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Influence of bearing raceway surface topography on the level of generated vibration as an example of operational heredity

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In this paper, an influence of surface topography of ball rolling bearing raceways of the vibration values has been examined. Experiments have been preferment using series of bearing types 6304. Surface topography of bearing raceways has been measured using a stylus profilometer Talysurf PGI 1230. The 2D and 3D roughness and waviness parameters have been analyzed. The vibration measurements of ball rolling bearings have been carried out using a measuring device "Anderonmeter". The concept of technological heredity and operational (exploitation) heredity in the aspect of production and operation of rolling bearings has been presented. Based on experimental study, an operation heredity analysis of ball bearings has been carried out. It has shown that the condition of surface texture of rolling bearing raceways directly affects the values of vibration generated by bearing units.

Keywords: Roughness, Waviness, Rolling bearing, Operational heredity, Technological heredity

1 Introduction

Production of rolling bearings includes many stages of technological process. If the technological process is selected adequately, the final product will meet the defined requirements. The current market requires bearing manufacturers to make high quality products while maintaining low production cost. Therefore, appropriate procedures should be used to improve the manufacturing process in order to produce better quality products[1]. This applies in particular to the mass production of precision parts such as rolling bearings[2]. Nowadays, in the modern production, in addition to the accurate determination of production errors, it is important to determine at what stage of manufacturing process the errors emerged and how they were changing during the entire production process. Then, the appropriate corrective (preventive) measures can be implemented in order for the final product to meet certain quality requirements[3]. Therefore, novel measurement systems designed for quick and inexpensive measurement should be applied[4]. Due the fact that rolling bearings are precise and important elements of mechanisms, their manufacturing process should be analyzed in detail in terms of transferring errors (defects) from subsequent stages of technological process. Such operations are called the analysis of technological heredity.

One of the basic components of rolling bearings are outer and inner rings. Their technological process consists of several important stages: forging, annealing, turning, heat treatment, grinding, polishing. By application of machining process, bearing rings obtain appropriate dimension and shape accuracy. Particularly important here are the final machining processes, that is grinding and polishing, because they affect the condition of surface layer of bearing ring raceways. Appropriately formed surface topography of raceways is very important because it affects the properties of rolling bearings. Excessive surface roughness of raceways can increase the rolling resistance and increase the friction between bearings' rings and rolling elements. As a consequence, the bearing's working temperature increases and its service life decreases. Also small raceway surface roughness is not desirable because it limits the formation of oil film on raceway surface[5]. It also results in increased wear of rolling bearings. Therefore, the appropriate finish machining, aimed at forming a suitable structure of raceway surface's top layer is very important and should be examined and improved. In order to assess the quality of final machining, the surface topography of bearing raceways should be measured in detail[6-7].

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Based on the standard ISO 2517-6:2010 there are two measuring method used to analyze surface structure of mechanical components. First is line-profiling method and second is areal-topography method[8]. The measurement of surface texture can be carried out using stylus (contact) profilometers or optical (non-contact) profilometers. In industry, mainly line-profiling method is used. The main advantages of this measurement method is short measurement time and the possibility of using portable measuring devices. However, these measurements are carried out only for one surface profile, so they do not provide detailed information about entire surface. Therefore, in some cases, 3D surface topography should be analyzed in detail using the area-topography method. The main disadvantages of this measuring method are long measurement time, sometimes reaching several hours for a single surface and high cost of the measuring devices. Due to a lot of factors influencing the measurement results, *e.g.* measuring environment (temperature, humidity, external vibrations), the condition of the measuring instrument, the quality of the measured surface, the analysis of the measurement results in many cases is difficult[9-10]. It should be added that in the case of elements made of plastic with the use of additive technologies, there is a risk of scratching the measuredsurface[11]. In particular, when considering the phenomenon of operational heredity of rolling bearings, the impact of the measurement procedure on the further proper functioning of the bearings should be taken into account. For example, scratching of the bearing raceway or contamination of the lubricant due to improperly measurement procedure may causes additional noise of bearing units. This is an undesirable phenomenon and not considered in many scientific papers.

