A MODERNISED METHOD OF MEASURING CRANKSHAFT STRAIN CAUSED BY BEARING ERRORS

KRZYSZTOF NOZDRZYKOWSKI, BOLESŁAW KUŹNIEWSKI
Institute of Basic Technical Sciences
Szczecin Maritine University, ul. Podgórna 51/53, PL – 70-205 Szczecin, Poland,
tel. (0-48-91) 433 45 21, fax (0-48-91) 434 10 98, e-mail: inpt@wsm.szczecin.pl

ABSTRACT

The article presents a new method of measuring crankshaft strain caused by bearing errors. These measurements are applied to evaluate the placing of the crankshaft in the engine's body and to make a possible correction of the bearing setting. It has been described how the measurements were performed, and the results have been analysed and interpreted.

Key words: crankshafts, strain, measurements

1. INTRODUCTION

While the engine is working the crankshafts are subjected to the pressure force of gases and the force of inertia from the mass of elements of the shaft-piston system, which are in rotary and to-and-fro motion. Besides bending, torsional and shearing stresses particularly dangerous torsional vibrations are caused by the periodical actions of those forces [1].

The above-mentioned kinds of stresses can be additionally caused by geometrical errors by the crankshaft itself (caused by processing or wear-and-tear use), bearing errors or improper coupling of the shaft with cooperating units, leading eventually to serious mechanical damage of the engine. In a situation like this, it is necessary to control the geometrical accuracy of the crankshaft at the stage of its production and to control the bearing correctness of the shaft in the course of its assembling and operation.

The direct measurement of the crankshaft strain is very inconvenient, which is why it is direct measurement methods that are applied [1,2,3].

The most common method of crankshaft bearing state evaluation is the measurement of the crankweb in the position of its particular angle positions during rotation. This kind of measurement is called 'springing' measurement and is brought about by means of a clock sensor installed among particular shaft strains. As a springing measure defined as a rule in vertical and horizontal planes it is usually accepted: the difference of sensor indications in two opposite positions of the strain during the shaft's rotation, which is is the difference between dimensions (Fig.1) [1,3]:

$$\Delta = An_1 - An_2 \qquad (1)$$

where:

An_1, An_2 – dimensions of the strained crank in its two extreme opposite positions measured on a particular plane.

For the vertical plane the opposite extreme position of the crank, it has been assumed to mark it as HMP (High Maximum Position) and LMP (Lower Maximum Position); respectively SS (Starboard Side) and PS (Port Side) are applied as the markings for the horizontal level.

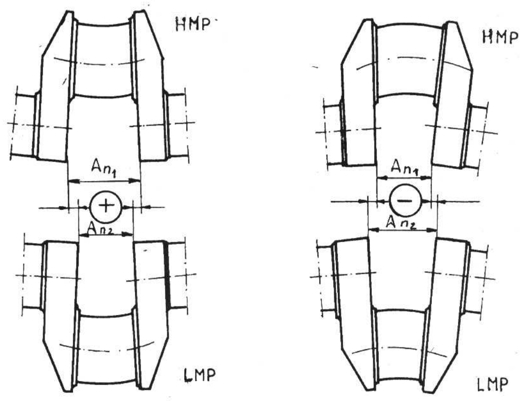

Fig.1. Instances of various states of shaft cranks

The basic assumption in the method currently applied is the fact that the deformations of particular crankwebs are symmetrical in relation to the symmetry axis of the cranks (Fig.3a). This assumption is rarely reflected in reality. The very measuring principle is burdened with errors resulting from the changeability of the measuring basis while the crankshaft rotates. This causes the measurement results to be misinterpreted, leading consequently to erroneous corrections in the bearing system of the crankshaft.

2. MEASURING THE STRAIN CRANK BY THE SYMMETRICAL METHOD

Considering the previously mentioned observations of the Institute of Basics and Construction of Machine Operation at the Maritime University of Szczecin, a method of crankshaft strain measurement has been worked out by the so-called symmetrical method.

The measurement according to the method suggested can be carried out by means of one or two displacement sensors installed at the outrigger of an appliance mounted at the appliance attached to a crank-pin at the half of its length. Fig.2 presents a diagram of a measuring system situated at a part of a single shaft crank, which is composed of: the measurement sensor 1, the outrigger guide 2, V-block 3, elastic clamping ring 4, clamp 5, and the crank-pin 6, with a neighbouring crank 6.

