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INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2013
Brasov, 23-25 May 2013

A STUDY ON FATIGUE WEAR CRACKS OF A 40Cr130 COATING IN DIFFERENT LUBRICATION CONDITIONS

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Abstract: *This paper analyses the contact fatigue behavior of a 40Cr130 coating deposited in electric arc on an 18MnCr11 base material. The samples were subjected to contact fatigue on the AMSLER installation in limit and mixed lubrication conditions and analyzed on the LEICA DMI5000 M microscope. A finite element analyses was made on CAD models of the samples to assess the stress distribution. The FEM analyses was done using the ANSYS 13 software. From the finite element analyses resulted where and how cracks appear in the sample. The coating had the purpose to improve the contact behavior of cams from the point of view of wear. The sample with coating subjected to fatigue wear in mixed lubrication conditions had the best behavior.*

Keywords: *ANSYS, contact stresses, 40Cr130*

1. INTRODUCTION

Internal combustion engines are composed of different parts subjected to wear due to the friction between contact surfaces. [1]

There are different types of wear which occur on these parts: adhesive wear that can lead to scuffing, abrasive wear, corrosion wear and fatigue wear. [3]

The camshaft is an important part in an internal combustion engine. His role is to command the fluid distribution in the engine. [2] To do this the cam law must be very precise and any imperfections on the cam surface can lead to the engine malfunction. [6]

The cam is influenced by all the wear types presented above. Improving the cams surface resistance to wear is an important aspect and can be achieved by different means. [4]

This paper analyses the way how a metallic deposition on the cam surface would improved its wear behavior. The materials used in the analyses are 18MnCr11 alloy steel for the sample and 40Cr130 for the coating deposited in electric arc on the sample. Fatigue wear tests were performed on both coated and uncoated samples and microscopy was used to assess the results.

Contact fatigue is highly influenced by the stress distribution. A finite element analyses was done on CAD models of the samples to highlight the stress state of the material and compare it to the results obtained from the fatigue wear tests.

2. MATERIALS, METHODS AND INSTRUMENTATION

In this paper is presented a method to enhance the contact behavior of sliding surfaces. This method consists of an electric arc coating deposition. The material used for the coating is a 40Cr130 wire steel alloy deposited using the Smart Arc 350 installation from Sulzer Metco on an 18MnCr11 base material. This layer has the purpose to enhance the fatigue, adhesive and abrasive wear resistance.

The 18MnCr11 samples, on which the deposition was performed, are of disc shape with a diameter of 49 mm and the thickness of 5 mm.

In table 1 are presented the deposition parameters used for the electric arc deposition using the Smart Arc 350 installation.

Table 1: Technical parameters

Smart Arc 350	40Cr130
U	28V
I	252A
Air pressure	60PSI

The samples were mounted on the AMSLER installation, presented in Fig. 1, to achieve the fatigue test.

Fig. 1. The AMSLER installation

In the test one of the samples is static and other one has rotational movement. For the test different combinations of contact materials were used: base material sample – base material sample and coated sample – base material sample.

The lubrication regimes used in the test were limit and mixed. The oil used for lubrication has a SAE 5W-30 (9,3 – 12,5 cSt) viscosity which is specific for modern internal combustion engines. The duration of the fatigue test was 30 hours, the loading force had a value of 177 N and the velocity of the moving sample was 375 turn/min.

To highlight the results after the test the samples were analyzed with the LEICA DMI 5000 M microscope which is presented in Fig. 2.

Fig.2. Microscopul optic LEICA DMI5000 M

The CAD models of the samples were made in Solidworks and imported in the Static Structural module from ANSYS 13.

