IMEKO TC15 - Experimental Mechanics - Proceedings of the
11th Youth Symposium on Experimental Solid Mechanics
Brasov, ROMANIA, 2012, May 30-June 2

DETERMINATION OF MO COATINGS BEHAVIOUR ON BENDING IN ORDER TO ESTABLISH SOME MECHANICAL PROPERTIES

C. AXINTE[1] A. BÂRCĂ[2] E.S. BÂRCĂ[3] P. AVRAM[4]
C.I. BĂRBÎNȚĂ[5] C. MUNTEANU[6]

Abstract: *Gears have the role of force and torque transmition by friction. They are subjected in operating to fatigue and bending, this being the reason of the pitting type wear appearance. The geometry, dimensions and weight can't be modificated that is why we decided to modify the contact surface by coating. We have chosen the steel type 16MnCr5 and we coated it with Mo. The selection of the materials was made after a detailed study of the literature. After we obtained the samples, we subjected them to bending tests to determine the mechanical properties. On the SEM analysis we obtained the quality of the coatings. The results showed how the coating influences the properties of the basic material.*

Key words: *gears, bending, coating, SEM.*

1. Introduction

In recent years, materials of high resistance of automotive, aviation and oil have been used with coatings deposited in order to match the mechanical strength with resistance to corrosion and wear, [1].

In last years, thermal depositions represent the solution for improving the material's characteristics.

Starting from the consolidated field of cutting tools, during the last few years their development has interested the oil, aerospace, transports and biomedical industry. The improvement of the tribological and corrosion characteristics was the main impulse to their application at first. The wide spread use of hard thin coatings also helped to consolidate the deposition techniques and justified the growing interest of the research field, [2].

In operating, gears are subjected to bending and fatigue on the teeth flanks. In this paper we proposed to study the behaviour of Mo coating on steel substrate, in order to estimate the bending resistance.

[1] "Department of Mechanical Engineering, Mecatronics and Robotics", *Technical* University of Iasi
[3]"Department of Mechanical Engineering, Mecatronics and Robotics", *Technical* University of Iasi
[4]"Department of Mechanical Engineering, Mecatronics and Robotics", *Technical* University of Iasi
[5]"Department of Mechanical Engineering, Mecatronics and Robotics", *Technical* University of Iasi
[6*] **Corresponding author,** "Department of Mechanical Engineering, Mecatronics and Robotics", *Technical* University of Iasi

The mechanical properties of an usual material can be improved by thermal deposition. In order to improve the material's characteristics, we decided to cover the surface of it with a thin layer.
We have done samples of 16MnCr5 steel, rectangular, with dimensions 25x10x2.

2. Experimental

In this paper we analyzed the samples obtained by thermal coating to determine their properties. We accomplished two analysis one qualitative and one quantitative, using efficient equipments.

For Bending Test, we used the device named Deben Microtest Materials Tensile/Compression/Bending 2KN/5KN testing, showed in Figure 1.

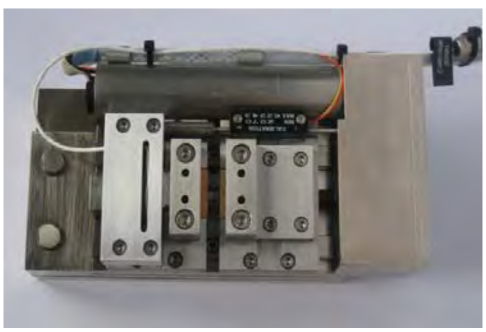


Fig. 1. *Deben Microtest*

Tensile/compression testing and also three/fourpoint bending play an important role in understanding the mechanical properties of materials. MICROTEST modules have been specifically designed to allow real time observation of the high stress region of a sample with an SEM, optical microscope, AFM or XRD system. Windows XP/Vista software sets drive parameters and displays the stress/strain curve live on the computer screen.

Loadcells from 2N to 5KN cover most applications, with extension rates from 0.005 mm/min to 50 mm/min. All stages have linear scales for elongation measurement and optical encoders for speed control. Options include three and four point bending clamps, fibre clamps and microscope mounting adaptors. All modules are controlled from Microtest tensile testing software.

The qualitative analysis has been made by Scanning Electron Microscope (SEM), which produces images by detecting low energy of secondary electrons, emitted from the sample surface due to its excitation by the primary electron beam. In SEM, the electron beam through the entire specimen, detectors built an image by mapping the detected signal beam position.

The Quanta 200 3D is equipped with an EDAX acquisition system provided, and is able to make qualitative and quantitative elemental chemical analysis by EDX (energy dispersive X-ray) and crystallography analysis.

