DEVELOPMENT OF THE METHODS FOR ELIMINATION OF DEFORMATION OF CRANKSHAFTS IN WIDE-LAYER HARDFACING

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Methods were developed for elimination of deformation of crankshafts of car engines caused by wide-layer hardfacing at their reconditioning. It is established that an effective method to eliminate deformations is preheating of hardfaced bearings and (or) application of axial tensile load to the crankshaft during hardfacing.

Keywords: *arc wide-layer hardfacing, crankshafts, deformation, measures of elimination*

Different methods of arc hardfacing are widely used for reconditioning of worn crankshafts of the car engines. According to the practice, wide-layer hardfacing with self-shielding flux-cored wire [1] is the most perspective among them. It differs by high efficiency, stable quality of obtained results and provides operating live time of reconditioned crankshaft on a level of new one. Along with it, significant heating [2] of working surfaces (main and crank bearings) takes place during wide-layer hardfacing, that results in deformation occurrence, i.e. change of initial length of the crankshaft. Most of crankshaft types are characterized by basic length l_0, which according to design documentation can be changed only in the narrow ranges (±0.3 mm). Therefore, if linear deformation Δl exceeds specified limits as a result of hardfacing, this promotes appearance of increased end-play and creates problems during setting of reconditioned crankshaft in the engine.

Present study is devoted to development of the methods for elimination of linear deformation (shortening) of the crankshafts by wide-layer hardfacing.

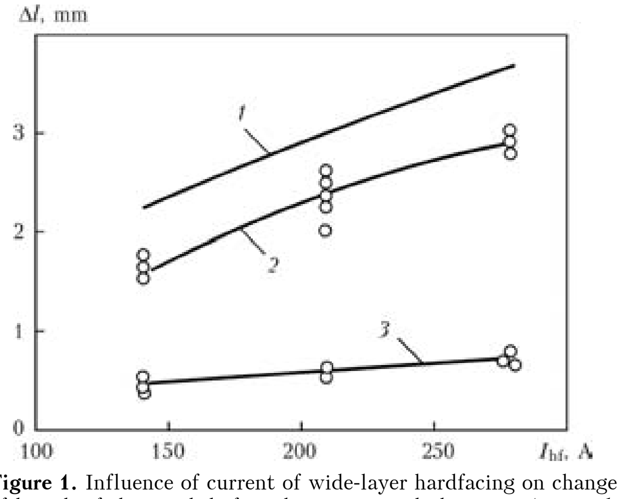

Figure 1. Influence of current of wide-layer hardfacing on change of length of the crankshaft and its structural elements: *1* — $\Sigma\Delta l$; *2* — Δl_c; *3* — Δl_m

Five-bearing crankshaft representing itself crank consisting of five main and four crank bearings was selected as an object for investigation. Such a structure of the crankshaft is widely used in many engines of present cars of domestic and foreign manufacture and differs only by geometry and chemical composition of the base metal (medium alloyed carbon steel or high-strength pearlite cast iron). Corresponding cylinder specimen-imitators were manufactured for determining shortening of separate structural elements of the crankshaft (main and crank bearings). Error of measurement of all linear dimensions made ±0.05 mm.

Figure 1 shows an influence of wide-layer hardfacing mode on total length of main Δl_m and crank Δl_c groups of bearings as well as on general length of the crankshaft $\Sigma\Delta l$ ($\Sigma\Delta l = \Delta l_m + \Delta l_c$) after hardfacing and cooling of the crankshaft to room temperature. As can be seen from the Figure, increase of current of hardfacing I_{hf} rises difference of lengths Δl before and after hardfacing of all structural elements and crankshaft in whole, and allowable limits, specified for basic length l_0 are significantly exceeded at maximum efficiency of hardfacing process. Besides, shortening of the main bearings Δl_m after hardfacing has insignificant dependence on I_{hf}. At the same time Δl_c is significantly higher than Δl_m and rises proportionally to increase of I_{hf} at similar currents of hardfacing. At that, input of Δl_c in $\Sigma\Delta l$ makes 73–80 %. Different influence of I_{hf} on Δl_m and Δl_c is related with the fact that the crank bearings are manufactured hollow in contrast to main bearings thereby temperature of their heating is significantly higher in the process of hardfacing. As a result, favorable conditions for more complete passing of shrinkage are developed in solidified weld pool and base metal of the crank bearing.

