SURFACE ROUGHNESS OF FORGED CRANKSHAFTS FOR MARINE ENGINES UNDER GRINDING WITH CUBIC-FORM BORON NITRIDE WHEELS

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Abstract: The article is devoted to the problem of provision and control the surface roughness of forged crankshafts for marine engines. A set of monitoring measures is presented to assess the possibility of continuing the effective operation of the machine in a grinding system of the product of complex shape and accuracy, unique in terms of material consumption and labor intensity. The crankshafts have a length of up to 12 m and weigh up to 25 tons. The work was performed with grinding machine type DB12500, equipped with Sinumerik 840D control system, as well as measuring and eccentric processing systems. The grinding tool was a Molemab B126-100639 S.630090 disc type grinding wheel with especially hard abrasive tool material (c-BN). A considerable length of the working part of the grinding wheel around the periphery (over 6 m) is an important prerequisite for ensuring tool durability in the cycle of productive and high-quality external processing of specified functional surfaces of considered large crankshafts. Processing allowances were distributed between the preliminary and final grinding transitions with a slight increase (redundancy to ensure accuracy) for crank-pins, which were processed by the second plan. The microgeometric surface quality was controlled using a Surftest SJ-201P portable surface roughness meter, which avoided the obvious problems of stationary profilometry in the control of large-sized multiple-profile parts. The obtained roughness parameters after grinding (Ra $\leq$ 0.4 μm) were found highly satisfactory, allowing effective polishing afterwards up to the level of Ra 0.3 μm necessary for the main functional surfaces.

Keywords: crankshaft, grinding, wheel, cubic-form boron nitride, roughness, profilometry.

Problem statement

The crankshaft is a crucial element of the marine engine, and special standards prescribe how they must be projected, e.g. the one issued by PRS Executive Board [1]. Nowadays, there are three main technologies for large marine diesel engine crankshaft fabrication, which produce assembled crankshafts, semi-built crankshafts and fully forged ones [2]. The first two technologies have crankshaft parts that joined together with the shrink-fitting method [3].

A critical step in the manufacture of forged crankshafts is the grinding of its sidewalls [4]. The customer sets very high demands on the surface topography with *Ra* < 0.3 μm, which is almost impossible to obtain with the grinding technology. Grinding is one of the final machining processes of the crankshaft fabrication. Main journals and cranks obtain the dimensions close to the upper tolerance, so that the surface can be finished by hand (lapping and polishing procedures).

Therefore, hand polishing is applied after grinding. Typically achievable *Ra* parameters after grinding are between 0.5 and 1.4 μm, while after polishing it lays between 0.1 and 0.3 μm [5]. However, hand polishing has very limited impact on the surface, so the grinding process has to prepare the surface as efficiently as possible. The study below is dedicated to the grinding process of the crankshaft machining.

Methods, object & subject of research

The examined grinding process was performed with a grinder DB12500 type (Fig. 1) equipped with the control system Sinumerik 840D, measurement system Marposs and eccentric machining system Pendulum.

Fig. 1. The DB12500 grinding machine

The grinding tool was the disc-type grinding wheel Molemab B126-100639 S.630090 shown in the Fig. 2. Its diameter was ø2000 mm, and width *B* = 140 mm, and it was covered with the cubic-form boron nitride (c-BN).

Fig. 2. The Molemab B126-100639 S.630090
grinding wheel during the operation

The use of large-diameter grinding wheels with abrasives of the highest hardness (diamond, cubic boron nitride) in various tasks of precise shaping makes it possible to carry out preliminary and final grinding of operationally responsible external surfaces in one processing cycle, due to the increased durability of the tool in the technologically correctly built cycle, for example, when grinding rolls of rolling mills after surfacing with wear-resistant wire material [6]. The maximal cutting velocity and rotational speed were $V_{max} = 50$ m/s and $n_{max} =$ 473 rpm, respectively.

Like in any machining technology, the final surface quality was dependent on the geometry and performance of the “machine – tool – workpiece” system. For any type of fabricated crankshaft, the grinding operations sequence has been assumed to be the same, namely, the main journals were to be grinded first (main axis of the crankshaft), so the final dimensions were achieved, and then the crank-pins were grinded.

In general, the grinding process can be described as follows:

• The grinding allowances of the diameter were ca. 1 mm, maximally up to 1.5 mm. It was more desirable to leave larger allowances on the crank-pins, in order to avoid the increased uncertainty when the angle of the reference crank-pin was measured.

• After initial grinding of all the main journals, the fine grinding was initiated.

• The allowance for the fine grinding was ca. 0.3-0.4 mm on diameter.

• Supporting tailstocks are always put down under the grinded main journal. After grinding, the journal is again supported, and the position of the crankshaft is corrected on the base of flexometer indications.

• High pressure washing of the grinding disc after each operation is performed in order to prolong durability of the tool.

The object of the research is marine engine forged crankshaft grinding system and technology on the base of machine model DB12500 using the tool model Molemab B126-100639 S.630090 from superhard abrasive based on cubic boron nitride.

The subject of the research is the surface roughness on the main journals and cranks of forged crankshafts 18W46 type after grinding.