QUANTA 200 3D Dual Beam elecronic microscope, showed in Figure 2 has two beams, electrons and ions. With the electron beams we can obtain images of more than 2 millions magnifications, and also the chemical composition, by the EDAX module. With the ions beam, we can obtain rapid and accurate grinding by various geometries (at μm) of sample material, revealing sub-surface structure, obtaining sections, deposition of layers, etc.. Ion system also offers high resolution images.

Fig. 2. *SEM QUANTA 200 3D*

3. Results and discussion

First we mounted the device under a stereomicroscope, in order to observe the microstructure's modifications during the Bending Test. Before the Bending Test start, we set up the parameters, Figure 3.

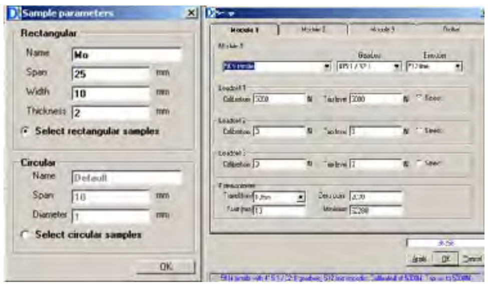


Fig. 3. *Bending Test Settings*

After we have done all the settings, we started Bending Test, observing the microstructure's modification by the stereomicroscope. When the first crack appeared, we stopped the device and we took a picture of the microstructure with the crack showed in Figure 4.

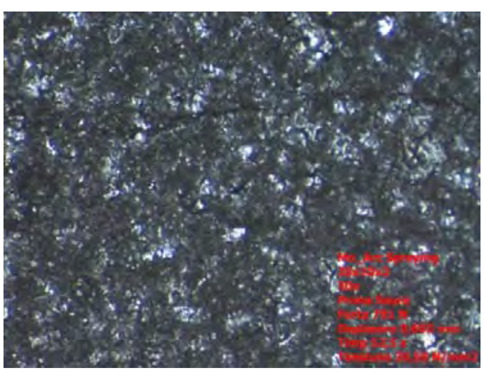


Fig. 4. *Mo coating microstructure, at 50x, when the first crack appeared*

The Deben Microtest soft, showed us the the foce, elongation and the stress of the material whin the first crack appeared. The results, showed that the force was 791 N and the material's stress was 39.55 N/mm^2.

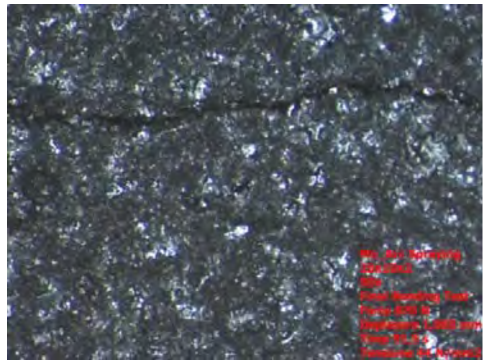


Fig. 5. *Mo coating microstructure, at 50x, at the end of bending test*

In Figure 5 is represented the Mo coating microstructure, at 50x, at the end of bending test. Deben Microtest soft showed us the also the force, elongation and the stress of the material. The force was 870 N and the material's stress was 44 N/mm^2.

The crack's propagation is slow and is orientated to the substrate.

We collected all the data and we processed them in order to determine the elasticity modulus, which is one of the most important characteristics of the material.

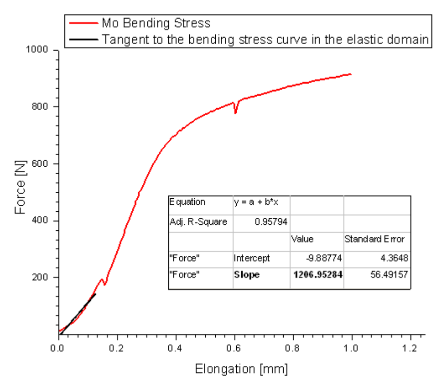
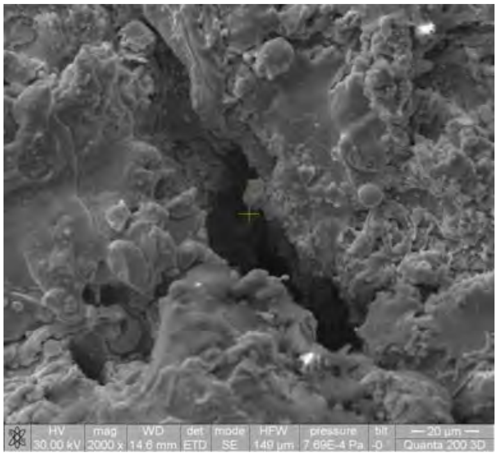