Application of repair rings. Setting of the repair rings (Figure 2) (before hardfacing) is one of the most simple and allowable methods of elimination of crankshaft shortening caused by hardfacing. At that thickness of each ring should be 0.5–1.0 mm higher of $\Sigma\Delta l$, determined from Figure 1. Finally, basic length of the crankshaft is regulated by mechanical treatment after hardfacing. The main disadvantage of specified method is that compensation of total shortening of the crankshaft is performed only with regard to first main bearing. Thus, axial displacement of the holes of oil channels for all groups of bearings relatively to fixed supply of lubrication in the engine oil system takes place. This, depending on $\Sigma\Delta l$ value, can result in partial or full overlapping of section of the hole of oil channel and breakdown of lubricant supply to wear surfaces. Practice shows that specified method can be successfully used in wide-layer hardfacing of the crankshafts of relatively small dimensions (for example, crankshafts of car engines of VAZ family, «Tavriya» etc.) where $\Sigma\Delta l$, as a rule, does not exceed 1.5 mm.

Application of preheating. Formation of relatively narrow weld pool over the whole length of hardfaced bearing virtually simultaneously with beginning of the hardfacing process is one the characteristic peculiarities of wide-layer hardfacing. Further, hardfacing rate (speed of rotation of hardfaced bearing) determines movement of a weld pool front and its solidification. As a result, whole surface of the bearing after hardfacing becomes covered by layer of deposited metal, the width of which equal to bearing length. Elongation Δl_t of the specimen at heating is determined by dependence $\Delta l_t = k l_i \alpha_{av} \Delta T$ (here, k — factor of proportionality; l_i — initial length of the specimen; α_{av} — average value of coefficient of linear expansion of specimen metal in considered temperature range; ΔT — difference between heating temperature and initial temperature of the specimen) according to general theory of deformation. Following it, if a bearing of the crankshaft of l_i length is preheated (before hardfacing) up to specific determined temperature $T_{preheat}$ than wide-layer hardfacing will already be performed on a bearing of $l_i + \Delta l_t$ length, where Δl_t is the increment of bearing length caused by heating. At that, length of the weld pool is also increased per Δl_t due to peculiarities of wide-layer hardfacing. As a result, it can be assumed that Δl_t value compensates shortening of Δl_c bearing at properly selected $T_{preheat}$ since wider solidified layer of the deposited metal prevents more complete passing of the shrinkage processes in the base metal during bearing cooling.

Wide-layer hardfacing of the specimen-imitators of corresponding bearings was carried out on optimum mode (I_{hf} = 250 A) at different preheating temperatures for studying the influence of $T_{preheat}$ on linear dimensions of the main and crank bearings. Obtained results (average value on two-three specimens) are given in the Table. It can be seen from data provided that an increase of $T_{preheat}$ promotes monotone decrease of residual linear deformation of the crank as well as main bearing and the latter becomes approximately equal zero at $T_{preheat} \approx 300$ °C. Higher temperatures of preheating result in that the basic length of hard-

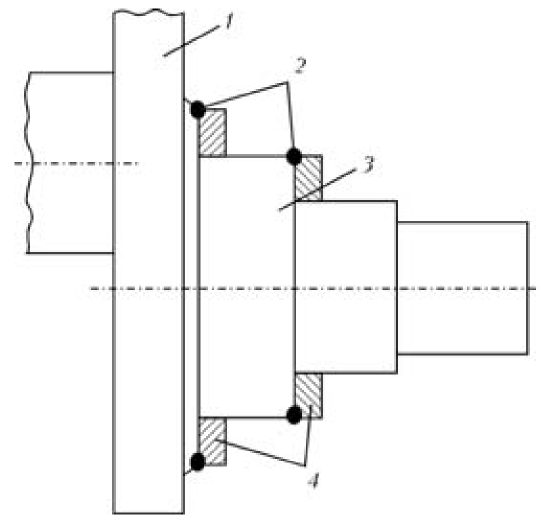

Figure 2. Scheme for setting of repair rings on the first main bearing for eliminating shortening of hardfaced crankshaft: *1* — bearing; *2* — tacks; *3* — first main bearing; *4* — repair rings

faced crankshaft will be more than in the initial one (before hardfacing).