Methodological issues of measurement geometric accuracy parameters – such as level, linearity, parallelism, runout and coaxiality – of the respective mechanical parts of the grinder DB12500 equipped with the control system Sinumerik 840D and measurement system Marposs are discussed and illustrated in more detail in our work [7]. The results of systematic control for estimate level declinations, linearity and parallelism deviations, some others accuracy parameters such as grinding disc perpendicularity, headstocks and disc cone runout and coaxiality, vertical position of the disc and headstock axes are also presented in [7].

On-machine and in-process surface metrology is important for quality control in manufacturing of precision surfaces [8].

According to the documentation, the main journals must have a very smooth surface with *Ra* < 0.3 μm, so the grinding prepares the surface leaving only little deformation that can easily be removed during polishing.

After grinding, the *Ra* parameter was measured with the portable surface roughness tester Surftest SJ-201P. It was chosen because of the obvious difficulty with applying the stationary profilometer to a huge detail such as the crankshaft 18W46 type.

The most important parameters of SJ-201P device are as follows:

• Measuring range 350 μm (from -200 to +150 μm).
• Diamond stylus tip of radius 5 μm.
• Sampling length 0.25 mm, 0.8 mm, 2.5 mm.
• Displaying range from 0.01 μm to 100 μm.
• Resolution is dependent on the measuring range, with the highest being 0.01 μm/10 μm.
• Data output via RS-232 interface unit.

As such, this device was considered sufficient to inspect the roughness of the crankshaft surface both after grinding and later, after hand polishing.

Roughness after grinding

Typical factory control examples of the distribution of roughness measurement results for the main journals CG (10 journals, measurements at 4 points on each) and the crank pivots CK (9 pivots, measurements at 4 points on each) after grinding are shown in the Fig. 3. The results are highly satisfactory, so that the final roughness below *Ra* = 0.3 μm is easily achievable through hand polishing.

Conclusions

Under the aforementioned conditions for the systematic control of the accuracy parameters of the grinding system on the base of machine model DB12500 using the tool model Molemab B126-100639 S.630090, the roughness obtained after grinding was fond to be highly satisfactory.

The presented work can be considered as methodological prototype of monitoring in road maps to check the state of the accuracy parameters of grinding machines and the level of microgeometric quality after processing the crankshafts. The development of a roadmap for control the machine accuracy and the level of microgeometric quality of grinding processing expands the possibilities of flexibility and reliability, increases the stability and efficiency of production.

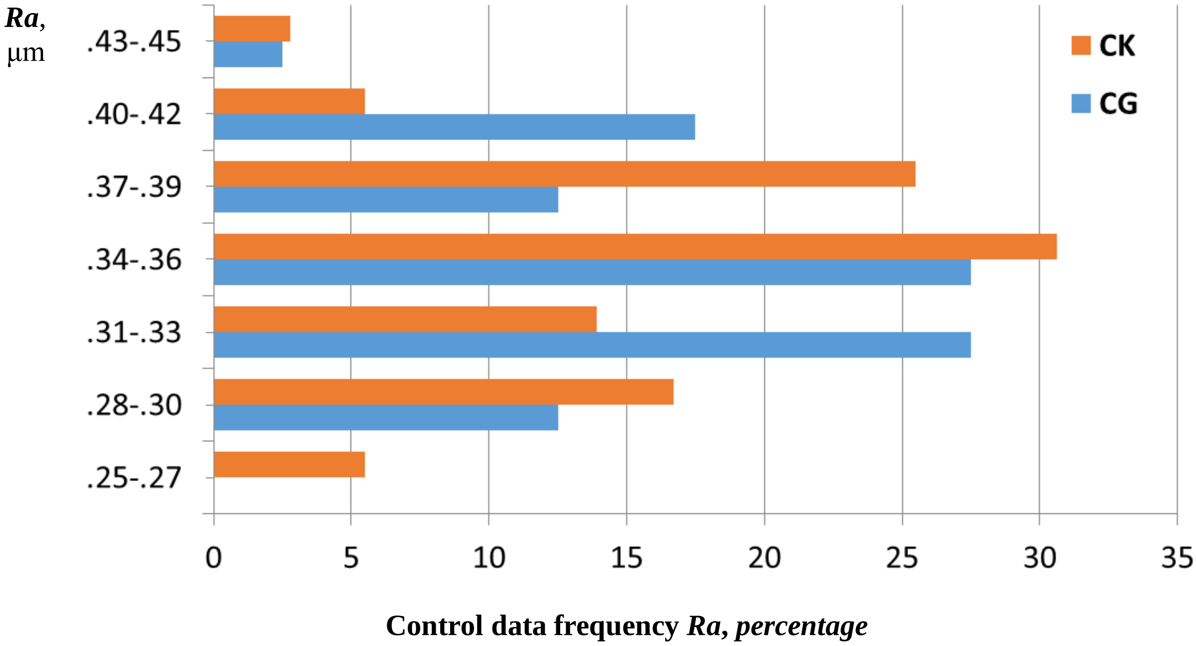

Fig. 3. The distribution of roughness measurement results
for the main journals (CG) and the crank pivots (CK)

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