Installing the device on the crank-pin is made possible (after previous dismantling of the connecting-rod big end and shank suspension) by a V-block connected to an elastic band, blocked by clamp 5. Outrigger 2 is fastened to the V-block of 120° angle of flare, the former constituting a guide for regulating the sensor position. Before measurement an adjustment of sensor position is carried out along the outrigger guide, in such a way that the cone-shaped ends of the sensors should be situated in the drill spots (or other marks made by the producer) defining the place of carrying out the measurement of ‘springing’.

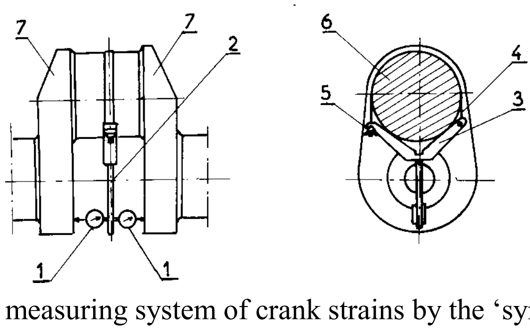

Fig.2. A diagram of the measuring system of crank strains by the ‘symmetric’ method on the example of a single crank.

Changes in sensor indications while the crankshaft rotates depict the crankweb strains of particular cranks in relation to their symmetry axis produced by the measuring device. Considering the insignificant strains of main pins and crank-pins during the rotation of the shaft, the measuring device mounted on the crank-pin constitutes an unalterable measuring basis for the position alterations of measurement endings of displacement sensors, dictated by the deviations of cranks neighbouring with them. Measurement by this method is performed in the full range of rotation of the crankshaft, which makes it possible to determine strain values of the shaft crankwebs in any of its angle positions, as also the extreme strains along with their mutual angle position. In case of applying one displacement sensor for the measurement the checking process has to be repeated in relation to both crankwebs of respective cranks, which necessitates turning the sensor handle in relation to the outrigger guide by 180°.

3. INTERPRETATION OF MEASUREMENT RESULTS

The measurement method presented makes possible a direct reading of the difference in the crankweb deviations from the constant measurement basis in various angle positions of the shaft (Fig.3b) [4].

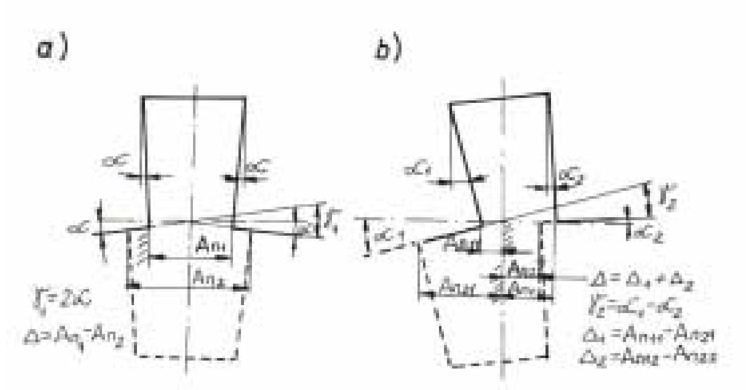

Fig.3. Interpretation of measurement results of single shaft crank strain performed by the traditional and the symmetric methods for the same result value Δ.

Assuming, in accordance with recommendations, that 'springing' should be defined at least in the vertical and horizontal plane, in a definite angle position of the crank (e.g. LMP) there should be performed a zeroing of the sensor, and next, in positions HMP, SS, and PS its indication should be read. The indication of the sensor with its pointer swinging to the left in relation to the opposite initial position means a positive 'springing' value (the distance between the crankweb and the measuring base is larger than the same distance in LMP). Thus, the 'springing' value should be written down with the '+' sign. If the sensor pointer swings to the right in relation to the initial position, it means that the distance between the crankweb and the measurement base is smaller than the same distance measured in LMP and the 'springing' value should be written down with a '-' sign. This is depicted by Table 1 and the shaft crank strain graph in the vertical plane, made on its basis (Fig. 4).

