

EVALUATION OF COATING MATERIAL STRUCTURE OF SCREW TYPE COMPRESSOR ROTOR CONTACT SURFACES

Fayzullaev Asomiddin Aloviddinovich

Assistant, «Theoretical mechanics and machines and mechanisms» department, TSTU, Uzbekistan

Abdurahmanov Nurlibek Bahtiyarovich

Assistant, «Theoretical mechanics and machines and mechanisms» department, TSTU, Uzbekistan

Khadjibekov Tahir Dilmurodovich

Assistant, «Theoretical mechanics and machines and mechanisms» department, TSTU, Uzbekistan

Shoumarov Rikhsibay Abbasovich

Assistant, «Theoretical mechanics and machines and mechanisms» department, TSTU, Uzbekistan

Xurramov Dostonbek Khusan ugli

Assistant, «Theoretical mechanics and machines and mechanisms» department, TSTU, Uzbekistan

ABSTRACT

In engineering, as well as in other manufacturing industries, the use of compressed air is an important catch. Compressor production and service company Fonons, Ltd often deals with damage of screw type compressors, sometimes even irreversible. Damages that draw up to 15% are linked to strong wear out of compressor friction knot (rotors). This, in effect, reduces the optimum productivity and work efficiency of the compressor, increases losses between rotors. Compressor service time diminishes. Work foundation is the analysis of methods how to improve screw rotor surfaces. It is necessary as one of the concluding treatment operations in the manufacturing process. It may reduce the influence of the abrasive elements on the contact surface, diminish wear intensity, and increase the service time. Improved contact surface of rotors, which are coated with TiN coating by using physical vapour deposition (PVD) technology, is analysed within the framework. Surface quality control is executed with modern methods, including surface 3D topography analysis and coating quality estimation with the atomic force microscopy (AFM). The main materials are analysed characterizing parameters change according to the recommendation for manufacturing wear proof coatings.

Keywords: wear, surface topography, atomic force microscopy, quality, and wear intensity.

INTRODUCTION

Are technologically most fashionable, efficient, safe, and wear proof. Generally, compressors are mechanical devices for increasing inflowing air pressure or energy transmission. Efficiency, wide range of speeds, pressure differences, compact design, low cost, rapid growth and a variety of other qualities allow the possibility for wide use in various technological processes. The basic parts in screw type compressor design are two specially created revolved, parallel placed rotors (Fig.1.). The pressure increases between those two rotors [1]. Fig.1. Rotors of screw type compressors During the exploitation time, the main active parts of oil flooded screw type compressors (Fig.1.) are subordinated to a wide range of speeds, pressure differences, changeable cyclic loads, and various working environments. The result of variable working circumstances can cause damage, which can be even irreversible. One of the most common compressor airend failures is the wear out of the main friction knot-faulty rotor profile of the compressor. That reduces the optimum productivity of compressors, increases leakage between pressures channels, as well as reduces its operational efficiency. Certain viscosity oils are used for reducing friction and wear intensity. There is an opinion that while the oil flows between the rotors, they do not wear out.

However, the experience of Fonons Service Company, Ltd. has shown that it is not enough to turn off the detrimental effect of the abrasive particles on the rotor contact surfaces. It is necessary to create a contact surface of the rotor which would allow them to work in extreme conditions. The excessive wear out of rotor contact surface is the beginning of the problem chain. The most common cause of screw compressor airend

damage is the abrasive particles. Abrasive damages appear if various abrasive particles penetrate between rotors or if something goes wrong with oil injection and atomization between the rotors. Thereby a partial or direct contact between rotors appears, causing an intensive wear of rotors. The interruption of oil supply becomes the general cause of damaged rotors and other completing compressor parts.

