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# The results of bearings diagnostics of ship electric motors and generators

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**Abstract.** The article discusses the results of in-place diagnostics of rolling bearings of ship generators and electric motors, carried out on more than one thousand five hundred units. The main methods for diagnosing the technical condition of rolling bearings, applied in the diagnostics on ships, are considered. The statistics of detection of various types of rolling bearing defects is given. The conclusions on the reliability of bearing assemblies with rolling bearings are drawn. The directions for further improvement of diagnostic methods and work practices are indicated.

## 1. Introduction

One of the crucial parts of the design of any ship electric generator or electric motor is presented by bearing units. The Bearing units with bearings, both sliding and rolling ones can be used in generators. Most of the bearing units of ship electric motors have a rolling bearing.

Rolling bearings may have different designs and differ in the type of rolling elements and cage. They can be double-row, single-row, self-alignment, etc.

The bearings with more complex design are used in electric generators. For example, in single-support machines double-row self-alignment rolling bearings can be used. Most of the electric motors, especially not of large power and dimensions, have bearing assemblies with single-row ball bearings. The identification of defects in operating rolling bearings of electrical machines is one of the tasks of technical diagnostics.

It is necessary to note the difference in approaches in the determination of the admission to further operation of the bearing units of shipboard electrical machines and similar onshore equipment. In ship conditions, as a rule, there is no possibility of carrying out monitoring of the technical condition of bearings, especially the possibility of removing equipment from service for routine repairs. For a long time, a ship may not enter the port, where it is possible to carry out bearing diagnostics by specialists of appropriate firms. Therefore, when determining the allowable residual operation life of the bearings of a ship electric machine it is necessary to reject more efficient bearings if they are defective. However there is no certainty that they will ensure that the operation capacity of equipment until the next repair.

The article analyzes the results of diagnostics of more than four thousand bearings of ship electric motors and a generator of one and a half thousand various electric machines with more than one hundred ships. The purpose of the article is to analyze the reliability of bearing assemblies and



determine the most common bearing defects in practice. The research work carried out since 1992, is performed by employees of the department of Ship Power Plants MSTU and “DiaMANT” company.

## **2. Methods and materials**

For the diagnostics of rolling bearings, several methods of vibration diagnostics were developed: the determination of peak factor, the analysis of the spectrum of envelope of the high-frequency component of the vibration signal and diagnostics based on impact pulses [1,2]. The last two methods for diagnosing rolling bearings are most common.

The method of impact pulses is easier in use and interpretation of results and does not require special qualifications from personnel conducting the diagnostics. Nevertheless, despite the simplicity, the method of impact pulses has a lower sensitivity and noise immunity and is much less commonly used when diagnosing bearings of ship machinery [4].

The method of the analysis of the spectrum of envelope requires qualified specialists and a bit more time-consuming operations compared to the method of impact pulses. This method allows determining a greater number of bearing defects and more reliably diagnosis for the prediction of residual resource.

The method of the analysis of the spectrum of envelope allows identifying the defects of the outer and inner rings (cracks, wear, chipping of tracks), the defects of a cage, the defects of rolling elements and assembly cocking of bearings [2,3].

According to the degree of development, defects can be divided into incipient and developed. Of course, the division into incipient and developed is to some extent conditional and often is determined by particular specialist and the experience of the organization performing the work.

Incipient defects have feebly-marked diagnostic properties, but, nevertheless, they are clearly visible in the spectrum of envelope. Such defects, for example, include the onset of runout of the outer and inner rings, manifested in the spectrum by an increase in the number of higher harmonics of the frequency of rolling bodies around the ring, or runout of the rolling bodies themselves (this defect is less common). When an incipient defect is identified, there is no need to immediately replace the bearing and it is possible to monitor its technical condition until the defect develops.

Developed defects should include shells on rolling elements, heavy runout, cracks and cuts on bearing rings, and especially a defect in a cage, which requires immediate replacement of a bearing. However, it is necessary to note that sometimes the spectral line of the frequency of rolling elements on the outer ring (which is a sign of a defect in the outer ring) is also seen in a completely new and proper bearing.

## **3. Experience of diagnostics of ship electrical machines bearings**

Different defects of bearings (with the exception of assembly cocking) appear at different operating times of bearing assembly. Unfortunately, in existing practice, the inspection of Russian Maritime Register of Shipping requires the replacement of bearings with incipient defects, despite the fact that their resources are far from being run out. Such decisions are explained by the inability to monitor bearings during the period between repairs, and the long absence of ships in ports where diagnostic work is possible. The attempt to equip ships with instruments for diagnosing was not successful due to the lack of trained specialists in a crew and heavy workload of machine crew.

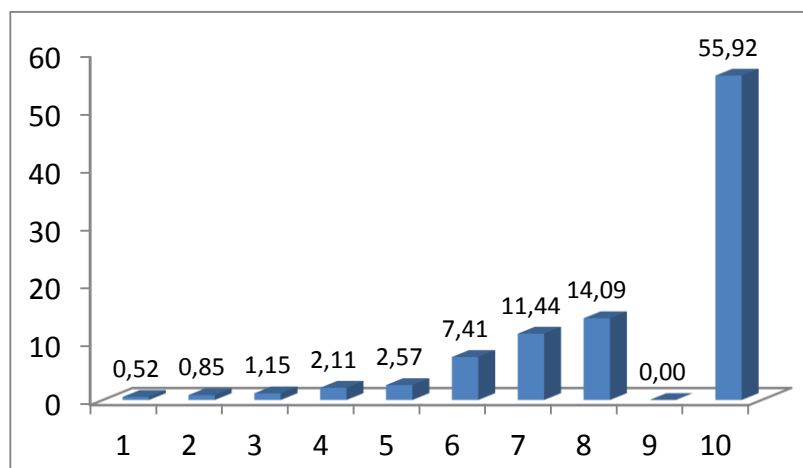
Therefore, the works on diagnostics of generators and electric motors are carried out immediately before repair, without the possibility of further monitoring the technical condition of bearings. And this fact, in its turn, tightens the requirements for their technical condition and leads to the requirement to replace an operational bearing, while no methods for calculating the residual operation life are applied.

