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# NEW METHOD FOR ACTIVE SURFACES QUALITY INSPECTION FOR HIGH DIMENSIONS BEARINGS

***Abstract:*** *The paper presents a stage of an ample research on high quality control for different type of large dimension bearings, with application in wind turbines for electrical energy production. There is presented a new and efficient method for bearing's active surfaces quality control, in terms of roughness, to ensure a good and safety functioning and a long life of these. The research involved the use of a powerful digital microscope for surface analysis followed by an assisted by PC algorithm for results obtaining in terms of roughness values. It has been observed that the proposed analyzing method could in the future to be successfully applied for a very large range of bearings, different dimensions and applications.*

***Key words:*** *method, quality, surface, microscope, algorithm, virtual instrument*

## 1. HIGH DIMENSION BEARING APPLICATIONS

Large dimension bearings can be used in a varied range of application, like: wind turbines, water turbines, industrial plants [1], [2]. The reason for which there are used large size bearings is that these must to support high loads during their functioning. In case of these, the behaviour of the bearing elements in motion, in contact is extremely important.

## 2. BEARINGS QUALITY CONTROL

Ensuring the safe and the highest standards of bearings functioning invokes a severe and rigorous inspection, referring first of all to the following aspects:
- dimensional control, referring to a correct placement of reported to the fix and mobile elements of the assembly in which the bearing will be disposed; it refers to the main dimensions (outer diameter, width, inner diameter, roller diameter etc.) [3], [4], [5];
- functioning control, regarding the bearing's behaviour while running (run out, axial beat etc.);
- hardness and metallographic inspection, referring to materials flaw analysis;
- surface quality control that is very important for a good and safe functioning, in terms of active surfaces (inner and outer rings raceway, rib surface, roller surfaces). The main parameter to be considered is the roughness [4].

## 3. ASPECTS ON SURFACES ROUGHNESS CONTROL

In the stage of research on active surfaces quality control for large dimension bearings, the main parameters in terms of roughness referred to:
- arithmetical mean roughness of the surface profile ($R_a$);
- root mean square roughness ($R_q$);
- maximum profile peak height of the assessed profile for the evaluated surface ($R_p$);
- maximum profile peak valley depth of the assessed profile for the evaluated surface ($R_v$);
- total height of the assessed profile ($R_t$);
- maximum height of the assessed profile ($R_z$).

For the main roughness parameters it was used the calculus relationships, according to the standards for roughness determination, as follows:

$$R_a = \frac{1}{10} \cdot \sum_{i=1}^{10} R_i \tag{1}$$

where $R_i$ represents the profile form deviation measured for 10 successive points, considered into a scanning reference base, considered on the tested surface.

$$R_q = \frac{1}{10} \cdot \sum_{i=1}^{10} (R_{i\_max} - R_{i\_min}) \tag{2}$$

$R_{i\_max}$ and $R_{i\_min}$ being the maximum and minimum measured deviation for the 10 successive scanning points.

$$R_z = \frac{(R_1 + R_3 + R_5 + R_7 + R_9) - (R_2 + R_4 + R_6 + R_8 + R_{10})}{5} \tag{3}$$

where $R_k$ (when k = 2n+1) represent the positive measured deviation values and $R_{k+1}$ represent the negative measured deviation values.

The determined roughness parameters must to be situated under roughness boundaries, for each functioning element, according to the roughness standards.

## 4. NEW PROPOSED METHOD FOR BEARINGS ACTIVE SURFACES ANALYSIS

The research object referred to 3 high dimension bearings, different types, used for wind turbines:
- double roll spherical bearings;
- single roll ball bearing;
- single roll cylindrical bearing.

