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Effective Service Life Testing of the Cam Mechanisms

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Abstract. This paper is dealing with the description of the effective service life testing of material suitable for production of cams and other parts loaded by contact stress. An aim is to determine the fastest procedure for obtaining of necessary information about phenomena at RCF (rolling contact fatigue). This procedure allows us to determine the suitable surface treatment or we can suggest the changes in the loading force and we can determine the real service life of the contact surfaces. In the next step we can suggest the correction of the theoretical model. By this model we usually estimate the service life of the contact surfaces.

Introduction

A part of the cam mechanism design is the service life estimation, respectively the determination of the suitable material for production. Very often we use only the theoretical estimation. Previous research shows that theoretical and real service life are considerably different [1]. The aim of this paper is to give a concrete procedure, which enables the effective testing of the service life and get the maximum of information about examined material. Important factor at the service life testing is time. Required service life is mostly 10^7 to 10^8 cycles, so the testing is very time consuming. Methodic given in this paper can be used by the service life determination of all other machine parts which are loaded by contact stress.

Testing procedure

The complete testing procedure we can divide into four phases. These are described below.

Phase 1: Theoretical service life

A value of the theoretical service life we determine according to appropriate theory. They are available in the literature e.g. [3], [6]. Usually, we are using two theories. The first theory [3] is based on the service life estimation by means of the surface hardness. The calculation is simple but the surface hardness does not describe all the mechanical properties of the examined material. The second theory [6] is based on two material parameters. These parameters better describe the mechanical properties of the material but the database of these parameters is limited. It is very expensive and time consuming to obtain the parameters for materials outside the database.

The comparison of these theories results shows that the service life determined by each theory can be very different [1]. Therefore we need to find a suitable experimental procedure which can help verify the accuracy of the theories respectively suggest their correction.

Phase 2: Testing preparation

The first step is the preparation of the experiment in the field of the suitable material selecting. This choice is necessary to make in according to the results from the calculations (FEM, analytic methods). It is also necessary to control the supplied material, its chemical composition and micropurity. In the next step we should determine exactly the parameters of heat, respectively chemical heat treatment. The parameters of these technological processes are very important for ensuring of required properties of the surface layers of the examined component. These are parameters of carburizing, heating etc.

It is necessary to take into account not only the material properties, but the influence of the working conditions on the RCF forming in the experiment too. The most significant is lubricant and its interaction with the contact surfaces and the shape of the contact surfaces too. Information about the interaction between oil and the contact surfaces is important because the behavior can change depending on change of the contact surface properties (change of surface tension, chemical interaction etc.). The properties of the contact surfaces can affect the RCF in two ways. The first one says that if there are cracks on the surface, it can lead to pitting [7]. The second problem can be, when the contact surfaces are too smooth, then can be insufficient space there for oil film [8].

After verification of the properties of the relevant steel, we can produce the test specimen. We produce two types of specimens, the first one is for testing the service life and the second type is for testing the material properties. By these specimens we can define quality and depth of the heat treatment (respectively carburizing, coating, weld deposit etc.). The depth of the carburizing layer can be determined by removing thin layers and then by using basic chemical analysis to determine the carbon content. Other parameters which are useful we can obtain by nanoindentation measuring. We can get information about mechanical properties of the examined specimens, hardness, modulus, visco-elastic properties and other in the dependence on depth, very detailed in the area of interest.

Phase 3: Testing

After choosing the suitable material, production of specimens and determining the right test conditions the specimens can undergo the service life tests. More about these tests in [2].