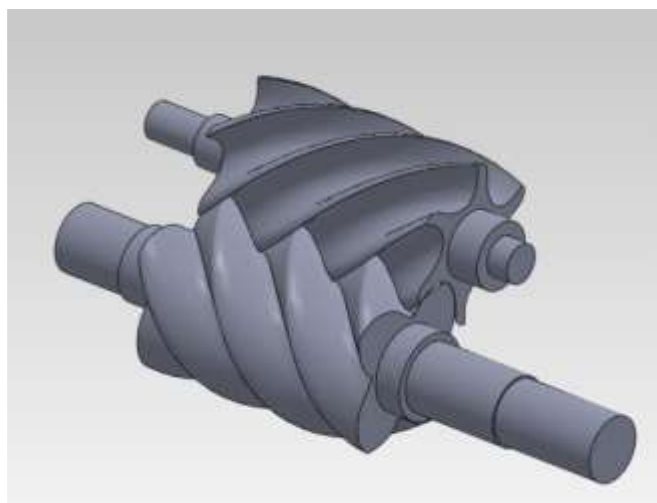


Figure 1. Oil flooded screw type compressors

Herewith, there is a necessity to increase wear resistance of compressor rotor contact surface against mechanical damages. Together with rotor contact surface improvements we could restore wear out joints. The main task of rotor profile restore is to get the initial parameters of the damaged surface. Before surface coating for low level ($0.5 \dots 10 \mu\text{m}$) wear of rotor profile, it is necessary to execute the mechanical surface treatment that in result liquidates wearing tracks, forming the correct profile geometrical form of rotors. In case of high level ($10 \dots 1000 \mu\text{m}$) wear a new contact surface should be build up with a new melted material layer which prevents wearing. The result of the mechanical treatment is the use of profiling tools, necessary compatible sizes and surface quality.

Rotor wear intensity (I_h) is a function which depends on a number of factors: material hardness (HV), plasticity (A), maximal endurance (R_m), surface topographies (R_a ; S_m1 ; S_m2 ; S_a) and a couple of less relevant factors. Nowadays, the industry has many different technologies for the improvement of surface mechanical properties. There is a constant increase in the number of cases where the latest technologies are used and superior and wear resistant layers have been applied on airend helical lobe rotors. New coated and restored rotors have much higher mechanical properties than uncoated ones. The major technological processes of coatings are melting, sputtering, deposition [2], [3]. The effectiveness of coating is characterized by the rotor wear resistance and overall economic efficiency of airend. Different coating materials are available nowadays. Materials may be homogeneous or heterogeneous. The foundation of this work gives an analysis of the surface quality of the rotor contact area, which was subordinated to processing. Sample rotor contact surface was coated with nano structured TiN layer, which was taken on a surface by using PVD technology, cathode arc deposition, and a thin coating was obtained. The TiN coating was deposited at the nano coating laboratory of Riga Technical University. The purpose of the coated layer is to increase the hardness of rotor contact surfaces, to improve surface quality, and to reduce wear intensity, thus obtaining a longer service time of the airend. High hardness and wear proof homogeneous material was coated on an explored test piece.

II. RESEARCH PART

The explored material samples were coated with nano structured TiN coating. TiN coatings have much better mechanical properties than basic material - higher hardness of the surface layer, resistance to wear and lower friction losses. That kind of layers is widely used in protecting coatings to protect products against aggressive environments and strengthen the contact surfaces of friction, as well as increase the product lifetime.