The accurate performance of active surface texture of rolling bearings affects many exploration parameters of rolling bearings such as: service life, bearings friction torque, load-carrying capacity or vibration values. Particularly in the case of rolling bearing applications in household appliances, where the comfort of use is important, rolling bearings generating low vibration should be used. Besides, excessive vibration of rolling bearings contributes to reducing the service life of mechanisms which may lead to an unexpected malfunction of the device. Therefore, vibration measurement of rolling bearing is very important and should be carried out for both new and operating bearings. There is a lot scientific work related to vibrations analysis of rolling bearings[12-14]. The condition of rolling bearing surfaces can be described using the roughness and waviness parameters analyzed based on 2D profile or 3D surface. Most of the research works focus only on the analysis of surface roughness, while waviness is neglected. In the case of precision mechanical elements, the waviness surface should be also analyzed, because waviness affects the operating parameters of mechanisms[15-16]. It should be noted that there is no universal surface roughness and waviness parameters that allow describing surface topography of bearing raceway satisfactorily. Besides, a quantitative description of the surface quality using roughness or waviness parameters is not always sufficient. The values of parameters that describe the quality of surface texture should be related to the functional properties of the analyzed device. Therefore, the article presents research aimed at assessing the impact of selected surface roughness and waviness parameters of bearing raceway to the values of generated vibrations. The research results will allow you to choose the appropriate measurement method and surface topography parameters that can be related to the value of the generated vibration. The investigation results will allow choosing the appropriate measurement method and surface topography parameters that can described to the value of the vibration generated by rolling bearings. In addition, an analysis of the impact of roughness and waviness of raceway surface on the vibration values generated by rolling bearings in terms of exploitation heredity was carried out.

2Technological and Exploitation Heredity

The concept of technological heredity involves many aspects of manufacturing. By analyzing the phenomenon of technological heredity it is possible to monitor every stage of the manufacturing process of a workpiece (product) together with a detailed analysis of changes of its features in the course of the technological process. This allows assessment of all significant technological factors that have occurred in the past and affected the current condition of the product.

In the literature there are many concepts related to the phenomenon of technological heredity, which have different meaning[17-18]. The concept of technological inheritance (TI) refers to the phenomenon of transferring certain features of an object (workpiece) between consecutive technological processes. In the case of bearing production, technological inheritance may mean the residual stress that changes as a result of subsequent technological processes, e.g. turning, heat treatment and grinding. Inheritance features can be useful or useless. However, if these features remain unchanged in the final product, then we are dealing with the phenomenon of technological heredity (TH). An example may be the excessive value of surface roughness and waviness of bearing raceways after a technological process. The concept of technological heredity covers many aspect of the manufacturing process[3,19].

Considering the production of precision elements, it is necessary to determine how the inherited features of a technological process affect the operating properties of analyzed product. Then a new concept of operational (exploitation) heredity (EH) should be formulated. Operational heredity determines how technological features of a product affect its operating features. The concept of operational heredity is closely related to the technological heredity and it is its consequence. An example of this is the analysis of impact of surface texture parameters of rolling bearing raceways, the values of which depend on the technological process (turning, grinding), on the main operating parameter which is the level of vibration.

3 Experimental Research

The experimental study involved the vibration velocity measurements of a series of ball bearings. Fifty single row deep groove ball bearings of type 6304 were tested. Based on measurement results, for each bearings vibration analysis was carried in full range of frequency band from 50Hz to 10 000Hz. Then, the examined bearings were disassembled to provide access to the raceways surface. The next step of research procedure was to measure raceways surface texture parameters, i.e. the roughness and waviness parameters (2D and 3D). The researches procedures presented in this article were conducted in the Laboratory of Computer Measurements of Geometric Quantities and the Laboratory of Rolling-Elements Bearings.

3.1Examined Bearings

The group of fiftyopened single row deep groove ball bearing types 6304 were used in research. This types of bearing are simple in design and can be used in wide variety of applications for example in white goods, driving elements. They are suitable for high-speed mechanisms and can accommodate axial loads in both directions. Figure 1 shows the examined bearing before and after assembling.

Fig.1 — Example of the examined type 6304 ball bearing(a) Assembled bearing, (b) Outer ring,(c) Inner ring, (d) Cage and (e) Steel balls.

3.2VibrationMeasurement

The procedure of disassembling of rolling bearing can cause damage to its components or addition additional contamination of the lubricant. This significantly affects the values of generated vibrations. Besides, re-assembly of rolling bearing components may change the construction characteristics of the bearing, which will also affect the values of generated vibration. Therefore, the first step of research procedure was vibration measurement using Anderonmeter instrument developed at The Kielce University of Technology. The working principle of the measuring system used to bearings vibration analysis is similar to most anderonmeters applied in bearings factories. The measured bearing is mounted into spindle and the inner ring rotates at 1800 rpm. Measuring tip of the piezoelectric sensor FAG SG 4.3 is lowered to the contact point of the outer bearing ring. Then the vibration velocity is measured. Vibration signal is appropriately amplified, filtered and then sent to the measurement control system. The undoubted advantage of the anderonmeter used in research is the application of a sensor working as a function of vibration speed[6,20]. The RMS value of vibration was expressed in the Anderon unit, which is closely related to the vibration velocity (see Eq. (1)) and it is commonly used in bearing industry[6,20].

