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SURFACE ROUGHNESS INVESTIGATIONS FOR SURFACE OF SHIPBOARD ENGINES CRANKSHAFT

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1. Introduction

The repair of shipboard diesel engines crankshafts is significant part of overall diesel engines repairs and thus is very important for ship building and ship repair industry. When the ship's diesel engine repairs are carried out crankshaft journal (bearing) surfaces must be renewed according very precise geometrical and surface roughness requirements. Currently technologies available for ship repair enterprises are sufficient to ensure these requirements, however, they are very time consuming and consequently expensive. Therefore it is necessary to undertake comprehensive research of the shipboard diesel engines crankshaft journals surfaces machining. This will allow to improve technological processes and to identify respective surface roughness parameters as well as to give adequate technological recommendations. It is important to note that crankshaft bearing surfaces must be seen as three-dimensional object with definition of microtopographical surface roughness parameters which reflect to real surface. To summarise all available scientific researches in this field it is stated that there are no analysis given regarding impact of technological regimes to the shipboard engines crankshaft journals surface microtopography.

Taking into consideration the above mention arguments, the comprehensive research has been done, using the new technological approach, which significantly simplifies technological work and allows crankshaft journal grinding performing inside the housing without removing it from engine. This technology saves significant financial resources as well as time of engine repair itself.
Subsequently this research contains actual production assignment with practical implication. Solving problems related with surface accuracy it is possible to considerably improve the crankshaft machining process as well as performance of maintenance operations and consequently overall quality of repair works.

2. Three-dimensional model for shipboard diesel engines crankshaft bearings

In the above mentioned research the model of crankshaft journals surface roughness was determinate. This mathematical model of the surface roughness should be complete enough to describe the real surface and in the same time simple enough to be practically applicable [1,2]. In order to successfully work out the crankshaft journals surface roughness model, during research a classification of rough surfaces and analysis of an irregular roughness model have been done.
It was defined that every type of mechanical machining and surface creation process has their own, unique surface roughness topography. However, all mechanically processed surfaces principally can be divided into two groups: isotropic and anisotropic surfaces. The Isotropic surface is surface whose roughness parameters in the all directions are the same but for anisotropic surface the roughness parameters are different depending on measuring direction (see Figure 1).

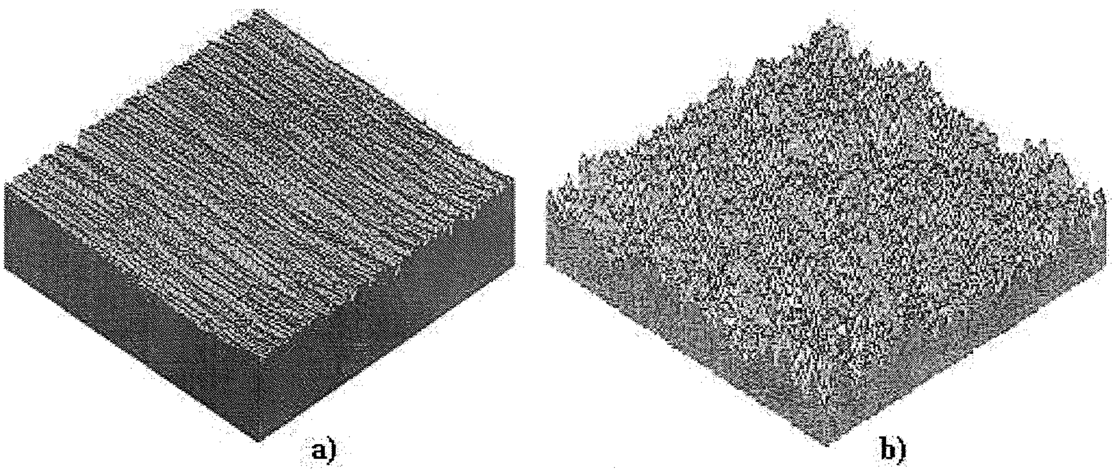

Fig.1. Samples of rough surfaces: a) anisotropic and b) isotropic

Isotropic roughness structure is typical for details which surface is machined by following methods: electro-erosion, sand or pellet blasting, vibro – abrasive, polishing and scraping. But anisotropic surface structure is characteristic for surfaces machined by different abrasive methods, e.g. grinding, superfinish, rolling and broaching, etc [3,4].
Despite the above mentioned classification surfaces with the identical structure can have absolutely different character of surface inequalities. Therefore, in this research the detailed surface irregularities classification were done. Generally by surface roughness mathematical functions these surfaces can be divided into three groups, namely, with regular character,

irregular character and mixed type. The regular type of irregularities characterises by periodical bodies of inequalities which are very similar and in the first approximation can be described by the periodical mathematical function. But the irregular type of inequalities characterises with irregular height and form of roughness. Furthermore, mixed type of profile is forming when regular and irregular character factors are combined, in fact this type is allocated between both above described kinds of irregularities.
According above described classification, the shipboard diesel engines crankshaft journals machining with the mechanical grinding method, can be looked as anisotropic surface with irregular character of surface roughness. This kind of surface can be described by the normal distribution (Gaussian) law. It was determinate, that the optimal microtopographical model of the particular surface is composed by the following parameters: roughness height parameter R_{aT} and two spacing parameters S_{m1} and S_{m2}. It is important to note that the measurement basis for these roughness parameters is a mean plane of overall roughness.