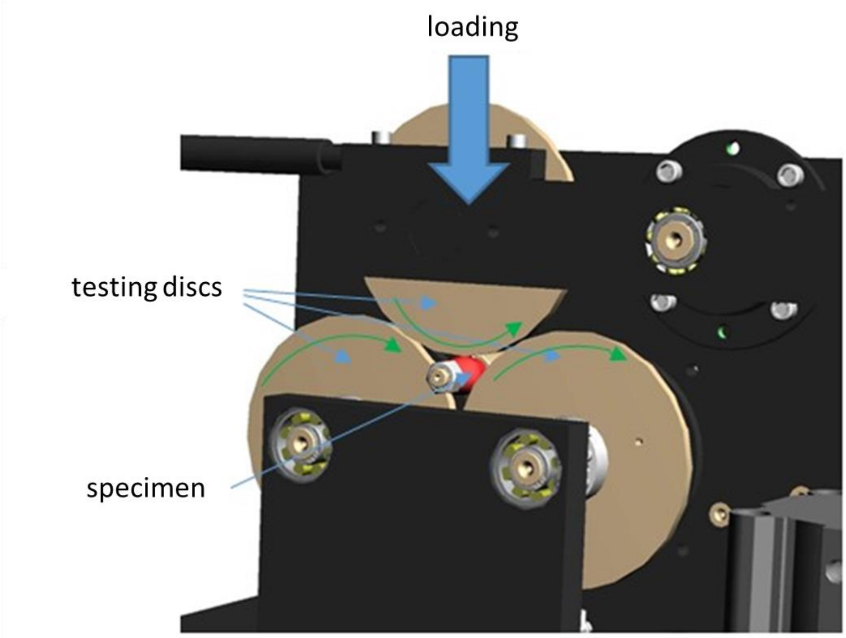

Fig. 1 Test rig

There is shown the test rig in Fig. 1. The basis of the test is that the specimen is inserted between the three discs and it is loaded by the force determined by means of the theoretical estimation or from previous tests. This way of testing allows the shortening of the time testing to 1/3. This is significant time saving because we need to test every specimen for 10^7 or 10^8 cycles. Tests are running to detection of defect or to achieving the desired number of cycles.

Phase 4: Results evaluating

After service life testing the tested surface can be observed by stereomicroscope (or other suitable microscope) by low magnification in the first step. The task is to obtain information about surface damage from a macroscopic view.

When we look through the specimens on the stereomicroscope, we can analyze the specimens on the electron microscope. There is picture obtained on a Tescan electron microscope in Fig. 2 (shown pitting on specimen).

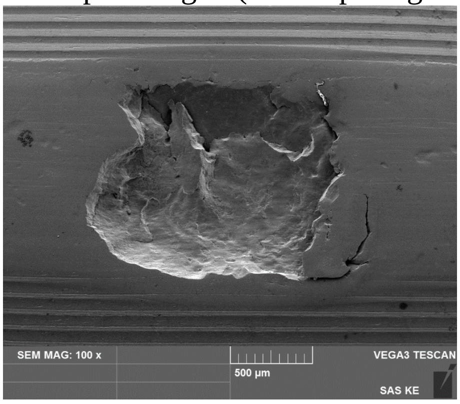

Fig. 2 Damaged surface

There are other possibilities of the specimen analysis on electron microscopes. We used Jeol JSM 7000F. This microscope works with high magnification and this allows detailed monitoring of the cracks. Except standard display allows display in regimes COMPO and TOPO (see Fig. 3 and Fig. 4). Thanks to these regimes we are able to find out more information about the examined specimen. The regime COMPO allows us to identify inhomogeneity on the basis of the differences in chemical composition. It shows grayscale in the dependence of atomic numbers. The regime TOPO shows topographic view at the examined surface.

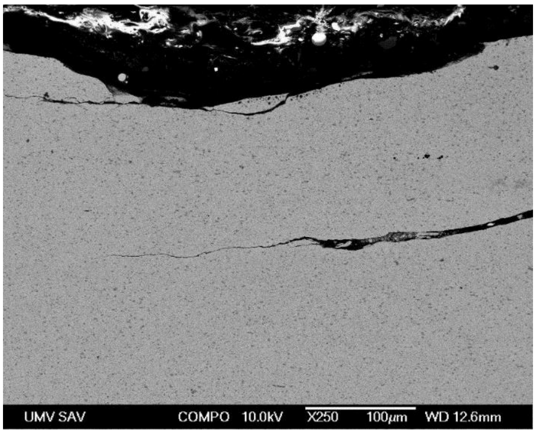

Fig. 3 Detail of the damaged part shown in regime COMPO

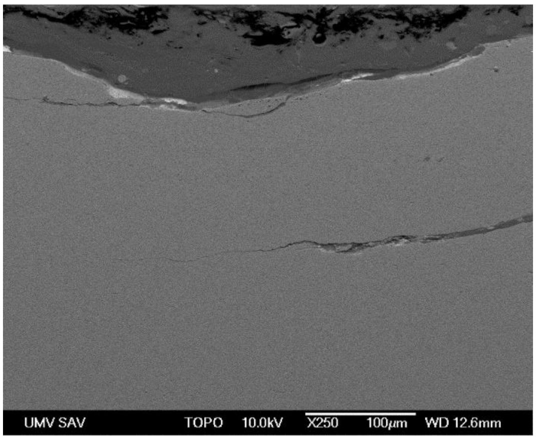

Fig. 4 Detail of the damaged part shown in regime TOPO

There is marked a maximal depth of cracks presence in Fig. 5. From this image we obtained a value of 0,33mm. The depth of maximal shear stress is 0.77 mm. This value was determined by analytical calculation [5].