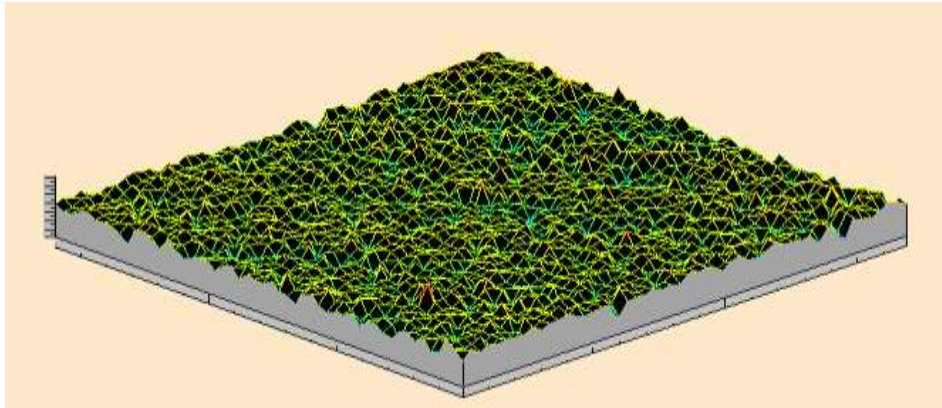


Fig.2. Surface 3D topography before coating

Titanium nitride is used in various industries for achieving higher wear resistance of wearing knots. However, screw compressor manufacturers are not using any coatings for oil flooded screw compressor rotors. TiN is used also as a top-layer coating, usually with nickel (Ni) or chromium (Cr). TiN is non-toxic and may also be used in medicine. For obtaining thin layer coating of such material, the physical vapor deposition methods (sputter deposition, cathode arc deposition or electron beam heating) [2] were used. High Young's modulus of TiN allows making thin coatings. TiN coating has significantly higher melting temperature (2930°C) in comparison with the carbon construction steel substrate (1400...1500°C). This allows screw rotor operation under heavy working conditions. Another quality of TiN is the low thermal expansion. The thermal regime of compressor fails frequently and occurs in dry contact operating cases. Physical vapor deposition technology allows forming functional property of coating material in the level of separate atoms and molecules [3]. The obtained coating in a vacuum allows extracting metal without admixtures and contaminations. Physical Vapor Deposition technology has many advantages:

- spacious speed range of coating;
- regular coated layer;
- coated layer with certain thickness;
- availability to form the crystalline structure of the coated layer.

The nature of the particle stream during the deposition technology depends on the particle type, energy and chemical activity, as well as on the substrate material. One of the most important processes in coating technology is surface preparation. Binding force of the coating material and the sample detail depends on the quality of the surface layer. To increase the adhesion nature of the materials, we can form it with understratum layer ≤ 0.1 mm of metal or their alloys (molybdenum, nickel, aluminium, titan and other) that promote the formation of hard chemical connection with the basic material. Substrate temperature is one of the most important parameters that govern the film microstructure. Substrate temperature controls the composition, structure and morphology of the film by affecting the adatom mobility on the substrate, as well as the rate of any chemical reaction occurring on the substrate [4].

The surfaces of rotor contact, which will be inferior to coating, get cleaned from dirt, subordinate to tooling. On the surface the necessary topography is created, which affects the binding of the sputtering material and wear resistance of the rotor contact surface. Before inserting the rotors in a vacuum chamber, they were degreased with a detergent. After fastening the air was pumped until the pressure level equalling $P = 6.7 \cdot 10^{-3}$ Pa. In order to increase the surface cleanness of the rotor contact surface, the vacuum chamber was used for the treatment with ion flow for about 3 minutes. Ion treatment removed upper layers where the most surface defects were. At the same time, it activated the overhead stratified surface, and chemical connections tore. After the surface treatment, the rotors were heated up for better binding of the materials. Afterwards the rotor contact surface coating was carried out through preparing operations accordingly to the case coating parameters: $P_N = 3 \cdot 10^{-3}$ Pa; $U_p = 140$ V; $I = 80$ A; $V_{ar} = 3 \cdot 10^{-3}$ Pa; $t = 20$ min. For equalizing the resulting stresses in the coating layer, the rotors were cooled in a vacuum chamber for 10 minutes.

In order to verify the quality of the coated surface, the analysis of the surface topography was executed by using Taylor Hobson Form Talysurf Intra 50 and Talymap Expert software. Due to TiN coating on the contact

surface of the compressors rotors, the main attention was paid to the influence of the parameters on rotor wear resistance and wear intensity.