Table 1. Exemplary measurement results of crank strain by the 'symmetric' method

Sensor indication*** / Crank position	Crank number													
	1		2		3		4		5		6		7	
	L*	P**	L*	P**	L*	P**	L*	P**	L*	P**	L*	P**	L*	P**
High maximum position (HMP)	+12	+10	+2	+4	+14	+8	-17	+2	-12	-10	-10	+6	+7	+12
Low maximum position (LMP)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Springing value in vertical plane HMP-LMP	+12	+10	+2	+4	+14	+8	-17	+2	-12	-10	-10	+6	+7	+12
Starboard side (SS)	+14	+3	+3	-1	-1	-2	-2	-10	-10	-8	-8	-3	+3	+2
Port side (PS)	+2	-2	-2	+3	+3	-7	-7	+5	+5	+2	+2	+2	-1	-2
Springing value in horizontal position SS-PS	+12	+5	+5	-4	-4	-9	-9	-15	-15	-10	-10	-5	+4	+4

* L – left crank side
** P – right crank side
*** Sensor indications in the table are given in hundredths of millimetres.

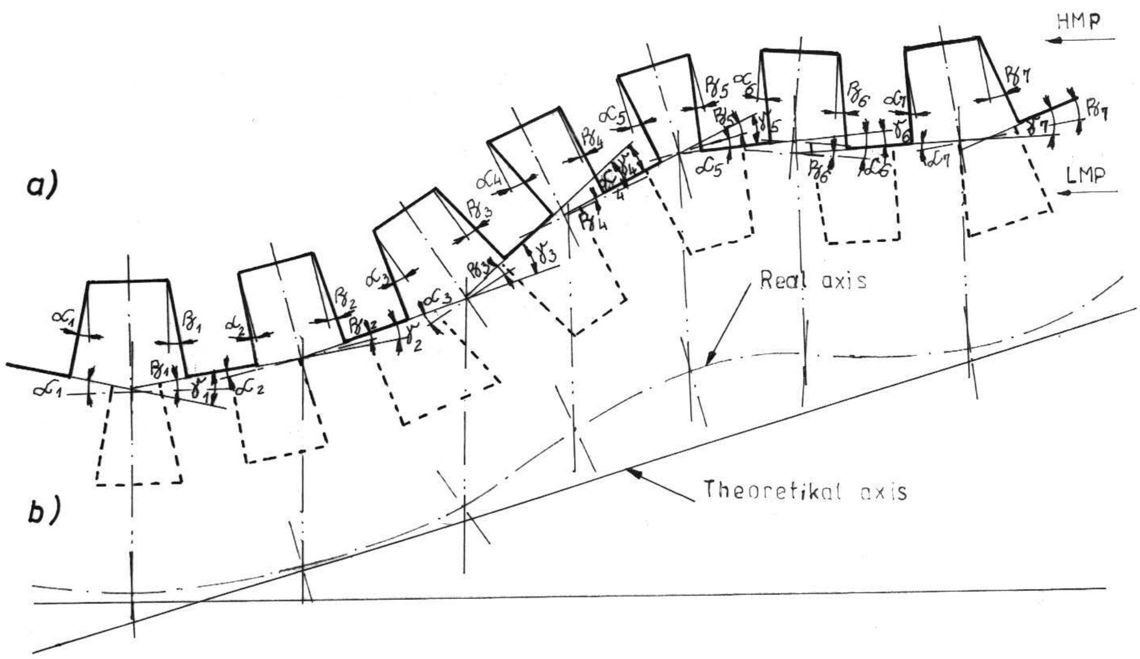

Fig.4. Geometric interpretation of measurement results of crank strain by the 'symmetric' method

The positive or negative 'springing' value for the horizontal plane is determined, of course, by the indication difference of the displacement sensor in positions SS and PS. When producing a shaft strain graph on the basis of the suggested measurement method, the 'springing' values and sign explicitly determine the position of the axis of the main crankpins neighbouring with a given crank. The designated springing values (Fig.4a) should thus be referred to the particular symmetric cranks (the thin pecked lines in Fig.4) with consideration of the mutual positions of the main pin axis. This will eventually determine the bending line of the crankshaft (Fig.4b) and make a correction of the main bearing positioning, in order to eliminate its strain. For the considered example of measurement analysis of crankshaft springing, bearings 4, 5 and 6 are definitely situated too high and in order to correct the placement of the shaft they should be lowered (by replacing the lower half-sleeves of bearing with thinner ones, or by their individual fitting). The necessity to correct the placement of the crankshaft results, of course, from exceeding the admissible values given in the Technological Motion Documentation of the engine, where these values are usually given in forms of graphs or nomograms [1,3].

4. CONCLUSIONS

The method presented makes possible more accurate measurements of crankshaft strain caused by bearing errors and a correct estimation of the crankshaft placement in the full range of its rotation. On the basis of mesurements made the mutual position of particular main pin axes and the bending line of the shaft can be determined, and a correction of main bearing positioning can be made, in order to eliminate shaft strain.

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