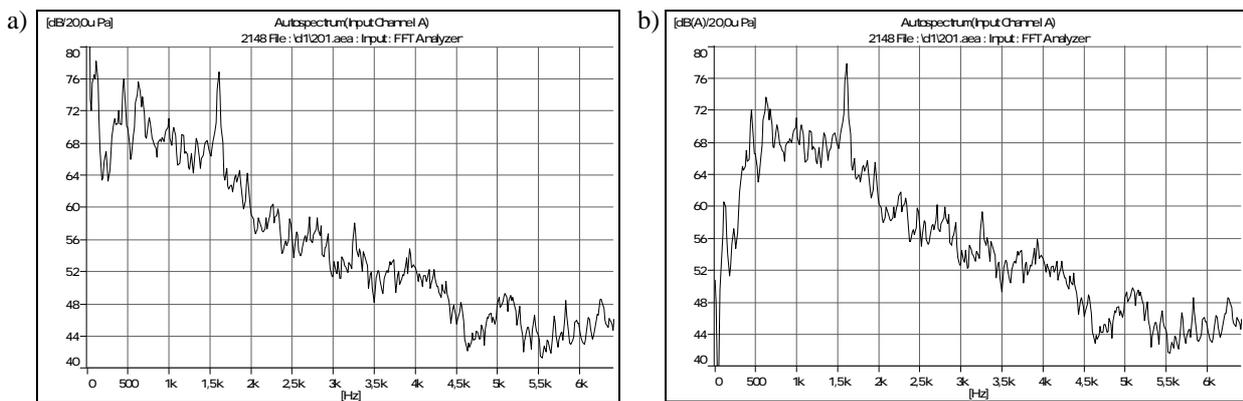


Fig.3 a) Linear spectrum of belt conveyor b) Weighting (A) spectrum of belt conveyor

5 TEST RIG DISCRIPTION

The scheme of the rig [10] is given in Fig.4. An idler (1) is driven by flexible belts (2). The idler (1) is supported in two points (P) and (L) to revolving/ swing-able frame (3). The circular velocity of the flexible belts is controlled by an electric frequency inverter which controls an electric motor (4). The swing-able frame is not connected to the frame (5). During quality assessment of an idler constant rated rotation is kept. Several examination test for the rig has been done at the condition of a rig deceleration. The rotating system has possibility of linear changing of rotating speed with time.

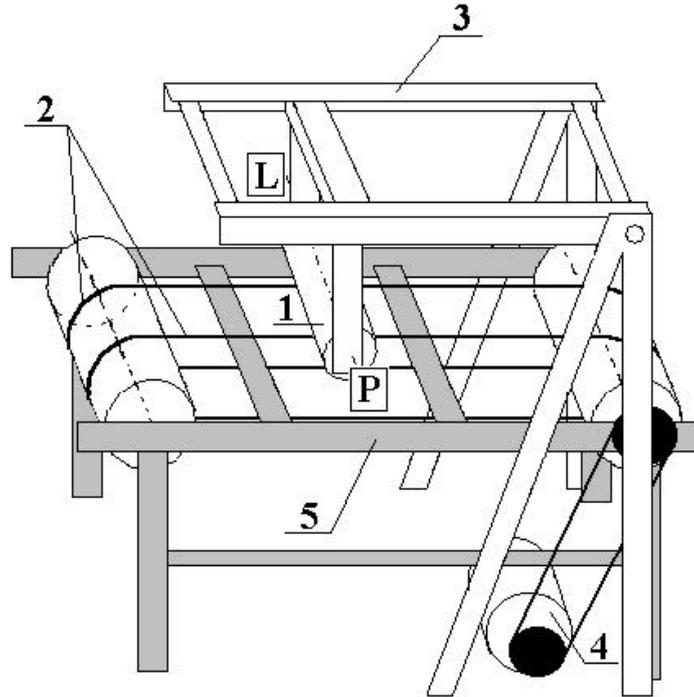


Fig.4. Test rig for vibration assessment of idlers

6 MODAL ANALYSIS OF IDLER/ RIG

Results of modal analysis for an idler are given in Fig.5. In the Fig.5 one can see modal frequencies. The modal analysis for the idler and the test rig is given in Fig.6 when we can see modal frequencies.