$$1And = \frac{V}{n\sqrt{N}} = 2\pi \cdot 30\sqrt{log_2\frac{f_h}{f_l}} \quad \ldots(1)$$

where,

And – anderon unit,

V – vibration velocity,

n – radian,

N – numer of octave,

f_h - the upper limit of the frequency band in Hz,

f_l - the lower limit of the frequency band in Hz.

3.3 Raceways Surface Topography Measurement

The measurements of roughness and waviness of raceway surfaces was carried out using stylus profilometer Talysurf PGI 1230 located in the Laboratory of Computer Measurements of Geometric Quantities in the Kielce University of Technology, Poland. Figure 2 shows an exemplary topography measurement of raceway of inner bearing ring.

The measuring device PGI 1230 is height accurate stylus profilometer used to examine surface in 2D and 3D. This measuring system is commonly used in laboratories and industry for precision measurement[16]. In the majority of research works, the surface topography examination is based only on analysis of 2D or 3D roughness parameters. In many cases the surface waviness is ignored. It should be noted that surface waviness is important as it is affects bearing's operational parameters[6]. Therefore, in this paper, next to the analysis of 2D and 3D surface roughness parameters, the surface waviness parameters are also examined. Four 2D roughness parameters (*Ra*, *Rt*, *Rsk*, *Rku*) and four waviness parameters (*Wa*, *Wt*,*Wsk*, *Wku*) were used in the research. In addition, the equivalents of roughness and waviness parameters were examined in relation to the 3D surface (*Sa*, *St*, *Ssk*, *Sku*). The surface area that has been scanning is1.35 x 1.35 mm. The sampling internal was ΔX=0.05μm, ΔY=10μm. The number of reputations was 125. The surface form was removed using third-order polynomial method. The Gaussian filter (ISO 11562) was used to surface filtration. The cut-off value was 0.25mm.

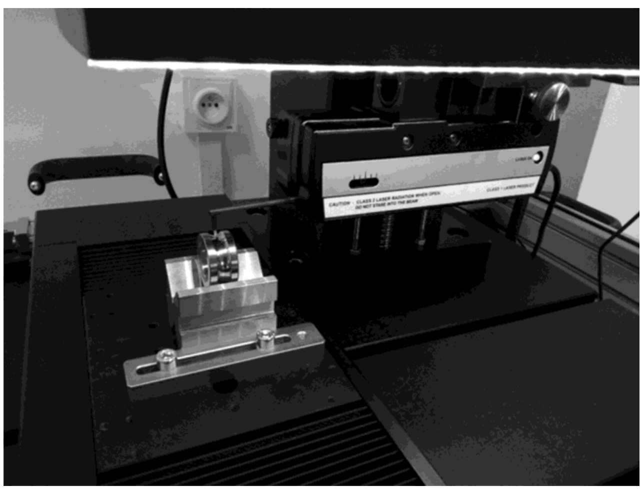

Fig.2 — Topography measurement carried out using stylus profilometer Talysurf PGI 1230.

4Research Results

4.1 Surface Roughness and Waviness of Bearing Raceways

The investigation results were presented in tables and as schemes presenting the dependence of the vibrations level on the selected surface roughness and waviness parameters. Table 1 presents 2D and 3D roughness parameters, whereas Table 2 shows 2D and 3D waviness parameters. The results in the first main column involve to the measured level of the generated vibrations. Vibration level was presented in Anderon units (see Eq. (1)). It should be noted, that the international standards related to surface topography measurements do not differentiate between parameters

Table 1 —Research results for roughness.

	Vibration level, *And*	Roughness 2D				Roughness 3D			
		Ra, (μm)	*Rt*, (μm)	*Rku*	*Rsk*	$Sa_{(R)}$,(μm)	$St_{(R)}$,(μm)	$Sku_{(R)}$	$Ssk_{(R)}$
$\bar{x}$	15.51	0.03	0.56	10.15	-1.57	0.03	1.25	31.10	-2.56
x_{max}	21.88	0.05	0.95	18.00	-0.29	0.04	2.81	76.90	-0.38
x_{min}	9.47	0.02	0.34	4.62	-2.85	0.02	0.69	5.89	-7.51
s	3.026	0.006	0.136	3.014	0.612	0.006	0.481	35.764	1.487
R	12.41	0.03	0.61	13.38	2.56	0.02	2.12	71.01	7.13

Table 2 —Research results for waviness.