## **4. Bearing diagnostic results**

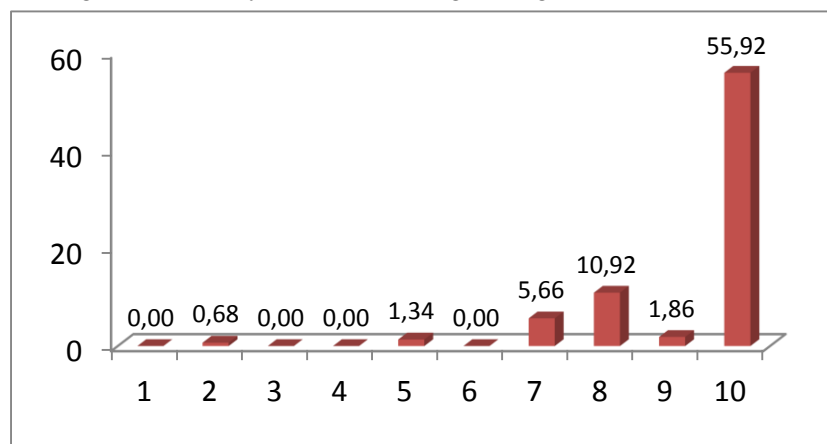
The sampling according to the identified defects is presented in Table 1 and in Figure 1 and 2, where they are presented as a percentage of the total number of bearings tested; Figure 3 shows a diagram reflecting the ratio of identified incipient and developed defects.

**Table 1.** Defects classified as developed

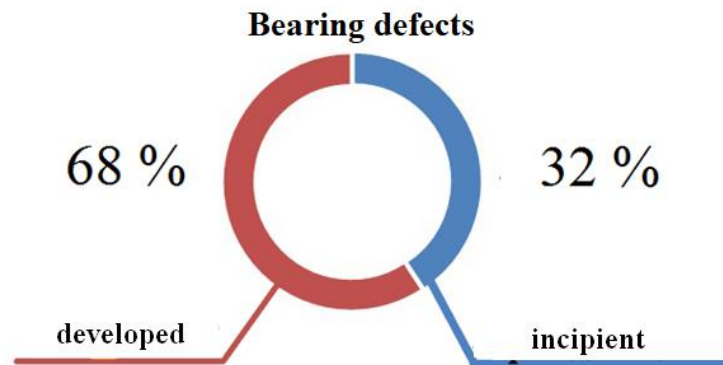
No	Defect item	Defects classified as developed	Defects classified as incipient
1	Defect on the outer ring, the beginning of the degradation of a cage.	19	–
2	Defect of rolling elements	31	25
3	Defect of the outer and inner ring	42	–
4	Defect of a cage and rolling elements	77	–
5	Defect of a cage	94	49
6	Grease defect	271	–
7	Defect on the inner ring	418	207
8	Defect on the outer ring	515	399
9	Assembly defect – cocking of rings	–	68
10	No defects found	2044	



**Figure 1.** Defects classified as developed: 1 – defect on the outer ring, the beginning of the degradation of a cage, 2 – defect of rolling elements, 3 – defect of the outer and inner ring, 4 – defect of a cage and rolling elements, 5 – defect of a cage, 6 – grease defect, 7 – defect on the inner ring, 8 – defect on the outer ring, 9 – assembly defect – cocking of rings, 10 – no defects found.



**Figure 2.** Defects classified as incipient: 1 – defect on the outer ring, the beginning of the degradation of a cage, 2 – defect of rolling elements, 3 – defect of the outer and inner ring, 4 – defect of a cage and rolling elements, 5 – defect of a cage, 6 – grease defect, 7 – defect on the inner ring, 8 – defect on the outer ring, 9 – assembly defect – cocking of rings, 10 – no defects found.



**Figure 3.** The ratio of the number of incipient and developed bearing defects.

## 5. Conclusion

1. The analysis of bearings diagnostics for a significant time period showed the following results:

- During monitoring it was found that more than 55% of investigated rolling bearings of ship electric machines are free from defects and are suitable for further operation;
- Significant part of bearings (32% has incipient defects of varying degrees of severity, these bearings can be left in operation by strengthening their control and monitoring their technical condition;
- The most common developed bearing defects are the defect on the outer ring of (14%), the defect on the inner ring (11.44%);
- The defect of a cage, the most dangerous defect that can lead to a sudden bearing failure, is much less common – 2.57%;
- Almost 2% of bearing defects are the result of poor-quality repairs (misalignment of the rings) and inadequate maintenance – 7.41% (grease defect);
- As a rule, the development of bearing defects begins with defects of the outer ring.

2. The above mentioned results once again confirm the high reliability of rolling bearings and the economic feasibility of in-place diagnostics of bearing units of ship electrical machines.

3. It is necessary to improve the methods of technical diagnostics of rolling bearings, and especially methods that allow predicting their residual operation life. Nowadays, there is a replacement of fully functional rolling bearings with incipient defects, which is reasoned by the lack of confidence in the fact that the bearing will properly operate before the next inspection survey.

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