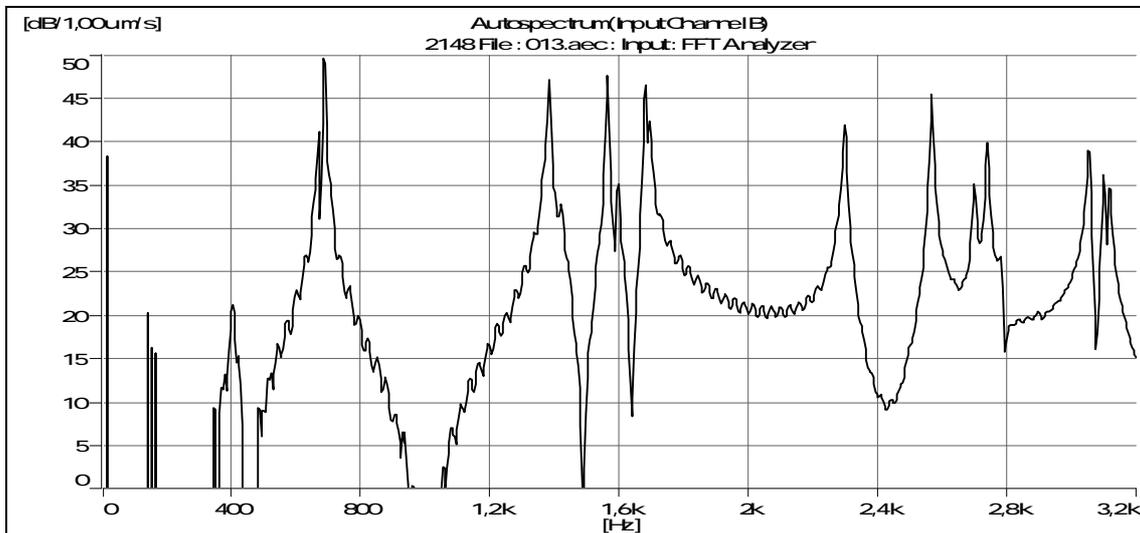


Fig.5. Modal frequencies of idler

7 VIBRATION GENERATED BY IDLER DURING OPERATION

The investigations presented in paper [9] show that vibration components generated during operation of an idler can be divided as rotation dependent and rotation independent, Fig.7a and b. The investigations were done at condition of system deceleration and at condition of constant rated rotation. The frequencies of rotation independent components of a spectrum can be examined by impulse excitation as it is given above. The causes of the rotation dependent components are unbalance, change of stiffness caused by change of number of balls taking a part in a force carried by idler bearings, deviation of roundness of an idler shell shape, deviation of bearing rings roundness,

deviation of centre of an idler rotation from geometrical centre of an idler, it gives run out of an idler, change of condition of an idler. The change of stiffness caused by change of number of balls taking a part in the force carried by idler bearings is dependent of a bearing clearance. With increasing of clearance decreases frequency of vibration generated by change of the bearing stiffness. The investigations presented in paper [9] shows that the change of idler condition caused by wear out of a idler bearings cause increasing of intensity vibration components. Both those that come from natural vibration and those that are rotation dependent. At condition when frequencies of natural vibration component have the same frequencies as rotation dependent components we have resonance. On the base of upper consideration we can formulate the term of an idler quality expressed by vibration signals.

