

# A new concept of a device for crankweb of crankshafts deformation measurements by the symmetrical method

Nowa koncepcja przyrządu do pomiaru odkształceń ramion wykorbień wałów korbowych metodą symetryczną

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**The patent pending design of the crank shaft deformation measuring device by means of the symmetric method, was presented. The new solution eliminates imperfections and inaccuracies resulting from the method currently used for this purpose, and enables correct assessment of the crankshaft positioning in main bearings.**

**KEYWORDS: measurements, deflection, crankshafts, marine engines**

Elimination of elastic deflections of large machine elements, especially flaccid ones with relatively small proportions of transverse dimensions to length, such as crankshafts of ship engines, requires their multi-point support. Maintaining, within the permissible deviations, the mutual concentricity of main bearings, being the place of shaft support, determines proper functioning of the crank and piston system, and as a result - the entire ship engine. A characteristic feature of slender large crankshafts is variable rigidity and resulting elastic deformations depending additionally on the support conditions [1-3]. This significantly impedes the measurements of crankshafts and their interpretation, because results of measurements are disturbed by elastic deformations of the measured object. In relation to large crankshafts, however, this property is commonly used as a criterion for the assessment of the geometrical condition at the stage of their manufacture, as well as for assessing the bearing condition of shafts in the body made periodically during engine operation [4, 5].

## Deflection as a criterion for assessing the bearing condition of crankshafts

The most common way to measure deflections of the shaft is to measure the springing of crank arms [4-8]. The spring measurements are carried out using a displacement sensor mounted between the individual crankshaft crank. The displacement sensor in the holder is embedded with the help of the tines in drillings, previously made for this purpose by the crankshaft manufacturers, on the inner faces of the crank arms. As

a measure of springing determined in the vertical and horizontal planes, the difference of the sensor readings is taken in two mutually opposite positions of the crankshaft during rotation (fig. 1).

According to the basic assumption of this type of measurement (resulting from the method and conditions of its implementation), deformations of crank shoulders are symmetrical with respect to the crank symmetry axis. It is also assumed that the deflections of the shaft are the result of mutual displacement of the crank main axes and, in case of exceeding the allowable spring value, it is recommended to raise or lower the axis of the main bearings adjacent to a given crank by half the calculated springing value.

However, this assumption is rarely reflected in reality and leads to misinterpretation of measurement results. It is not taken into account that the cause of deformations may be the deteriorating condition of only one bearing adjacent to a given crank. It is also difficult to interpret the influence of the mutual impact of deformations deformed to varying degrees on the value of springing. The measured quantity is actually the local change in the distance between the crank shoulders, not the size of the crank arms deformation.

Currently used measuring instruments, due to a number of imperfections, have limited possibilities to detect crank deformations. There are such crank deformations, in which traditional measurements will not show deflections [9]. In particular, this applies to unusual situations, e.g. when axes of main plugs adjacent to a given crank are moved parallel to each other or in the case of symmetrical or asymmetrical cross-over of their axes.

These observations were confirmed in simulation studies of deformations of the modeled crankshaft after the introduction of possible inaccuracies in the location of its main plugs [9, 10]. This analysis has also shown that due to the varying rigidity and uneven distribution of centers of gravity of the masses in subsequent cross-sections, not only the flexural strains of the shaft, but also the twisting of the crank arms occur. These results show, therefore, that the crank arms measured in a given angular position cannot be considered a size situated in a vertical or horizontal plane, but it should be considered a spatial position.

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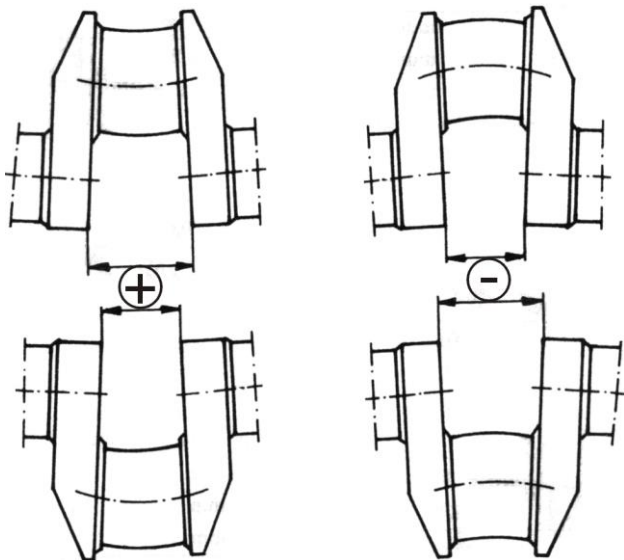


Fig. 1. Examples of different states of a crank shaft deflection

### Construction of a device for measuring the deformation of crankshaft crank shoulders

Assuming that the basis for assessing the performance and arrangement of the shaft in the main bearings will be measurements of its deformation, a specially developed measuring instrument was used, which is an improved version of the traditional spring measuring device. This device (description in patent application [11]) allows individual assessment of deformation of crank arms.