TiN layer coated on surface gives certain characterizing parameters. The obtained data displays that the surface layers have clearly visible repeated increase in hardness HV and reduced parameter values of surface topography Sa, Ra, Sm. In this sample case, friction μ was increased. Examining the surface 3D topography image (Fig.3.), we can deduce that thin ($h=2.85\mu\text{m}$) coating does not smooth out processing tracks of the surface and unevenly placed outgrowths ($0.15\dots0.3\mu\text{m}$) appear on the surface. These growths appear during PVD processing. For better understanding of the surface forms and the character of ledges, rotor contact surfaces were exposed to the analysis of surface quality that was executed by the atomic force microscopy. The analysis of the surface topography with AFM was performed in a nano level where we can estimate the surface topography much deeper. Solver P47-PRO AFM with NT- MDTNova information processing program was used for scanning. The scanning was executed in several modes: contact, noncontact and in the mode of force modulation using CSG, NSG, and FMG type probes. Examining the surfaces by AFM (Fig.6) showed uneven surface that had already been testified by the analysis of surface 3D topography. On the surface, higher and lower ledges of different forms were found ranging from $140\dots330\text{nm}$, as well as cavities. AFM output surface in the mode of contact b) AFM 3D topography.

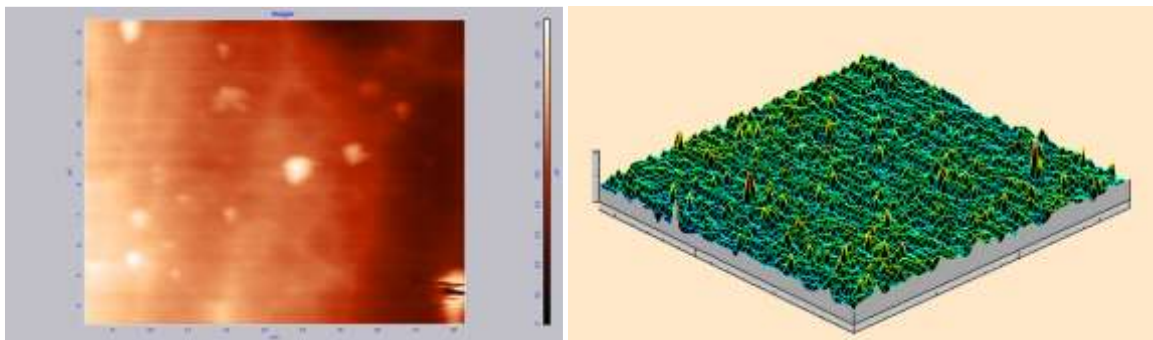


Fig.3. Surface 3D topography after coating

The forms of ledges have a diamond shape, whereas cavities – circular shape. These ledges create the porosity of coating. These are the microdroplets of titanium. The microdroplets appear when the cathode arc method in the environment of vacuum is used. Such amount of microdroplets in the investigated coating resulted from the low temperature of the substrate during the deposition that could not alloy the coating material. The substrate temperature also has a significant influence on the coating microstructure and its adhesion; the influence increases with the rise of the temperature [5], [6]. The mechanical processing of this layer may produce the detachment microdroplets.

REFERENCES

- 1) Сакун И.А. Винтовые компрессоры – Ленинград: Машиностроение, 1970;
- 2) Tracton A.A. Coatings technology – USA, Taylor & Francis Group, 2007, 371p;
- 3) Asthana R., Kumar A., Dahotre N. Materials science in manufacturing – Elsevier, 2006, - 630p. Harsha Sree K.S., Principles of physical vapor deposition of thin films - Elsevier, San Jose State University, CA, USA, 2006, - 1160p.;
- 4) Krella A., Czyzniewski A. Cavitation erosion resistance of
- 5) nanocrystalline TiN coating deposited on stainless steel – Elsevier, published in Wear, vol. 265, 2008, 963-970p.;
- 6) Carvalho N.J.M., Zoestbergen E, Kooi B.J., De Hosson J.Th.M. Stress analysis and microstructure of PVD monolayer TiN and multilayer TiN/(Ti,Al)N coatings – Elsevier, published in Thin solid films, vol. 426, 2003, - 179-189p.;
- 7) Zaytsev D., Development of wet compressor for applications in compression-resorption heat pumps, Ph. D. Thesis, Delft University of Technology, The Netherlands, 2003, 208p.;
- [8] Ferreira Carlos A. Infante, Zaytsev D., and Zamfirescu C., Wet Compression of Pure Refrigerants - 2006., International Compressor Engineering Conference. Paper 1778.