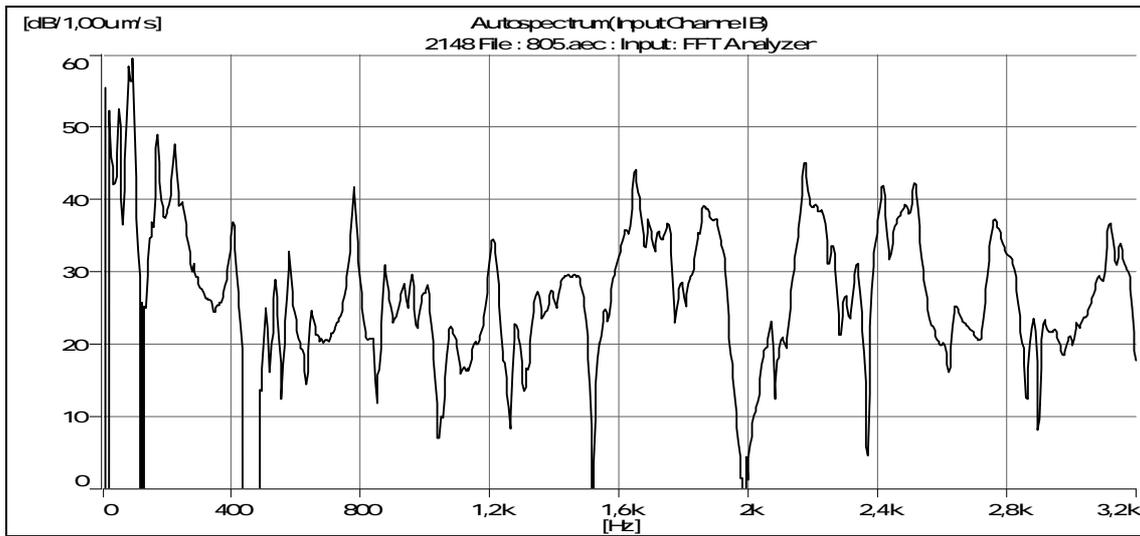


Fig.6 Modal frequencies of idler and test rig

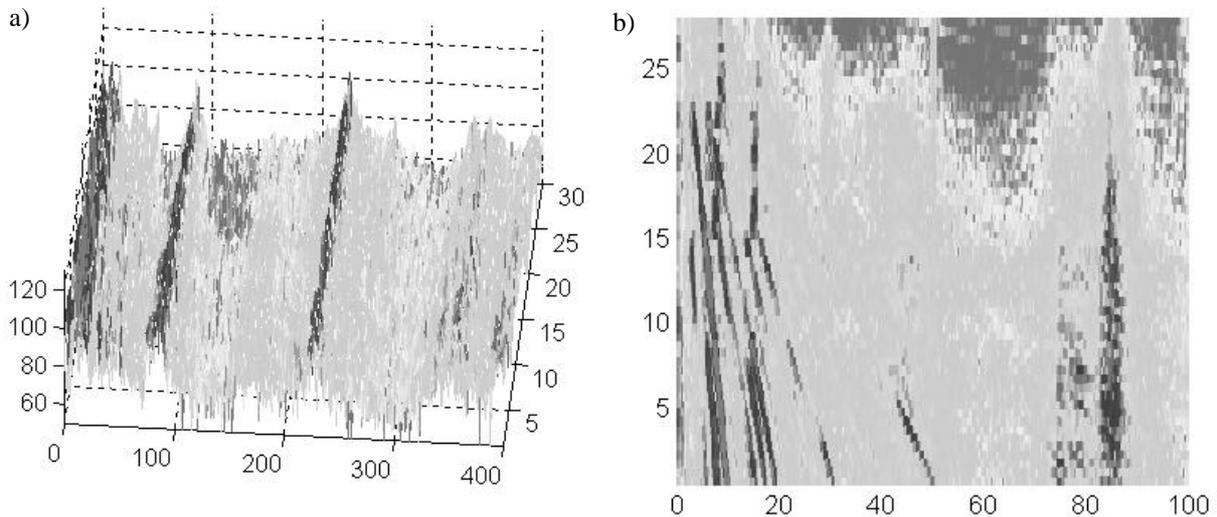


Fig.7 a) Water fall spectrum of acceleration for point P, idler in good condition b) Upper view of water fall spectrum for point P, idler in good condition

8 QUALITY OF IDLERS ASSESSED BY VIBRATION SPECTRUM

An idler during quality assessment is supported at two ends of an idler axle as it is given in Fig.4. At the places of the axle supports two accelerometers are mounted and vibration signals are received. In paper [8] there are given results of investigations on influence of: design, production technology, operation, change of condition to idlers quality. There are taken idlers: in good condition and it is denoted as K1, an idler with a plastics shell, in good condition, is denoted as Kr1, a renovated idler is denoted K3, an idler in bad condition is denoted K5. The characteristic frequencies are taken into

consideration. Frequencies are split into two scopes I and II. As it is given in [9] the frequencies given in the scope I are mostly rotation dependent. The frequencies given in scope II are rotation independent if the idler is in good condition. For an idler in bad condition some higher frequencies may be rotation dependent. So we can see the splitting the frequencies into two rotation scopes: dependent and rotation independent is not quite strict. So it has to be mentioned that in the first scope (I) occur some frequencies which are rotation independent. This conclusion also comes from results given in 3rd chapter of the paper. The frequency of 9.5 Hz is rotation dependent and is connected with unbalance, It is stated that for the idler with plastics shell (Kr1) the vibration level is about 20dB lower in comparing to idlers with steel shells (K1, K3, K5). The unbalance gives a typical rotation dependent component. The vibration levels are compared to the new idler (K1) for characteristic frequencies from 75Hz to 3136Hz (comparing idlers K1 to K5) found increase of vibration level for all characteristic components but 83 and 752Hz. These increase is in most cases higher then 10dB. But levels for characteristic frequencies from 75Hz to 3136Hz for the idler in good condition (K1) and for the idler in good condition with plastic shell (Kr1) have a vibration level for many frequencies more than 20dB lower for an idler with plastics shell.

9 CONCLUSIONS

To fulfill customers satisfaction some progress in quality assessment of idlers was needed. The paper gives the background for the progress. The paper has shown vibration parameters has to be added to parameters given in Polish standard [4]. Presented investigations have shown relation between design features of an idler and a vibration spectrum generated by the idler during its rotation. It may be stated that the vibration spectrum of the idler is a measure of the idler quality. During rotation of the idler two types of vibration spectrum components are generated. These components are rotation dependent and rotation independent. The investigations has shown that for some characteristic frequencies the level of vibration between a good and a bad idler is about 10dB higher for bad idler. The vibration level for a new idler with a plastics shell is for natural vibration components 20dB lower than for new idler with a steel shell. The level of unbalance component is also 20dB lower for an idler with a plastic shell.

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