	Vibration level, *And*	Waviness 2D				Waviness 3D			
		Wa,(μm)	*Wt*,(μm)	*Wku*	*Wsk*	$Sa_{(W)}$,(μm)	$St_{(W)}$,(μm)	$Sku_{(W)}$	$Ssk_{(W)}$
$\bar{x}$	15.51	0.02	0.08	1.69	-0.05	0.03	0.19	2.66	-0.02
x_{max}	21.88	0.09	0.18	1.94	0.21	0.12	1.54	8.04	0.41
x_{min}	9.47	0.01	0.01	1.51	-0.36	0.01	0.03	-3.35	-0.58
s	3.026	0.016	0.031	0.097	0.147	0.018	0.218	1.43	1.427
R	12.41	0.08	0.17	0.43	0.57	0.11	1.51	11.39	1.00

3D calculated for roughness and waviness surfaces. For example, the parameter *Sa* means the arithmetical mean height of roughness surface as well as of waviness surface. Therefore, in order to better understand the measurement results in this paper, additional markings were introduced, namely parameters $Sa_{(R)}$, $St_{(R)}$, $Ssk_{(R)}$ and $Sku_{(R)}$ refer to the 3D surface roughness parameters, while $Sa_{(W)}$, $St_{(W)}$, $Ssk_{(W)}$ and $Sku_{(W)}$refer to the 3D waviness parameters. Tables 1 and 2 present the results of statistical calculations for all measurements (fifty measured bearings), where $\bar{x}$ – mean value, x_{max} – maximum value, x_{min} – minimum value, *s* – standard deviation, R=(R_{max}- R_{max}) – range.

Analyzing the arithmetical mean roughness value Ra, it can be noted that the values of this parameters were very low for the examined bearings and ranged between $Ra\ \epsilon$ <0.02μm, 0.05μm>. The mean value was $\overline{Ra} = 0.03$μm. This value demonstrates correctly conducted grinding and polishing processes of bearing raceways. Moreover, the low value of standard deviation *s* = 0.006μm (see Table 1) indicates a significant convergence between the values of the roughness parameter *Ra* obtained for a series of tested bearings. It should be noted that in bearing industry quick inspection of raceway surface quality is mainly based on measurement and analysis of parameter *Ra*. This parameter does not provide detailed information about the shape of the measured profile, yet it is suitable for monitoring the condition of a stable technological process. Therefore, the technological parameters of the machining process are selected so as to obtain the desired values of surface roughness parameter *Ra*. Similar results were obtained for the equivalent of the parameter *Ra* but referred to the topography of the 3D surface that is the arithmetical mean height *Sa*. Also for this parameter, very low roughness values were obtained. The measurement discrepancy was also very low (*s* = 0.006μm – Table 1). The values of parameter *Ra* obtained for roughness 2D profile and the value of parameter $Sa_{(R)}$ calculated based on the roughness 3D surface overlap. Therefore, it may be initially concluded that it is not necessary to carry out time-consuming and complicated 3D surface topography measurement for a stable technological process.

Analyzing the values of the surface waviness parameters (see Table 2), i.e. *Wa* and $Sa_{(W)}$ it can be noticed that similarly as for surface roughness parameters, low values were obtained here. However, the standard deviations obtained both for mean waviness value *Wa* and the arithmetical mean height of waviness surface $Sa_{(W)}$ are higher. This shows a greater discrepancy between the values of the *Wa* parameters (obtained for 2D waviness profile) and $Sa_{(W)}$ (obtained for 3D waviness surface).