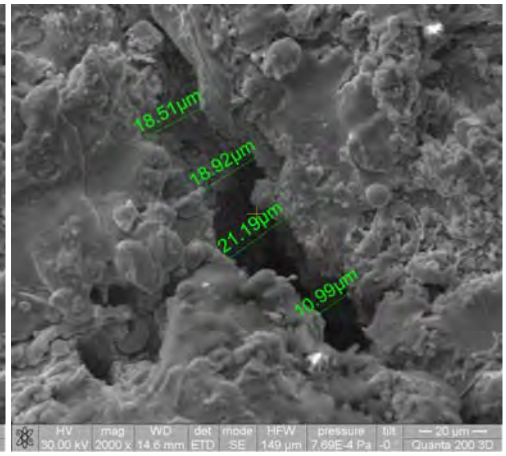
Fig. 5. *Mo coating Bending Stress*

Mo coating was deposited on a steel substrate, and the Hooke type curve is the result of the Bending Test

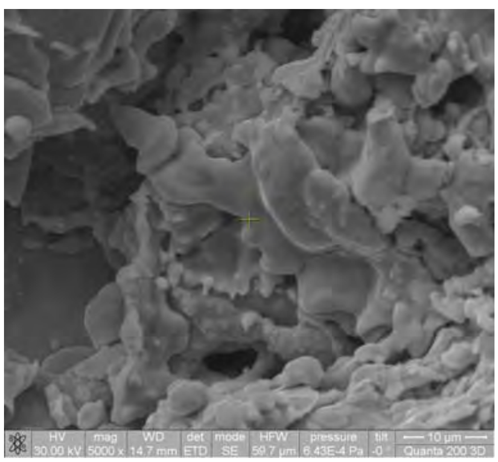
$$E_{Mo} \approx 120 \text{ GPa}$$



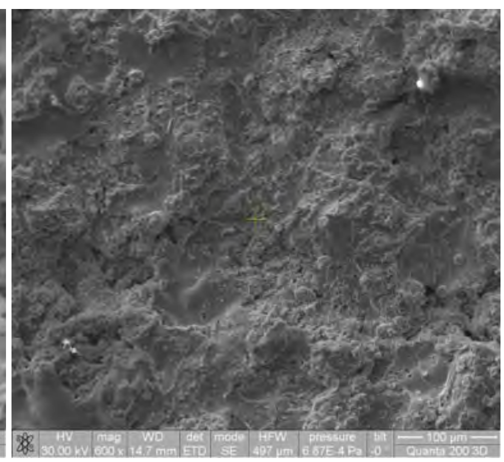
a)



b)



c)



d)

Fig. 6. *Mo coating SEM microstructure*

ln Figure 6, could be observed the SEM microstructures of Mo coating obtained by SEM Quanta 200 3D before bending test.

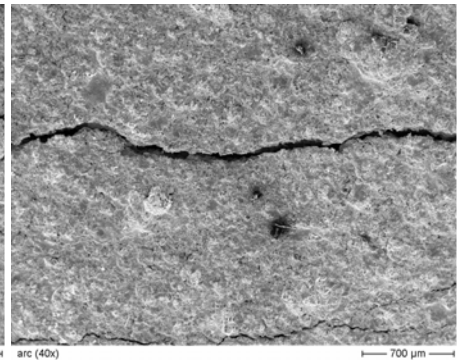
In Figure 6 a) and b) we can see cracks which have appeared most likely in the coating process.

Thermal spray process in electric arc is achieved by melting filler material, and spraying it on the covering surface with a jet of air or gas with a speed of 250 m/s.

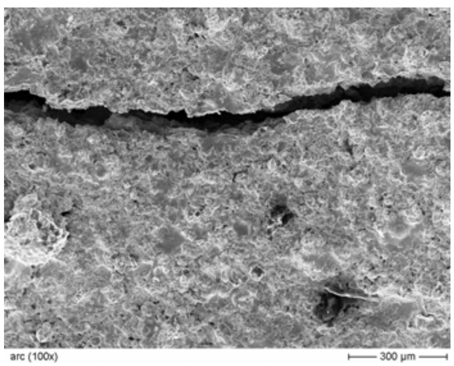
When Mo melted wire comes in contact with the cold basic material, it solidifies very quickly generating tensile stresses in the deposited layer, compression type for basic material and strain tensile for the coating, being the cause of the cracks.

In Figure 6 b) is shown the highest area of the crack, 21.19 μm, and in Figure 6 c) and d) are shown SEM microstructure of Mo coating at diferent magnifications.