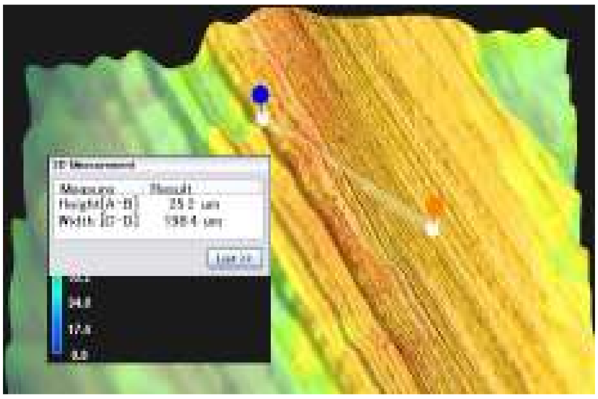
Our research on bearings inspection referred to the following aspects:
- visual inspection;
- dimensional inspection;
- surface quality inspection;

- metallurgical, hardness and metallographic inspection. Surface quality inspection represented an important stage of the research.

The used equipment for surface quality inspection consisted in a digital microscope with optical zoom range between 100x and 5000x. The microscope is provided with a software environment that allows 2D and 3D surfaces analysis, for which 200x optical zoom has been used. Due to the digital microscope it was possible to capture images for finite are surfaces for each analyzed probe [6].

Regarding the applied procedure, the more steps were accomplished. The first one consisted was the dispensing of different samples of bearings to be analysed (for each bearing, 2-3 samples for each element were taken (from inner and outer ring, rollers, cage)).

In the 2nd step we have used the digital microscope for finite scanning areas for analysing each sampled probes, providing from the studied bearings; for each analyzed area, three sections were made, to obtain the profile in each section; in figure 1, such of section is presented, the width (C-D) being the reference base for which the surface profile was determined.



a)

b)

**Fig. 1** Example of creating a section for an analyzed surface of a sample provided from the outer ring of a double roll spherical bearing:
a) 3D measure; b) profile measurement

In this way, the roughness evaluation via Keyence digital microscope was made capturing images for 3D measure (figure 1,a) and also for profile measurement (figure 1,b). For each section line, the char profile was obtained (figure 2), then being taken the numerical data concerning the deviations.

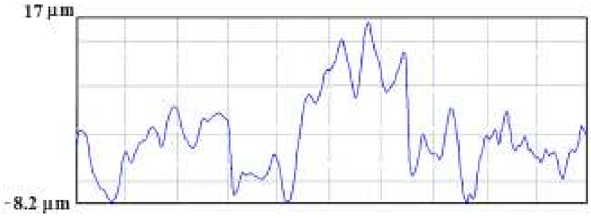



**Fig. 2** Chart profile generating for a section line

For each analyzed surface were made at least three determinations, given by three section lines and, therefore three chart profiles. This procedure was adopted, knowing that metrological standpoint at least three measurements must be performed. Our research invoked the measuring via digital microscope in two modes (3D and profile measurement). Thus means that for each sample surface analysis, two pairs of three deviation values (read from charts) were considered.

The same procedure was applied for all samples providing from rollers, inner and outer rings, for all analyzed large dimensions bearings.

The data processing consisted in applying the mathematical relationships (equations (1) ÷ (5)) for calculating the roughness parameters. Besides, for total roughness determination ($R_t$), for each generated chart profile, the difference between the maximum and minimum deviation values was considered. For the maximum profile peak height of the assessed profile, was taken into account a coefficient (*c*). This regards the weighting current values disposing reported to the mean value for each chart profile of deviation distribution (equation (4)).

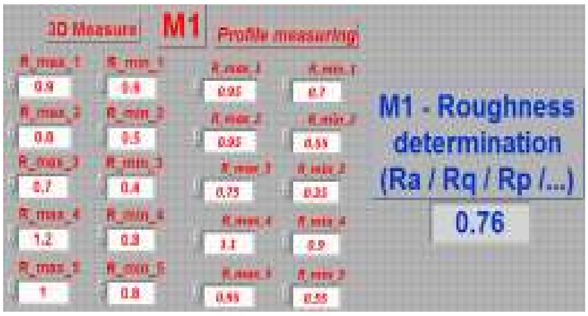
$$R_p = R_t \cdot c \quad (4)$$

To complete all information on roughness values for the analyzed profiles, the maximum profile peak valley depth was also determined. The calculus relationship (equation 5) was established due to the profile chart diagram, considering that “0” is the reference value from which the values depth deviation can be measured.