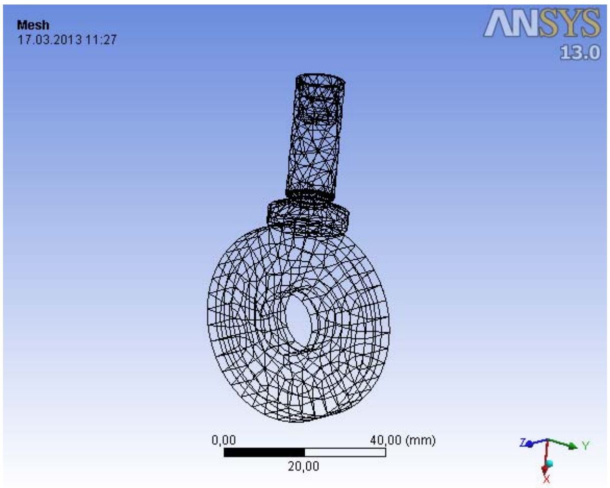

Fig. 3. The mesh of the model without coating

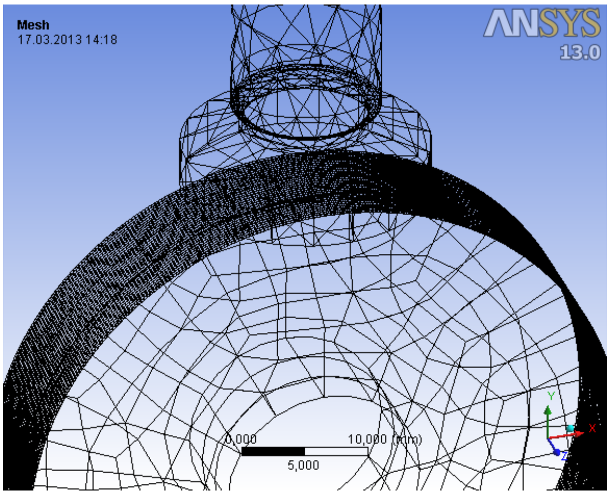

Fig. 4. The mesh of the model with coating

The mesh of the model without coating is made of 6166 nodes and 2459 elements (Fig. 3.) and the mesh of the model with coating 118706 nodes and 18263 elements (Fig. 4.). The disc is supported by a cylindrical clamping with the tangential direction free. The follower applies a force of 177 N to the disc surfaces. The disc has a rotational velocity around its axis of 375 turn / min. The material properties of the components were defined in the Data Engineering module from ANSYS 13.

3. FINITE ELEMENT ANALYSES RESULTS

3.1. The stress distribution for the model without coating.

Fig. 5 presents the equivalent stress distribution in the sample. The stress is calculated with the Von Mises equivalence theory. As can be seen from the image the sample shows a Hertzian stress distribution with the maximum value of 10,916 MPa on the side edges of the sample.

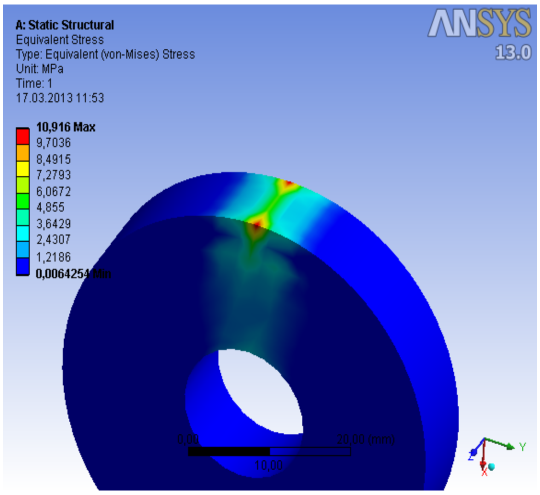

Fig. 5. Equivalent stress distribution of the sample without coating

The equivalent stress has two components: the normal stress and the tangential stress. The normal stress has two components: one downward to the surface σ_1 and one perpendicular to it σ_2. If the friction force between the surfaces is 0, σ_1 is normal to the surface and σ_2 is tangential to it. The components σ_1 induces a compression in the sample and σ_2 traction. In Fig. 6 is presented the normal stress distribution. The components σ_1 has a value of 8,4845 MPa and σ_2 2,1903 MPa.