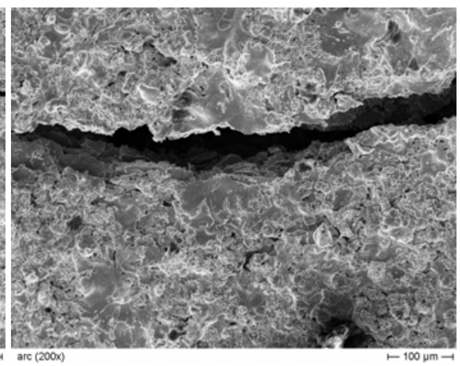
a)



b)



c)



d)

Fig. 7. *Mo coating SEM microstructures after Bending Test*

ln Figure 7, could be observed the SEM microstructures of Mo coating after bending test.

In Figure 7 a) we could observe the main crack and some auxiliary cracks.

The bond stresses inside the material are very high, that is why beside the main crack, have appeared these cracks. The main crack's propagation in sectional area is slow, because the material yielded near the area of the fracture, therefore the stresses propagation are higher along the coating layer than in it's depth.

We have taken pictures of the main crack at diferent magnifications, showed in Figures 7 b), c) and d), to observe it better.

4. Conclusions

In this paper we have studied the way of improving materials properties by coating their surfaces. We have chosen an alloyed steel with good properties and we have coated it by electric arc process, with Mo.

The results of Bending Test showed that the bending stress's curve is type Hooke, so we can say that the basic material (steel) is the one who dictates the behavior at this type of request.

Steel has the elasticity modulus of 210 GPa, but the coating, decreased it almoust to half value, the overall elasticity modulus being 120 MPa.

As a result of Bending Test, we obtained an elastic material, which can resist to a force of 791 N and a stress of 39.55 N/mm^2.

SEM analysis has been made in order to determine the quality of the material and it's microstructure deformation after Bending Test. On this analysis we observed that the coating is homogeneous, but present some cracks due to deposition process. Even in this case, after Bending Test, we realized that the material has a good behaviour and the bond stresses are very high.

In SEM analysis we discovered some auxiliary cracks, so we can say that the stresses propagation are higher along the coating layer than in it's depth.

Acknowledgements

This paper was financially supported by EURODOC project, "Doctoral Scholarships for research performance in Europe", financed by the European Social Fund and the Romanian Government.

References

1. Bell, T., Dong, H., Sun, Y. *Realising the potential of duplex surface engineering*. In: Tribology Int., 31/1–3 (1998a) 1–3, 127–137.
2. Bell, T., Mao, K., Sun, Y., Surface engineering design: *Modeling surface en gineering s ystems for improved tribological performance*. In: Surf. Coat. Technol., 108–109 (1998b) 360–368.
3. Cheng, H.S., Gears. In: Modern Tribology Handbook. Bhushan, B. (ed.), CRC Press, New York, 2001, 1095–1129.
4. Adams, M.J., Briscoe, B.J., Cartner, A.L., Tweedale, P.J., Assessing the durability of organic coatings. In Mechanics of Coatings. Dowson, D. et al. (eds), Tribology series, 17, Elsevier, Amsterdam, 1990,139–147.
5. Amaro, R.I., Martins, R.C., Sebara, J.O., Renevier, N.M., Teer, D.G., Molybdenum disulphide/titanium low friction coating for gears application. Tribology Int., 38 (2005) 423–434.
6. Munteanu C, Lorenz P, Bărbînță C-I, Pipa G-R, Bistriceanu I, B A-C and Axinte C: *Using X-Ray diffractometer to determine the rail breaking causes*. In: MODTECH Proceedings 2011.
7. Bărbînță C-I, Munteanu C, Pipa G-R, Lorenz P, Chicet D, Bărbînță A-C and Axinte C, A *railway rail fracture expertises using the e lectronic microscopy*. In: MODTECH Proceedings 2011.
8. C Axinte, D-L Chicet, I-L Bistricianu si C Munteanu, *Materials specific to gears used in automotive industry*. In: Bulletin of the Pollitechnic Institute of Iasi (2010).
9. I-L Bistricianu, D-L Chicet, C Axinte si C Munteanu, *Wear test and SEM analysis for CP-Ti air oxidised samples*. In: Bulletin of the Pollitechnic Institute of Iasi (2010).
10. D-L Chicet, I-L Bistricianu, C Axinte si C Munteanu, In: Bulletin of the Pollitechnic Institute of Iasi (2010).
11. C Axinte, C Munteanu, A-C Barbînta si E-S Bârca, *Gears materials analysis in order to establish the mechanical properties*. In: ROTRIB'10 Proceedings, Bulletin of the Pollitechnic Institute of Iasi (2010).
12. C-I Barbînta, C Munteanu, C Axinte, D-L Chicet si A-C Barbînta, *The influence of the metallographic characteristics of R7T steel on railway wheels durability*. In: ROTRIB'10 Proceedings, Bulletin of the Pollitechnic Institute of Iasi (2010).