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Modeling of Stressed State Crankshaft of Boosted Diesels

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Modeling of Stressed State Crankshaft of Boosted Diesels

Nadezhda Marina [α] & Ekaterina Ovchinnikova [σ]

Abstract - The high alternating dynamic loads on the crank mechanism set for diesels challenge improve operational reliability connecting rods and crankshafts, which cannot be solved without a large complex of scientific research. As the experience of JSC «Volzhsky diesel them. Mama's "study the stress state of the connecting rods in a factory bench tests are expensive, require additional time and cost deadlines constrain the development of serial production of diesel engines. Solve the problem can be analytically using numerical methods of strength of materials, theory of elasticity, finite element. However, this approach is real only if the disposal of researchers of modern computer technology and software, corresponding to the level of complexity of tasks. But even then it prompt decision possible under the condition that the design of the new part of the crank mechanism is not very different from what a mathematical model which is already there. Otherwise, the time and labor costs increase appreciably. So often cheaper and faster to determine the stresses arising in the details, experimental methods - on physical models.

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I. Introduction

The problem of increasing of operational reliability of crankshafts boosted diesel engines is especially important due to the impact of variables dynamic loads, causing metal fatigue cracks. One of the main means of solving of the research problems of crankshafts or their models with high gradients of stress to determine stress points and obtain a picture of the whole area of the structures are the following physical methods: brittle lacquer method, moiré fringe method and polarization-optical method.

II. Methods

A prospective way to study the stress-strain state of the structures of the engine is the modeling on planar and three-dimensional photo elastic models. The solution of the problems in terms of stresses and isostatic model of the connecting rod [1] is known, and it resulted in qualitative pictures and diagrams of isochors and quantitative distribution of stresses in fringe arrangement. In comparison with other methods this polarization-optical method eliminates the full-scale research designs that require bulky and expensive equipment for loading, register the stress pattern along the crankshaft continuously, which is its main advantage. The accuracy of the polarization-optical method increases in locations with high stress gradient and does not depend on the environment. In comparison with the non-contact physical methods such as a method of brittle lacquer and method of moiré fringes the polarization-optical method makes it possible to get results the directly with high accuracy and with little expenditure of funds.

Polariscope with diffuser is taken as an instrument for the study of stress-strain state of crankshafts with polarization-optical method [1]. It should be noted that such polariscopes were not used in our country, and significant research effort was applied to optical systems for the creation of parallel light beams. There is no information on the study of model of the crankshaft engine with polarization-optical method in the technical literature.

III. Main Part

At JSC «Volgo Diesel – Mamins» the reduced scale models of the crankshaft were made of optically active material based on epoxy resin EH-5 of hot curing. Manufacturing technology of material includes the development and forms making, blending of components, pouring the mixture into molds, polymerization, forms disassembling and annealing the workpiece.

Plasticizer (dibutyl phthalate) is added into preheated to 80°C epoxy, and then the polymerization accelerator (dimetilanalin) and at last hardener (methyltetrahydrophthalic anhydride) in an amount of up to 40% are introduced. After the addition of each component, the mixture is thoroughly stirred at a constant temperature of 80`C. The prepared mixture is poured into preheated to 50-60°C forms. Polymerization of the material takes place in an oven under the condition of a slow rise in temperature.

Polymerization condition:

- model holding at 80°C for 24 hours;
- temperature increasing up to 100°C at 50°C per hour;
- model holding at 1000°C for 24 hours;

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- temperature increasing up to 120°C at 50°C per hour
- holding at 120°C for 24 hours;
- gradual temperature decrease (for 2.50C per hour) to 60°C.

The produced model was annealed to relieve residual thermal stresses and stabilize the properties of the material at 130°C. Temperature increasing during the annealing occurs 10°C per hour while the reduction occurs 50°C per hour.

The main property of the elastic model of crankshafts used in the study of stress-polarization optical method is their optical sensitivity, which is an indicator of the stress ratio or the price of a strip of material [2]. High optical sensitivity of the used material gives the simplicity and accuracy of measurement. To determine the stress optical ratio flat calibration pattern in the form of a disk, which was tested for compression by diametrically applied forces (Figure 1) was produced.

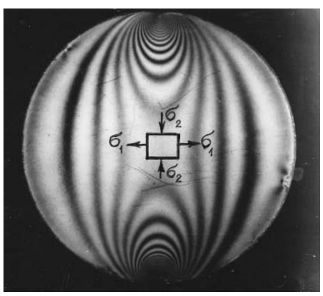

Figure1: Flat Calibration Sample

Simultaneously with the optical constant measurements longitudinal and transverse strains disk to determine the elastic modulus and Poisson's ratio for the formulas of the theory of elasticity

$$E = \frac{4(4-\pi)\cdot P}{\pi\left[4(D_2-D_1)t_1 - \pi\cdot D(t_2-t_1)\right]},$$

$$\mu = \frac{4-\pi}{4\frac{D_2-D_1}{D_1}\cdot\frac{t_1}{t_2-t_1}-\pi}$$

where P - force disk compression; D_1 and D_2 - length of horizontal diameter of the disc before and after loading; t_1 and t_2 - center thickness of the disc were carried out. In the given case $E = 34\cdot 10^8\, МПа$, $\mu = 0{,}37$.

To investigate the polarization-optical method models of the crankshaft were placed between the polarizer and analyzer, and their loading was carried out in the load frame via a hard disk with a bolt.

By modeling the loaded state of the crankshaft qualitative pictures and diagrams of quantitative isochors expressed in distribution of fringes arrangement of quasi-static stresses on the loaded circuit model (Figure 2) have been obtained.

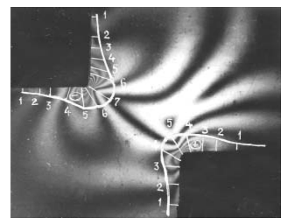

Figure 2: Diagram of Quasi-Static Stress Distribution in Fringes Arrangements on Crankshaft Model Outer Loop

IV. Conclusion

By modeling the stress state of the crankshaft by polarization optical method qualitative pictures of the isochors for different models of the tribe of the crankshaft and diagrams of the quantitative distribution of stresses in fringes arrangements. On the basis of fringe patterns processing theoretical stress concentration factors in the fillets of the crankshaft are defined.

Table 1: Theoretical Stress Concentration Factors in the Fillets of the Crankshaft Variants of Crankshaft Fillets

Options crankshaft fillets	The maximum order of the bands n_{max}	Nominal order strips n_{nom}	The theoretical stress concentration factor $k=n_{max}/n_{nom}$
1	6	2,5	2,4
2	5	3	1,7
3	10	4,5	2,2

Realized and studied according to the proposed method fillet crankshaft optimum profile for the engine 6ЧН21/21 provide reduced theoretical stress concentration factor from 2.4 to 1.7, i.e. 30%, as confirmed by studies on flat models of crankshafts. It allows optimizing and reducing the value of the maximum stress at a minimal structural changes and increase service life and operational reliability of crankshafts boosted diesels. Considerable optimization of the distribution of stresses in the fillets of crankshafts can be achieved by a set of structural measures to reduce both the total related to the form of knee-shaft, and the local stress concentrations, depending on the relative curvature and shape of the profile of the fillet.

When determining the causes of the accident of crankshafts according to the nature of the fracture it is necessary to find out its root cause that led to the stress concentration and the place where the sequential formation of a fatigue crack started. In this case the main problem is to retard cracking, to remove and disperse crack stress concentrators from the tops. In this connection the selection of process of a method of surface plastic deformation by the artificial creation of the initial processing of the residual compressive stresses [2] on the elements of the crankshaft is required.

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