Another important group of surface parameters are parameters related to the total height of roughness profile *Rt* and total height of surface *St*. These parameters are very sensitive to single peaks, so they allow to obtain a lot of information about the nature of unevenness. Namely, if *Rt(St)*> 0.5μm, then the analyzed surface has sharp peaks. However, if *Rt(St)*< 0.5μm, the profile (surface) is more rounded, and consequently the surface is more resistant to abrasion. The parameter values were in the range *Rt*ϵ <0.34μm, 0.95μm>, while $St\ \epsilon$ <0.69μm, 2.81μm>. This indicates the distribution of sharp peaks and valleys on the bearing raceway surface. This type of surface transfers lubrication better, which is especially important for bearing surfaces and sliding surfaces. The values of these parameters significantly exceeded the values of *Ra* and $Sa_{(R)}$ parameters. The standard deviations of *Rt* and *St* parameters were also higher. However, the value of standard deviations obtained for 3D surface parameters $St_{(R)}$ were higher than the parameters obtained for 2D profile *Rt*. This may result from the fact that the parameters *St* is a spatial parameter and determines the total height of the surface (the vertical distance between the highest and lowest points of surface) measured in the area of 1.35 x 1.35mm. In the case of *Rt* and *Wt* parameters, measurement and analysis was carried out only for a single 2D profile. The analysis of the *Wt* waviness parameter should be carried out especially in the case of sealing surfaces and surfaces involved in progressive, rotary and rolling movements. Analyzing the total height of waviness profile *Wt* and waviness surface $St_{(W)}$, it can be noted that waviness values are much lower than equivalents of these parameters calculated for roughness. This is due to the application of different range of filtration, which results in reduction of the value of waviness parameters in relation to the roughness parameters.

Despite the popularity of parameters *Ra*, *Wt*, *Sa* and *St* they do not specify in detail the nature of analyzed surfaces. Therefore, in addition to the parameters that describe the surface roughness and waviness in a general way, the functional parameters defining the shape of unevenness should be examined[21]. This is particularly important for responsible machine parts, which certainly include raceways of rolling bearings.

These are parameters based on average characteristics in the height direction, among others skewness parameters (*Rsk*, *Wsk*, *Ssk*) and kurtosis parameters (*Rku*, *Wku*, *Sku*).

Analyzing the results presented in Table 1, we can see that for the parameters of kurtosis calculated for the roughness profile (*Rku*) and the surface roughness ($Sku_{(R)}$) there is a very large discrepancy between the obtained results. However, the values of parameters *Rku* and $Sku_{(R)}>3$ indicate surfaces with high, sharp peaks and deep valleys. The example of the topography of such surface is presented in Fig. 3. This type of surface is especially important for bearing surfaces because they have a low coefficient of fraction, while kurtosis parameters calculated for the waviness profile (2D) and waviness surface (3D) reached much lower values. However, the interpretation of these results is similar to the interpretation of the kurtosis roughness parameters.

Other important application parameters are the parameters determining the asymmetry of: roughness profile (*Rsk*), waviness profile (*Wsk*) and surface (*Ssk*). Considering the results presented in Tables 1 and 2, we can see that the analyzed parameters related to asymmetry of profile or surface, i.e. *Rsk*, *Wsk*, *Ssk* reached negative values. This indicated that material is concentrated in the vicinity of peaks of the roughness profile. The negative value of the parameters *Rsk* indicates the presence of "deep valleys" in the surface of the examined element. This type of surface allows for better retention of a lubricant. So we can conclude that this surface texture is recommended for bearing surface.

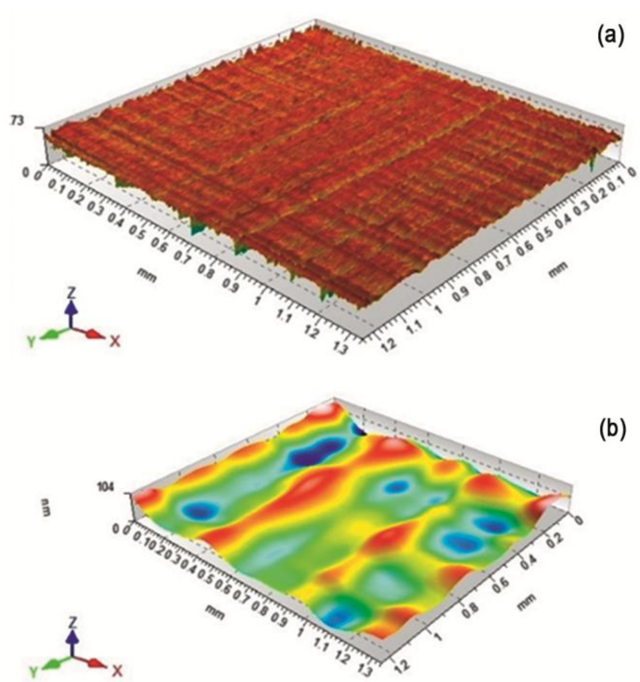

Fig. 3 — Topography of the surface of rolling bearing raceway (a) 3D surface roughness and (b) 3D surface waviness.