3. Calculation formulas for the three dimension surface roughness model components

During research the topographical parameters of the crankshaft journals surfaces were defined. None of these parameters are currently foreseen in the any of technical standards. Therefore, mathematical calculations of these surface roughness parameters were done, based on real metrological and technological surface parameters of the crankshaft journals.
The formulas of the surface roughness parameters R_{aT}, S_{m1} and S_{m2} were determinate [3]. The microtopographical surface roughness height parameter:

$$R_{aT} = \frac{1}{A} \iint_{\Omega} |h(x, y)| dx dy \tag{1}$$

where: A – area of the viewed surface, mm^2;
$h(x,y)$ – surface roughness (points) deviation from the mean plane, in coordinates x and y.
The mathematical expectation for parameter R_{aT} can be calculated in the following way:

$$E\{R_{aT}\} = \frac{1}{A} \int_0^A E\{|h(x)|\} dx \tag{2}$$

Furthermore, it is possible to adapt equation (2) in more suitable and functional way:

$$E\{R_{aT}\} = \frac{1}{A} \int_0^A \int_0^\infty y f(y) dy dx \tag{3}$$

where: $y = |h(x)|$.

In case of a normal distribution, according the Gaussian law function $f(y)$ divides even:

$$f(y) = \frac{2}{\sigma_T \sqrt{2\pi}} \exp\left\{ -\frac{y^2}{2\sigma_T{}^2} \right\} \tag{4}$$

Topographical spacing parameters S_{m1} and S_{m2}:

$$S_{m1,2} = \frac{2}{n(0)_{1,2}} \tag{5}$$

where: $n(0)_{1,2}$ – number of „zeros" within one length unit, when the profile crosses the mean plane in the two perpendicular directions to each other.

The mathematical expectation for parameters Sm1 and Sm2 can be calculated in the following way:

$$E\{S_{m1;2}\} \approx \frac{2}{E\{n(0)_{1,2}\}} \tag{6}$$

Nevertheless, it is important to note that very often surface roughness measuring equipment or specific measuring conditions (as it is in the case of crankshaft bearings) do not allow reading of the microtopographical parameters R_{aT}, S_{m1} and S_{m2}. Therefore, to obtain microtopographical values of above mentioned parameters the discrete method were applied, by breakdown of observing surface in to the several separate profiles. Thus calculations of the microtopographical values of R_{aT}, S_{m1} and S_{m2} have been done using discrete values recorded in two dimension profile. For this purpose the following formulas were determinate:

$$R_{aT} = \frac{1}{MN} \sum_{j=1}^{N} \sum_{i=1}^{M} R_a(i, j) \tag{7}$$

$$S_{m1} = \frac{1}{MN} \sum_{j=1}^{N} \sum_{i=1}^{M} S_{m1}(i, j) \tag{8}$$

$$S_{m2} = \frac{1}{MN} \sum_{j=1}^{N} \sum_{i=1}^{M} S_{m2}(i, j) \tag{9}$$

where:
- M – number of measurements within single profile;
- N – number of profiles examined;
- i – the examined profile;
- j – the measurement within profile.

Note: measurement S_{m1} and S_{m2} should be done in the perpendicular directions to each other. Naturally, these formulas allow making transition from discrete values of R_{aT}, S_{m1} and S_{m2} measured in profile to the surface roughness microtopographical parameters.

4. Three-dimensional roughness parameters applicable for diesel engine crankshaft bearings

During an experimental part of research a multifactorial analysis of collected data were analysed using computer programme SPSS v. 12.0. Practically the mathematical correlations between technological regimes values (used in the experiment) and obtained surface roughness parameters R_{aT}, S_{m1} and S_{m2} were established. Thus by multifactorial analysis the empirical formulas for surface roughness parameters calculation formulas were determinate. The following formulas correspond to the shipboard diesel engines crankshafts journals grinding:

$$R_{aT} = 0{,}42 \frac{Z^{0,3} t^{0,29} S_{rad}^{0,11}}{V_{det}^{0,01}} \tag{10}$$

$$S_{m1} = 0{,}09 \frac{Z^{0,1} t^{0,3} S^{0,18}}{V_{det}^{0,03}} \tag{11}$$

$$S_{m2} = 8{,}9 \frac{t^{0,22} S^{0,16}}{V_{det}^{0,4} Z} \tag{12}$$

where:
S_{rad} – radial feeding of the grinding stone (mm/move);
t – grinding depth (mm);
Z – grinding stone graininess;
V_{det} – longitudinal feeding speed of detail /device/ (m/min).