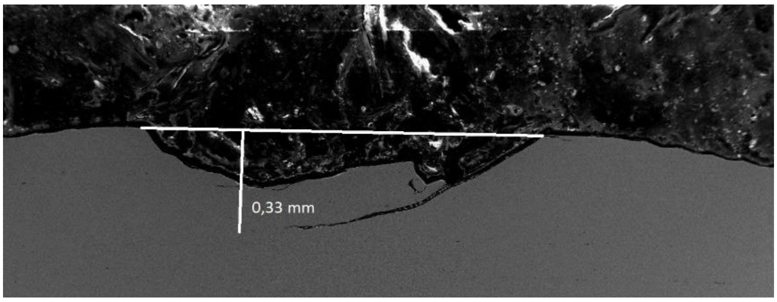

Fig. 5 Depth of damage determining

From microscopic analyses we can obtain information about observing the technological process, determining of depth and uniformity of the heat treatment [4]. In Fig. 6 is shown image with a marked depth of the carburised layer (obtained on optical microscope).

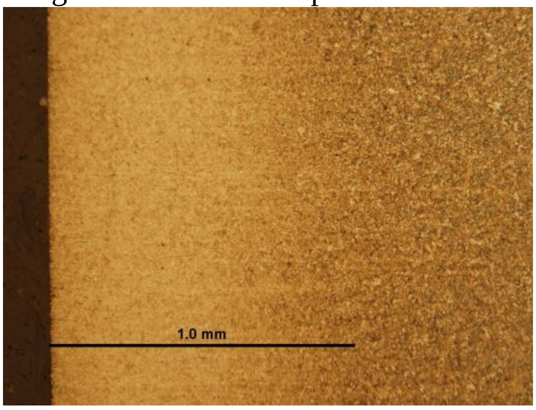

Fig. 6 Depth of the carburized layer is about 0,8 mm

In Fig. 7 and Fig. 8 shows a detail of the crack root. From these images it is clear that the crack does not form on the grain boundaries. There is not the increase presence of impurities, inclusions, cavities in the examined steel. In Fig. 7 globular carbides are clearly visible, their chemical analysis was performed. We can say that the crack did not form from any inclusion or impurity or cavity. It was formed only by the exhaustion of mechanical properties of the examined steel.

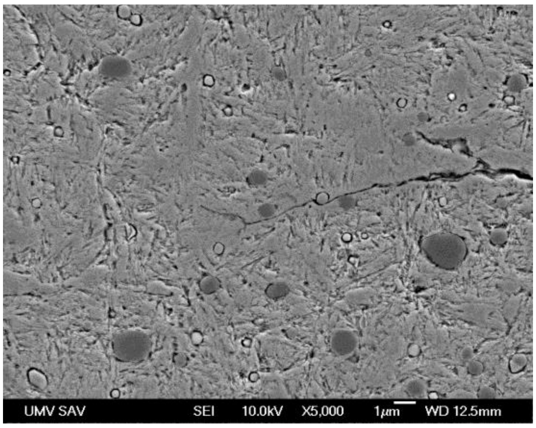

Fig. 7 Crack root shown with carbides

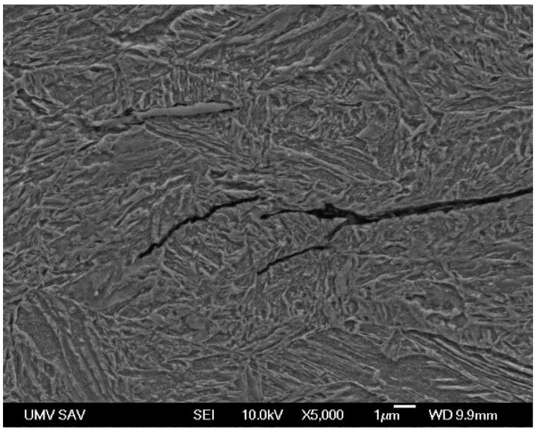

Fig. 8 Detail of the crack root

From analysis can we say whether the structure is uniform, micropurity of the examined material is convenient and to determine the content of the inclusions and cavities. We can determine if the damage occurred in the material and the cracks are formed on the basis of exhaustion of the mechanical properties of the examined steels or on the basis of non-uniform structure. To have complete information about the examined material, it is useful to measure microhardness and specimens continually (at service life testing) undergo the defectoscopic tests (detection of surface and subsurface defects).

Conclusions

From results of the tests we can say that the examined material will meet conditions for the service life respectively for loading force. After the evaluation of experimental testing we will suggest an adjustment of the mathematical model and possibly technologic parameters of the heat treatment (mainly depth of the carburized layer and carbon concentration).

The most suitable solution of the material problematics of the rolling contact fatigue is to choose the material which will be loaded in its elastic area. This is possible to achieve either material with high yield strength, with sufficient heat or chemical heat treatment surface layer or with weld deposit.

Acknowledgments

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