Analyzing Fig. 3 that shows examples of the surface topography of the inner bearing raceway it can be seen that there are numerus sharp peaks and valleys, which is confirmed by the values of the calculated parameters of skewness and surface asymmetry (see Table 1 and Table 2). Such a nature of surface results, among others, from the method of finish machining (grinding). Numerous valleys on the bearing raceway surface are desirable because such surface facilitates retention of lubricant which prevents overheating of the rolling bearings and thus extends the service life of the mechanism.

It should be noted that a large difference between some parameters describing the roughness and waviness surface of bearing raceways can result from a malfunctioning manufacturing process or bearing rings damage. Some parameters are more sensitive to single surface scratches or defects. Such parameters include those related to height of the surface irregularities, i.e. *Sp*, *Sv* and consequently *St*. Therefore, a series of rolling bearings should be examined in order to carry out statistical calculation and average the measurement results. In addition, many different parameters which are characterized by lower sensitivity to single surface damage should be analyzed, for example parameters *Ra* and *Sa*. Figure 4 shows examples of surface topography of raceways damaged as a result of the manufacturing process, assembly or operation.

4.2 Influence of Surface Roughness and Waviness on Vibration Values

Two groups of parameters were used to analyze the impact of surface roughness and surface waviness of rolling bearings on the values of generated vibrations. The first of them were parameters describing the arithmetical mean roughness and waviness values (*Ra*, *Wa*, Sa). The second group represented parameters defining the total height of profile or surface roughness and waviness (*Rt*, *Wt*, *St*). These are the parameters that are most often used for quantitative evaluation of surface texture quality.

Analyzing the vibration measurement results presented in Tables 1 and 2, we can see that the values of vibration generated by a series of rolling bearings were in the range *RMS*∈<9.47And, 21.88And>. Talking into account the general

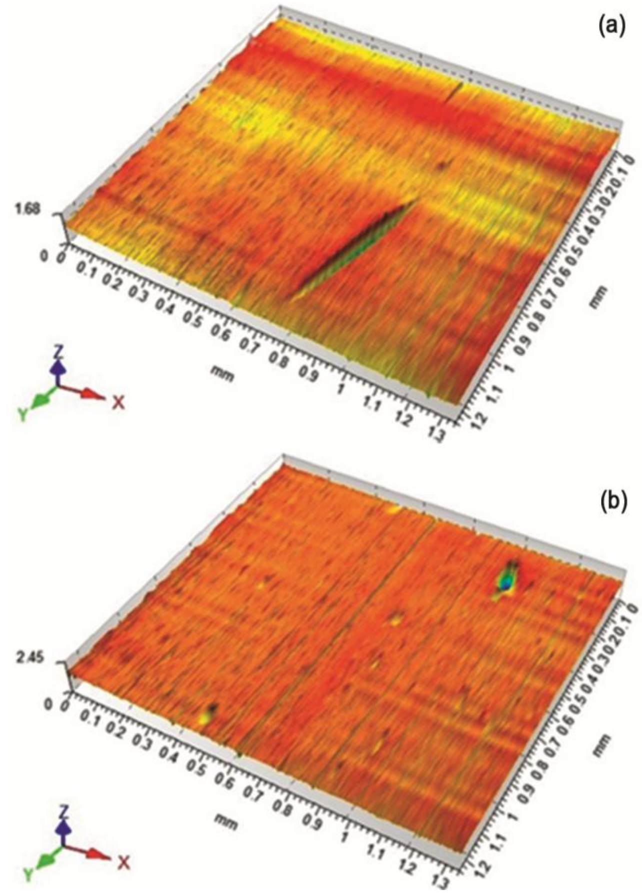

Fig. 4 — Topography of the surface of damaged bearing raceway (a) surface scratching and (b) local indentations.

requirements for ball rolling bearings type 6304, these are acceptable values. In order to carry out detailed interpretation of the impact of roughness and waviness parameters of bearing raceway surface on the vibration values, the results were grouped and presented in form of graphs.

Analysing the relationship between the arithmetical mean roughness value and the level of generated vibrations, it can be concluded that an increase in the *Ra* parameter causes a slight drop of the level of generated vibrations (see Fig 5a). Similar correlations obtained for $Sa_{(R)}$ parameter (see Fig. 5b). Similar is for 3D roughness parameter *Sa*. However, the very low variability (range) between the analyzed parameters *Ra* and $Sa_{(R)}$ should be taken into account (see Table 1). The range of the *Ra* parameter is R=0.03µm, while for Sa parameter it is R=0.02µm. Therefore, based on the above results, it is not possible to determine unequivocally the impact of changing parameters Ra and Sa on the generated vibration. The low variability of these parameters results from the properly machined surface of the raceway of the bearing rings.