The empirical formulas for calculation of the R_{aT}, S_{m1} and S_{m2}, obtained in the research are directly applicable in cases when the grinding of crankshafts journals will be carried out by the elaborated grinding device. Even more when in the practical work it is necessary from technological regimes values to prognoses the microtopographical values of the mean arithmetical deviation of surface R_{aT} and the perpendicular spacing parameters S_{m1} and S_{m2} – surface spacing parameters between the peaks.

5. Conclusions

The research of the three-dimensional roughness parameters model for surfaces of shipboard diesel engines crankshaft bearings allows obtaining the following conclusions:
The model of microtopographical surface roughness is based on mean arithmetical deviation of surface - R_{aT} and two spacing parameters S_{m1} and S_{m2} - surface spacing parameters between the peaks. These two spacing parameters are measured in the perpendicular directions to each other. Moreover, this model fully complies with crankshaft grinding technology and its parameters can be obtained in practical work.
The microtopographical surface roughness parameters necessary to characterise crankshaft journals were developed. The formulas were provided allowing switch from discrete profile surface roughness parameters to the microtopographical parameters R_{aT}, S_{m1} and S_{m2}.
The experimental researches with the technological equipment have been made. Thus determinate the real impact of technological regimes to the microtopographical surface roughness parameters R_{aT}, S_{m1} and S_{m2}. Results achieved during these experiments were analysed multifactorially and this analysis allowed to determinate the empirical formulas for calculation of above mentioned parameters. Obtained formulas exactly reflect to the elaborated equipment for grinding of crankshafts journals. Therefore these formulas will be applicable to the ships' engines repairs, when the impact of the technological regimes needs to be evaluated.

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Torims T., Rudzītis J. Kuģa dzinēju kloķvārpstu virsmas raupjuma pētījumi.

Dota jauna kuģu dīzeļa dzinēju kloķvārpstas gultņu slīpēšanas tehnoloģija. Šī tehnoloģija atļauj uzlabot apstrādes procesu un būtiski samazināt apstrādes procesa laiku kuģu dīzeļu dzinējos.

Taču radītā slīpēšanas tehnoloģija attiecībā uz iegūto virsmas raupjumu, tā parametriem nav pilnīga. Tā prasa zinātnisku analīzi. Ir svarīgi atzīmēt, ka kloķvārpstu gultņu virsmas raupjums ir jāapskata kā trīs dimensiju (3D) lielums. Tāpēc jānosaka reālās virsmas 3D virsmas raupjuma parametri. Izveidots kuģu dīzeļa dzinēju kloķvārpstas gultņu virsmu raupjuma 3D modelis. Iegūtās virsmu raupjuma parametru aprēķinu formulas ļauj pāriet no diskrētiem virsmas profila raupjuma parametriem uz mikrotopogrāfiskiem parametriem: R_{aT}, S_{m1} un S_{m2}. Eksperimentālie pētījumi parādīja, kā iegūtās formulas precīzi apraksta reālo raupjumu.

Torims T., Rudzitis J. Surface roughness investigations for surface of shipboard engines crankshaft.

The new grinding technology for shipboard diesel engines crankshaft bearings has been developed. This novel technology allows improving technological processes performance and considerably saves the repairing time of the ships diesel engines.

However, impact of this novel grinding technology to the surface roughness parameters is not yet clear and requires addition scientific analysis. Furthermore, it is important to note that crankshaft bearing surfaces must be seen as three-dimensional object with definition of microtopographical surface roughness parameters which reflect to real surface. The 3D-model for shipboard diesel engines crankshaft bearings was developed. The formulas were provided allowing switch from discrete profile surface roughness parameters to the microtopographical parameters R_{aT}, S_{m1} and S_{m2}. Obtained formulas exactly reflect to the elaborated equipment for grinding of crankshafts journals.

Торимс Т., Рудзитис Я. Исследование шероховатости поверхности коленчатых валов судовых двигателей.

Представлена новая технология шлифования подшипников коленчатых валов судовых дизельных двигателей. Данная технология позволяет улучшить процесс обработки и существенно уменьшить время обработки подшипников судовых двигателей.

Необходимо отметить, что предлагаемая технология шлифования требует нового отношения к шероховатости обработанных поверхностей. Необходим дополнительный теоретический анализ: шероховатость подшипников коленчатых валов судовых двигателей необходимо рассматривать как трехмерную величину. К ней следует определить параметры шероховатости как трехмерные. Поэтому создана 3х-мерная модель шероховатости подшипников коленчатых валов судовых двигателей, и предложены формулы расчета микротопографических параметров шероховатости: R_{aT}, S_{m1} и S_{m2}. Экспериментальные исследования показали, что полученные формулы точно отражают характер реальной шероховатости.