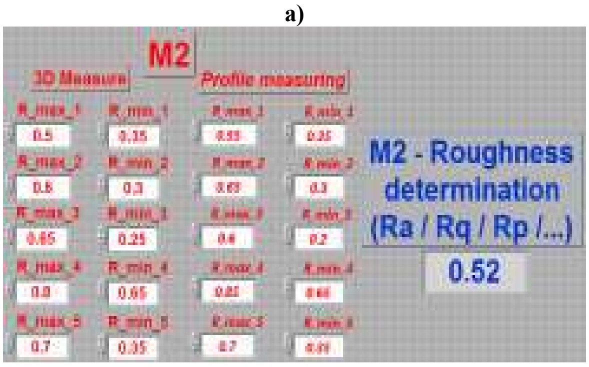
$$R_v = 0 - R_t \cdot (1 - c) \quad (5)$$

In order to processing more efficient the data, it was developed a software application (*Roughness determination.vi*), using the Lab VIEW virtual instrumentation software environment. Calculus algorithms transposed into virtual instruments (via Lab VIEW) proved to be a very good solution regarding the results properly and efficiency obtaining [7].

This allows that, by introducing the read values on measured deviation, providing from all generated chart profiles, to be displayed automatically the roughness results ($R_a$, $R_q$ etc.). The software application was designed to show the results in terms of roughness for each of the three measurements (M1, M2 and M3), based on the two pairs of three measured deviation values. By entering the read deviation values from the chart diagrams, automatically the results on roughness for each of the three measurements are displayed (figure 3).




a)

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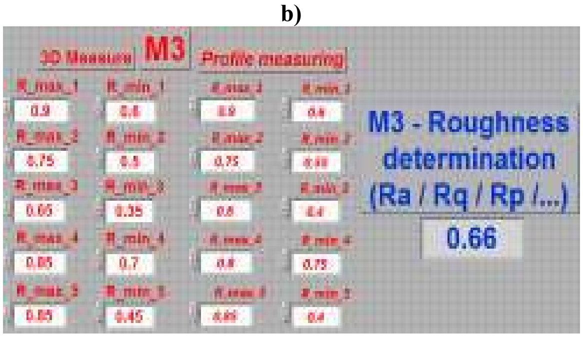



c)

**Fig. 3** Automatically results obtaining for all three measurements for a sample probe

Obviously, based on the three measuring results, the application shows also the average value of the roughness for the probe analyzed surface (figure 4).

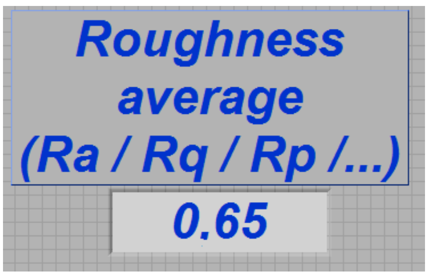
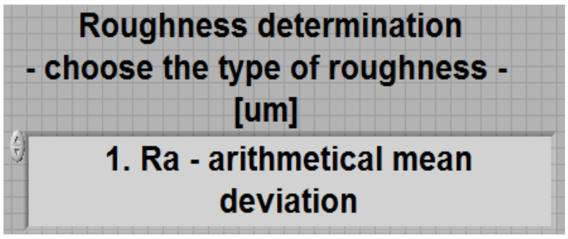
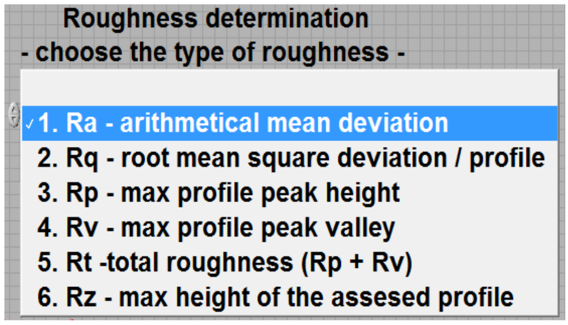