The measuring base consists of fangs, through which the device is embedded in drillings made by shaft manufacturers on the inside faces of crank arms. The deformation assessment takes place in the direction perpendicular to this base. This is ensured by the caps that terminate the mandrels, in which the measuring instrument is provided. The sockets are slidably mounted on the mandrels and pressed with constant force to the inner faces of the crank shoulders. The measure of deformations, recorded continuously, are the changes in circumferential pressures occurring on the faces of the lining of the caps. The measurement takes place in a symmetrical system, in conditions corresponding to the traditional method. The cap linings are made of a material susceptible to deflection and terminated with a sensitive membrane to measure surface pressure. The displacement sensor - similarly to the traditional method - allows for a total measurement of deformation of crank arms. The analysis of the scanned image of surface pressures allows (in accordance with the assumptions of the measuring device concept) an individual assessment of the non-rectangularity of the internal faces of the crank arms with the crank symmetry axis and the appropriate delimitation of the measured springing value.

The device, according to the concept [11] (fig. 2a) has a body 1, to which the displacement sensor housing 2 is mounted. It was initially assumed that it will be a clock displacement sensor with axial movement of the stylus (the use of a small-sized inductive displacement sensor with axial displacement of the stylus cooperating with wire or wirelessly with a digital indicator is predicted).

The body 1 is provided with a plunger 3. The measuring rod of the sensor and the plunger 3, which are

mutually coaxial with each other, are provided with ends 4 with ball centers. The plunger 3 has a screw mechanism 7 for adjusting its length. This mechanism makes it possible to obtain the sensor's initial voltage, and at the same time, guarantees a secure fit and fixation of the measuring device with ball centers in the drillings made by crankshafts on the inside faces of the crank shoulders (fig. 2b).

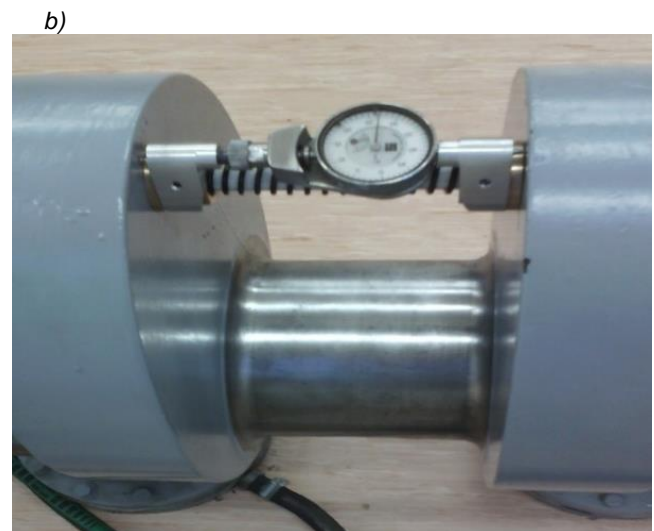
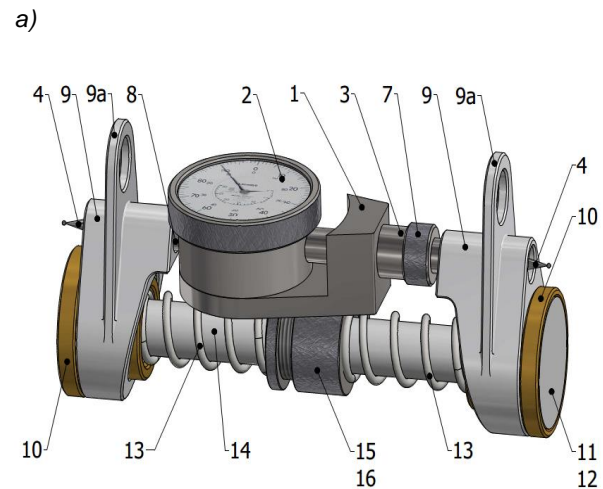
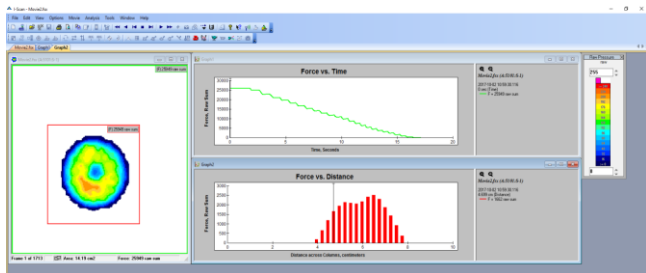