It should be noted that in spite of the fact that introduction of additional operation of preheating in the technological process of hardfacing makes it more energy- and labor-consuming, such an operation is useful for some dimension-types of crankshafts and being necessary measure, reducing formation of cracks in the deposited and base metals for cast iron crankshafts. Moreover, it should be considered that application of preheating increases the danger of draining of liquid weld pool from cylinder surface in the process of wide-layer hardfacing. Therefore, usage of specified method for elimination of deformations is possible only in those cases when diameter of bearings of the crankshaft exceeds 50 mm.

Application of tensile loads in the process of hardfacing. It is well-known fact that medium-carbon steels differ by sufficiently high deformation ability ($\delta > 10$ %) at normal temperature. If pearlite high-strength cast iron (for example, VCh 50-2) is a material of the crankshaft than it will be low-plastic ($\delta \approx 2$ %) at normal temperature. However, its elongation can achieve 12 % with temperature increase and tensile and yield strengths reduce per order. Deformation of heated samples from high-strength cast iron occurs at relatively small (6–7 MPa) tensile loads [3] under welding process conditions. Base metal of bearings of the crankshaft depending on their dimensions, hard-

Influence of temperature of preheating on change of dimensions of the main and crank bearings

Parameter	$T_{preheat}$, °C					
	20	100	200	300	400	500
Δl_c	−2.88	−2.42	−1.92	−0.54	0.25	1.04
Δl_m	−0.68	−0.44	−0.35	0.42	0.76	0.82

Note. Negative value — shortening, positive — elongation of the bearing as compared to initial dimensions.

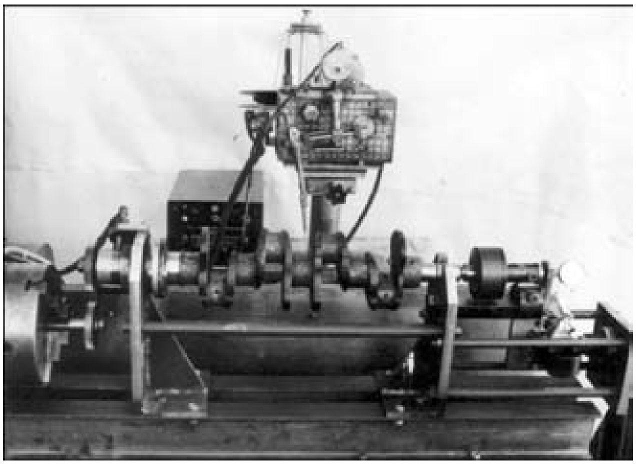

Figure 3. Appearance of device for applying and regulating of axial tensile load to crankshaft in the process of hardfacing

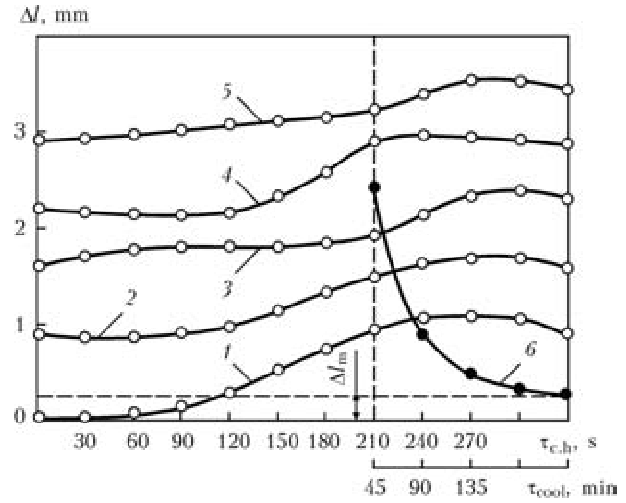

Figure 4. Dynamic curves of change of length of the crankshaft in the process of wide-layer hardfacing of main bearings (*1*–*5*) and in the process of its cooling (*6*) under effect of axial tensile load