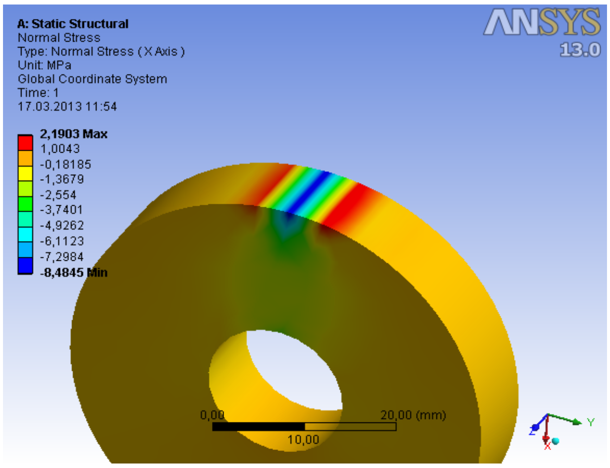

Fig. 6. Normal stress distribution in the sample without coating

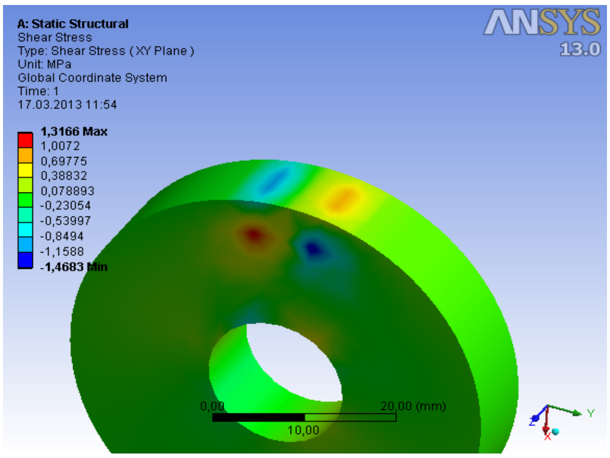

Fig. 7. Tangential stress distribution in the sample without coating

The tangential stress is in a plane at 45° then the normal stress direction. Fig. 7 shows the tangential stress distribution in the sample. The values of the maximum tangential stresses in the two 45° planes are: 1,3166 MPa and 1,4683 MPa.

3.2. The stress distribution for the model with coating.

Fig. 8 presents the equivalent stress distribution in the sample without coating. The maximum equivalent stress happens in the base material and has value of 28,877 MPa. The maximum equivalent stress on the coating surface has a value of 21,659 MPa.

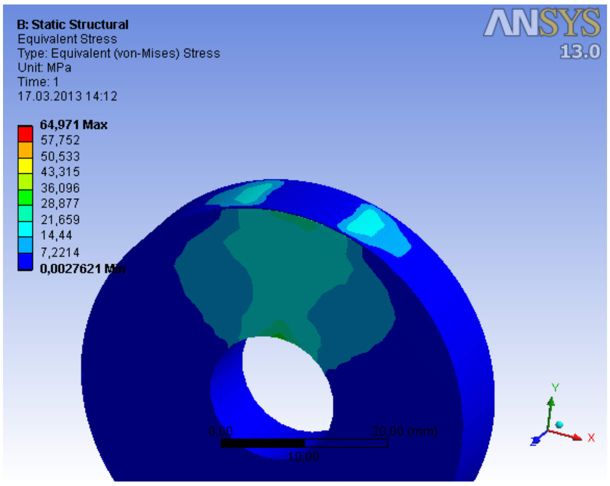

Fig. 8. Equivalent stress distribution of the sample with coating

In Fig. 9 is presented the normal stress distribution. The σ_1 component has the maximum value of 10,993 MPa. The σ_2 component has a value of 9,9623 MPa on the coating surface. Only the normal component affects the base material.

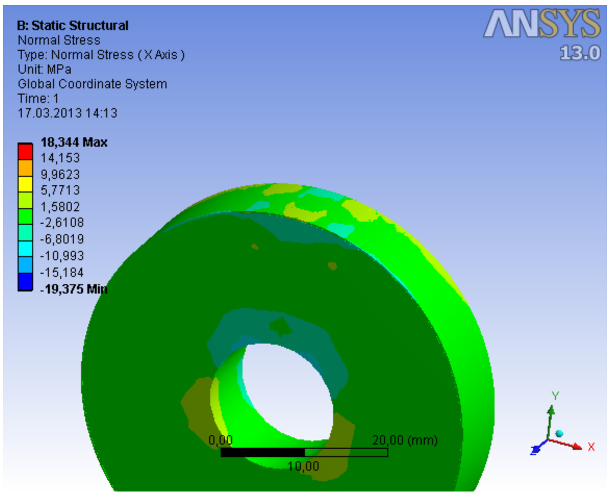

Fig. 9. Normal stress distribution in the sample with coating

The tangential stress increases due to shear stress at the interface between the base material and the coating. As can be seen in Fig. 10 the maximum tangential stresses in the two 45° planes are: 10,633 MPa and 10,359 MPa.