Fig. 2. New design of the device for measuring the crank shoulders deformation by the symmetrical method (a); measuring device mounted between crankshaft cranks (b)

On the outer cylindrical surface of the plunger 3 and the gripping portion 8 of the displacement sensor 2, sliding sockets 9 with pressure pads are slidably mounted. The grips 9a of the pressure sockets 9 facilitate the assembly and positioning of the measuring instrument between the crank arms. The front surfaces of the pressure pads 10, provided with cladding 11 made of a material susceptible to deflection, while not being permanently deformed, are finished with a sensitive membrane 12 designed to measure surface pressures. The springs 13 mounted on the guide 14 provide constant pressure on the faces of the cladding 11 and membranes 12 for measuring the surface pressure to the inner faces of the crank arms. The screw mechanism 15, 16 makes it possible to adjust the preload of the springs 13 and the pressure of the sockets 9. The pressure of the spherical retaining hubs 4 for drilling on the inner

faces of the crank arms and the pressure of the cladding 11 ended with a sensitive membrane for measuring the surface pressure 12 for the inner faces of the crank shoulders, is implemented independently.

a)



b)

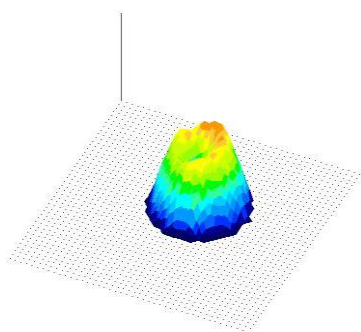


Fig. 3. Example of surface pressure scan for the selected crank angle position (a); 3D view of the surface pressure distribution (b)

Results of the peripheral measurements of surface pressures (depending on the state of elastic deformations of the cladding 11) at the interface of the membranes 12 with the inner faces of the crank shoulders are depicted on the computer monitor in the form of a map (scan) of surface pressure (fig. 3). Transmission of measurement data to the computer's memory takes place wirelessly.

Measurements are made during rotation of the shaft, which makes it possible to observe changes in surface pressures in a dynamic manner. Fig. 4 presents an exemplary distribution of surface pressures at the membrane joints with the inner faces of the arms of the selected crank for four consecutive angular positions of the shaft, with the change of its location at  $90^\circ$ .

The measurement method is similar to traditional measurements, but the data is recorded continuously in the range of the rotation angle of the shaft, at which measurement is possible:

- in the case of the disassembled crank and piston system - in the full  $360^\circ$  angle,
- in the case of mounted crank-piston system - in the range of the angle corresponding to two extreme positions of the measuring device close to the connecting rod shaft.

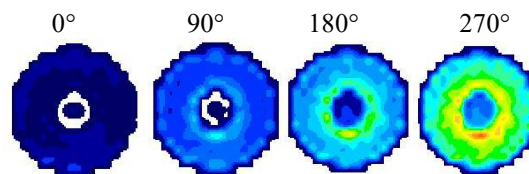
Based on the analysis of results using computer data processing techniques, it is possible to determine the mutual positioning of the axes of individual main plugs adjacent to a given crank. For the proposed measurement concept, a procedure for interpreting the results was also developed, according to which, by creating a chain of related cranks, we can determine the deflection line of the shaft, and then adjust the bearing

based on these measurements to eliminate its deformation.

## Conclusions

The tests carried out on the real object have shown that the combination of the proposed measurement system with the traditional measurement enables correct assessment of the bearing condition of the crankshafts.

a)



b)

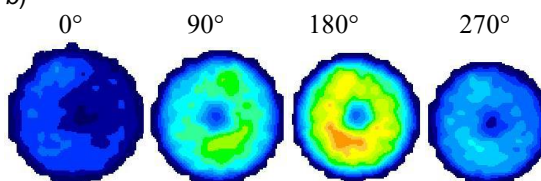


Fig. 4. Distribution of surface pressure when changing the angular position of the shaft at  $90^\circ$ : a) left side of the crank, b) right side of the crank

The displacement sensor measures the total value of crank arms deformation, while the system of measuring the peripheral surface pressings cooperating with it enables (in accordance with the principle of proportional deflection to the applied load) an individual, quantitative delimitation of the measured spring value, proportionally to neighboring crank arms. The presented instrument concept and measurement procedure can be used to assess the geometrical condition of large crankshafts at the stage of their execution, as well as to periodically assess the condition of crankshaft bearings during engine operation.

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