Analyzing the trend lines presented in the above charts (see Fig. 6a and Fig. 6b), we can see that an increase of the arithmetical mean waviness value (*Wa*) of the race's waviness profile and arithmetical mean height ($Sa_{(w)}$) of the race's waviness surface causes a

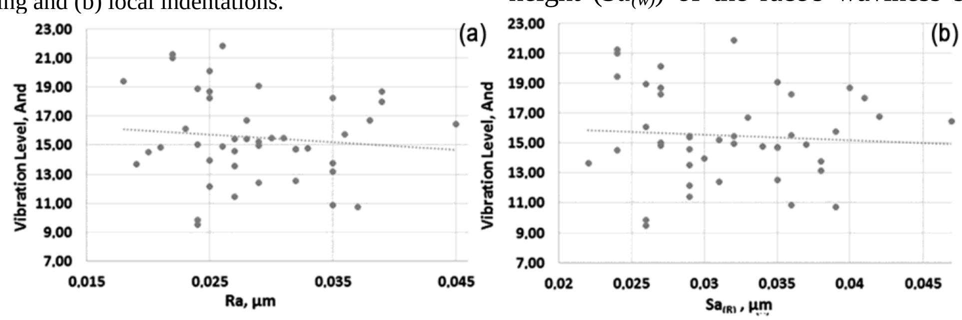

Fig. 5 — Charts of the relationship between vibrations(a) Arithmetical mean roughness value (Ra) of the race's roughness profile and (b) arithmetical mean height (Sa) of the race's roughness surface.

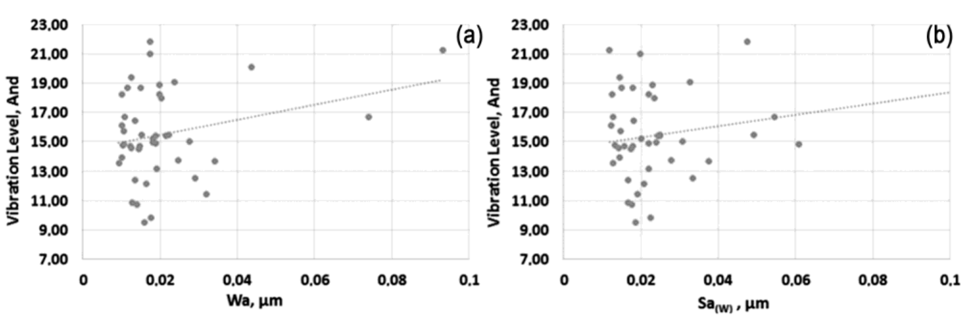

Fig 6 — Charts of the relationship between vibrations and (a) Arithmetical mean waviness value (*Wa*) of the race's waviness profile and (b) arithmetical mean height ($Sa_{(w)}$) of the race's waviness surface.

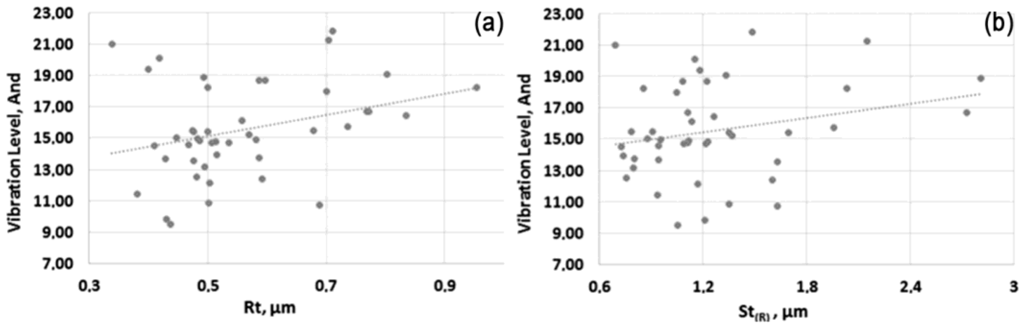

Fig. 7 —Charts of the relationship between vibrations (a)Total height of the race's roughness profile (*Rt*) and (b) the total height of surface roughness of bearing races ($St_{(R)}$).