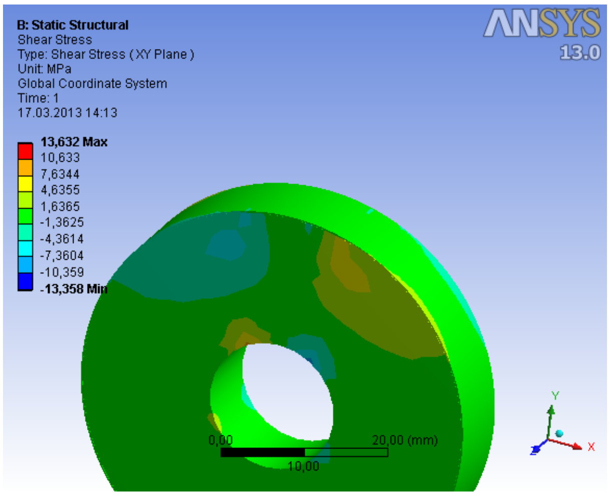

Fig. 10. Tangential stress distribution in the sample with coating

Contact fatigue usually leads to the appearance to pitting and spalling which are caused by cracks. There are two types of cracks depending on the location of the crack initiation. The cracks caused by the normal stresses initiate at the surface and propagate downward in the material and ramify, eventually reaching the surface again and causing a spall. The cracks produced by the tangential stresses initiate in the maximum shear stress zone and propagate almost parallel to the surface.

From the finite element analyses results that in the case of the sample without coating the maximum stress is the normal one and in the microscope analyzed sample, surface initiated cracks should appear. In the sample with coating both types of cracks should appear because of the high normal and shear stresses.

4. MICROSCOPY ANALYSES

4.1. Microscopy analyses of the sample in limit lubrication conditions

Fig. 11 shows a microscope cross section image of the sample without coating subjected to contact fatigue in limit lubrication condition. As can be seen in the image, surface initiate cracks are much highlighted. This sample was affected by scuffing during the test.

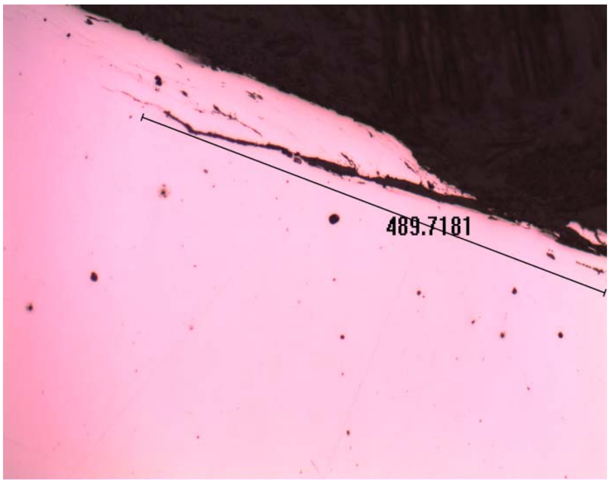

Fig. 11. Cross section microscope image of the sample without coating in limit lubrication conditions

In the cross section of the sample with coating, cracks initiated at the surface and at the interface between the base material and the layer are present (Fig. 12 and 13).

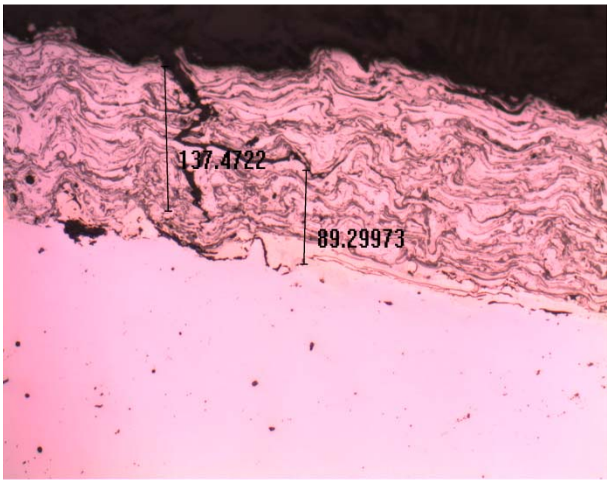

Fig. 12. Surface initiated crack in the sample with coating in limit lubrication conditions

For this sample no scuffing appeared during the test.