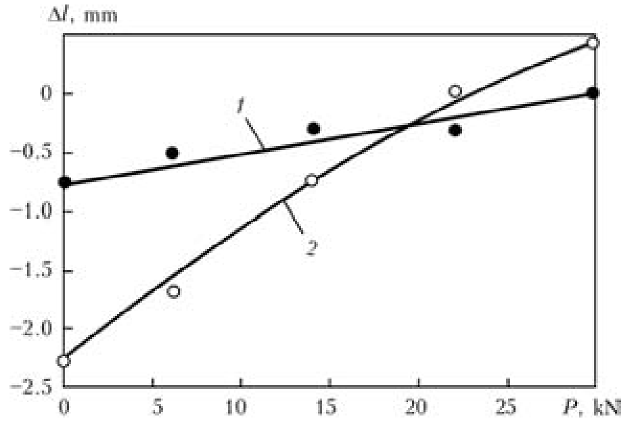

Figure 5. Effect of axial tensile load on change of length of main Δl_m (*1*) and crank Δl_c (*2*) bearings of the crankshaft in wide-layer hardfacing

facing mode and location of heating source can heat up to 800–1150 °C due to thermal cycle of wide-layer hardfacing.

Investigations of influence of axial tensile loads on length of the crankshaft under conditions of real thermodeformation cycle of wide-layer hardfacing were carried out based on that. The investigations were performed using specially manufactured device (Figure 3) allowing carrying out wide-layer hardfacing of the crankshaft at simultaneous application of tensile load to it. The device consists of metal body with fastened to it clamping mechanisms (left and right), providing fixing of the crankshaft in necessary position as well as its rotation and possibility of axial elongation under tensile load effect. The latter is applied to the crankshaft with the help of screw-jack through measuring resilient member, i.e. shrinkage dynamometer DOSM 3-3 and leverage system. The device body is fixed on a base of universal hardfacing machine UD-209. Rotation of the crankshaft with regulated speed is performed from spindle of UD-209 machine through gear drive. The devise allows regulating tensile load in the ranges from 0 to 30 kN.

Wide-layer hardfacing was performed on optimum mode (I_{hf} = 220–250 A) for considered type of the crankshaft. Figure 4 shows dynamic curves of change of crankshaft length in the process of hardfacing of the main bearings ($\Delta l - \tau_{c.h}$) and in the process of its cooling ($\Delta l - \tau_{cool}$) under effect of constant tensile load P = 30 kN. A time of cycle of hardening $\tau_{c.h}$ includes time used for bearing hardfacing (300 s) and time for setting of hardfacing machine for hardfacing of the next bearing.

A conclusion can be done according to obtained data that the length of crankshaft increases as a result of thermal elongation as well as plastic deformation caused by effect of tensile load in the process of bearing hardfacing. Then, the length of shaft reduces due to passing of shrinkage process in the base and deposited metals during cooling. At room temperature Δl achieves a constant value equal Δl_m characterizing actual elongation ($\Delta l_m > 0$) of the crankshaft, occurring under effect of axial tensile load.

It is seen from Figure 5 that Δl changes in sign as well as value depending on axial load. Moreover, shortening of the crankshaft as a result of hardfacing of crank Δl_c and main Δl_m bearings is different and depends on tensile load. It is obvious that additional application of preheating of the bearings allows reducing optimum value of tensile load.

It should be noted that the latter method for control of residual deformations can be considered universal since it is applicable to any type of the crankshaft independent on its geometry, shape and chemical composition of the base metal.

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