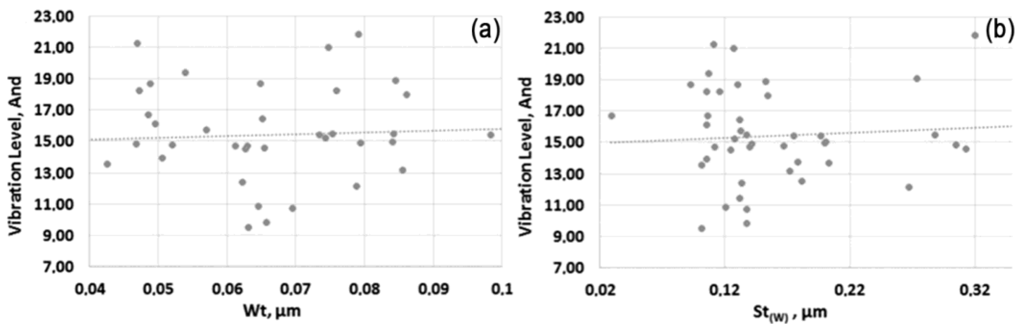

Fig. 8 —Charts of the relationship between vibrations(a) Total height of the race's waviness profile (*Wt*) and (b) the total height of surface waviness of bearing races ($St_{(W)}$).

moderate increase in the values of generated vibrations. The values of these parameters show a greater spread. However, similar as for roughness, surface waviness parameters *Wa* and $Sa_{(W)}$ largely overlap.

More unequivocal conclusions can be drawn when considering parameters defining the total height of roughness profile. Analyzing the graph presented in Fig. 7a one can see that an increase in the value of surface roughness parameter *Rt* causes a visible increase in the vibration values. This increase is particularly visible after exceeding the value of the parameter *Rt* equal to 0.5µm. It results from the shape of roughness profiles. As described in section 4.1, the value of surface roughness parameter *Rt*>0.5µm defines surfaces with sharp peaks and valleys (see Fig. 3). During a short working time of a bearing, oil unevenly spreads over raceway surface and does not fill up the oil pockets. This may result in generation of excessive vibration values. Similar conclusions can be drawn from observing the values of the parameter of total surface roughness $St_{(R)}$(vertical distance between the maximum roughness surface peak height and the maximum roughness surface valley depth). Also here, an increase in the value of vibration was noted as a result of an increase in the values of $St_{(R)}$ parameters (see Fig. 7b).

Analyzing the influence of an increase in the total height of the race's waviness profile (*Wt*) and the total height of surface waviness of bearing races ($St_{(W)}$), a moderate increase in the values of vibration level (see Fig. 8) was noted. However, compared to the roughness parameters, this impact was smaller.

5 Conclusions

In the case of precision machine parts such as rolling bearings, several stages of manufacturing process should be analyzed in detail in order to detect possible errors and inaccuracies. Then, preventive procedures should be introduced in order to limit the transfer (inheritance) of errors from individual technological processes to the final product. Then, the methods of analysis of technological heredity and exploitation heredity can be applied. Based on research results presented in this paper, the fallowing conclusion have been draw:

1 For stable bearing manufacturing process, only of 2D roughness and waviness parameters analysis is sufficient.
2 The most popular roughness and waviness parameters namely *Ra*, *Wa*, *Rt* and *Wt* are good correlated to values of vibration of rolling bearing

expressed in Anderon unit.

3 For a new group of rolling bearings or after changing the parameters of a manufacturing or technological process, it is advisable to analyse surface topography described by 3D roughness and waviness parameters.
4 Analysis the phenomenon of technological heredity indicated that the parameters of final technological process (grinding and polishing) affect the surface texture of raceway of bearing rings.
5 The application of grinding and polishing results in the formation of raceway topography characterized by high (sharp) peaks and valleys
6 Considering the phenomenon of exploitation heredity in the aspect of ball bearings, it can be stated that appropriately machined raceway surface, and thereby surface texture of bearing raceway affects the operational properties of ball bearings which are the values of generated vibrations.

To sum up, a novelty of the research presented in this paper are guidelines for bearing manufacturers and research centers, which kinds of roughness and waviness parameters should be examined in the aspect of production rolling bearings that generates low vibration level.

The research presented in this paper is preliminary. Further, the author will examine the surface texture parameters of bearing races for individual stages of their production. Then, the critical factors of each production stage will be indicated. Furthermore, additional parameters of surface topography will be examined and they will be correlated with vibration analyzed in different frequency bands. In addition, research will be carried out in order to determine how other technological parameters such as roundness deviation, clearance, lubrication types will affect other operational parameters of rolling bearings. Moreover, damaged rolling bearings characterized by higher values of surface roughness and waviness of raceways will be examined in order to better determine their impact on the exploitation parameters of ball bearings.

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