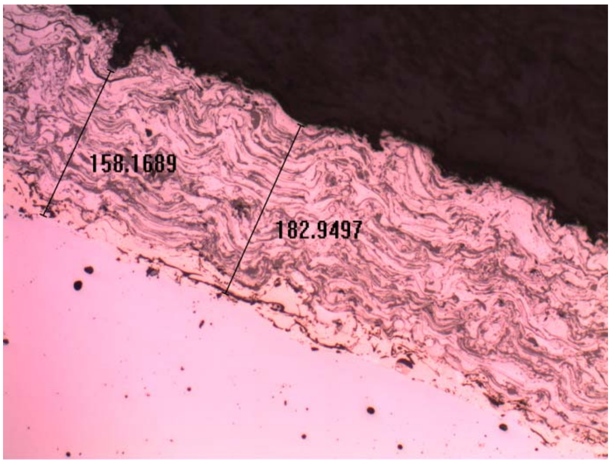

Fig. 13. Crack at the interface in the sample with coating in limit lubrication conditions

4.2. Microscopy analyses of the sample in mixed lubrication conditions

The samples subjected to contact fatigue in mixed lubrication conditions behaved better. In Fig. 14 is presented a cross section of the sample without coating from which results that still surface initiated cracks are present.

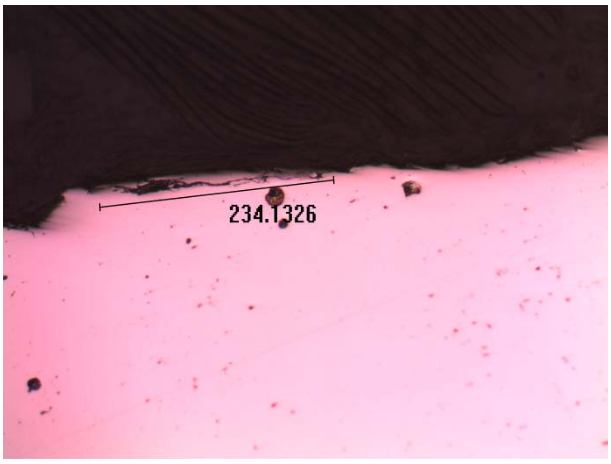

Fig. 14. Cross section microscope image of the sample without coating in mixed lubrication conditions

The sample with coating in mixed lubrication conditions had the best fatigue behavior. No major cracks are present on the surface in the material. Fig. 15 shows a cross section in the sample with coating.

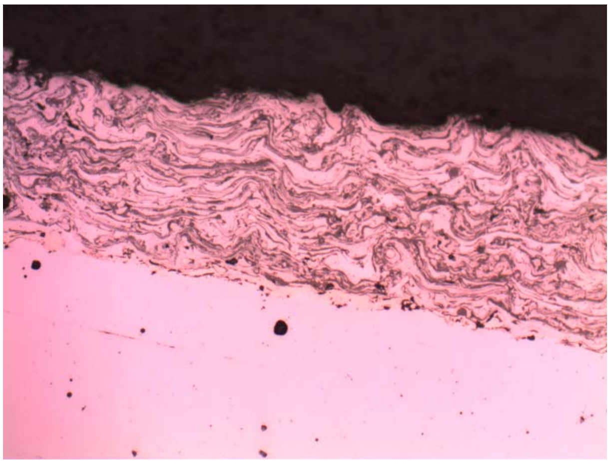

Fig. 15. Cross section microscope image of the sample with coating in mixed lubrication conditions

5. CONCLUSIONS & ACKNOWLEDGMENT

The stress distribution has a great influence on contact fatigue as otherwise was highlighted in the paper and correlated to the microscope analyses.

Even if the stresses were higher the coating improved the behavior of the sample due to its good adherence, hardness and high yield strength.

To use the coating at its highest capacity a good lubrication is needed so the high stresses don't cause cracks.

Acknowledgment: We thank to SC Plasma Jet SA for the support in the plasma jet deposition of the analysed layer from this paper.

I give thanks to the Faculty of Mechanics for the support and for making available the science of materials and Materials Science laboratories for performing the necessary tests for the paper.

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