**Fig. 4** The averaged values displaying based on the three measuring results (M1, M2, M3)

The results displaying on roughness can be selectively made, due to a text box dialog that allows to the user to select the type of roughness parameter to be calculated and shown (figure 5). Thus means that the application to determine the results on roughness in terms of all defined parameters ($R_a$, $R_q$, $R_p$ etc) (see paragraph 3). Once selected the roughness parameter to be displayed, the user have to introduce the deviation values, providing from charts diagrams, referring to the determined parameter. For example, if need to know what are the value results for $R_p$ roughness, there will be introduced all the measured values (2 x 3 pairs values, see above) concerning the maximum profile peak height of the assessed profile.




a)




b)

**Fig. 5** The text box dialog to select which type of roughness parameter must to be determined: a) the text box dialog; b) the list of selection

The roughness results analysis must take into account the roughness boundary values corresponding to each bearing element analyzed surface (rollers rib / rollers raceway / rollers contact surfaces etc.) [8], [9]. As an example, in the table 1 there are presented the $R_a$ roughness boundary values corresponding to the rollers providing from a double roll spherical bearing:

*Table 1*

**The roughness boundary value corresponding to the roller diameter, $D_{we}$, according to DIN 5402-1: 1993**

| Dwe [mm] | | $R_a$ [μm] | |
|---|---|---|---|
| over | up to | on rollers lateral surface | on rollers end faces |
| 26 | 40 | 0.2 | 0.5 |

For this reason, we anticipated that the software application must to include a virtual LED who can inform about the results. If the LED lights, thus means that the analyzed surface will correspond by the point of view of roughness values (figure 6). Else, the LED remains in "0" logic state.

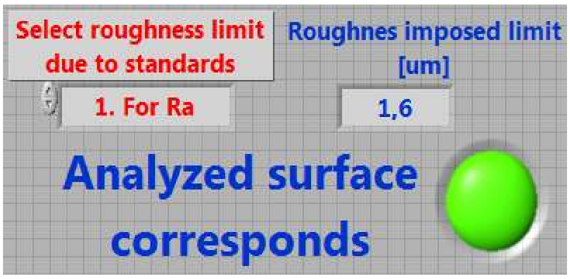



**Fig.6** The LED state displaying, in case in which the analyzed surface corresponds standpoint $R_a$ roughness

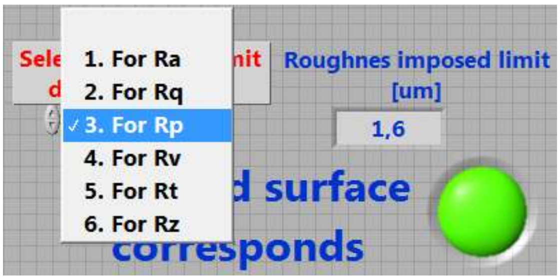



**Fig. 7** Selection of the roughness parameter for results evaluation – choosing the maximum profile peak height

From this point of view, another text box dialog is included, to choose the roughness parameter to evaluate the results. In this way, not only for $R_a$, but for all roughness parameters, the results on measured values could be compared with the boundary values corresponding to the standards.

## 5. RESULTS AND DISCUSSION

The automatically displayed results on the *Roughness determination.vi* were synthesized in tables, one for each sample referring to each bearing element. A representative example of results presentation can be seen in table 2. It is about the raceway surface of the outer ring providing from a double roll spherical bearing:

*Table 2*

**The measured roughness parameters for the outer ring**

| Measures | $R_a$ [µm] | $R_q$ [µm] | $R_p$ [µm] | $R_v$ [µm] | $R_t$ [µm] | $R_z$ [µm] |
|---|---|---|---|---|---|---|
| **m1** | 0.76 | 7.04 | 13.77 | -15.53 | 29.3 | 3.22 |
| **m2** | 0.52 | 10.08 | 13.89 | -15.66 | 29.55 | 7.02 |
| **m3** | 0.66 | 8.5 | 13.85 | -15 | 28.85 | 6.3 |
| **Average** | 0.65 | 8.54 | 13.84 | -15.4 | 29.23 | 5.51 |

Due to the new developed and applied method for surface quality control, we have found that two of the three analyzed large dimension bearings corresponded standpoint surface quality. This concluding information could be very properly and quickly obtained, due to the applied method for surface quality inspection. As a result it was demonstrated that the applied method could be further applied for large series of bearings, not only having large dimensions, even for medium and small dimensions.

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