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Aviation ground equipment internal combustion engines valve seats resource increasing by wear resistance of composite materials

Improvement of power plants of aviation ground equipment with new wear-resistant materials will significantly extend their resource, increase fuel efficiency, safety and economy. All this requires a thorough study and determination of the economic benefits of using such materials. With the constant increase in the load of engine installations, scientific interest in the wear resistance of major components of engines of aviation ground equipment assemblies is also growing.

Introduction. Over time, the requirements for efficiency, environmental friendliness, reliability and resource increasing [1] of internal combustion engines (ICE) of aviation ground equipment (AGE) are constantly increasing. In particular, almost all modern engines have two inlet and two exhaust valves to increase fuel efficiency due to improved mixture formation and more complete purging of the cylinder.

This significantly improves the engine performance, but at the same time places increased demands on the wear resistance of the valve head-seat system, especially the exhaust group, which has an elevated operating temperature. Otherwise, the loss of tightness of the valve mechanism completely offsets the positive impact of the design improvement in the form of double valves in the cylinder [2].

Previously, large number of materials for ICE of AGE valve seats have been suggested. This study is aimed at investigating the wear resistance of a composite material based on titanium carbonitride and determining the possibility of its use for valve seats of ICE of AGE. In order to investigate the wear resistance of a composite material based on titanium carbonitride intended for valve seats of modern ICE of AGE.

Main text. Since the composite metal-ceramic carbonitridotitanium materials were intended to work as valve seats of ICE of AGE, the modes of tribotechnical tests were chosen to simulate the conditions of operation of the "seat-valve" pair under the most stable operating conditions of an ICE of AGE. Namely, at an oscillation frequency of 15 Hz, which corresponds to the average rotational speed of the camshaft, which exerts a cyclic action on the valve for a rotational speed of 1800 rpm in accordance with the nominal operating mode of the ICE of AGE and a load of 500 N, which corresponds to a friction contact area load of 10 MPa, since this is the maximum pressure on the contact area of the valve-seat system. The amplitude was 10 μm, the test base was $5 \cdot 10^5$ cycles - these indicators remained constant and unchanged throughout the entire series of tests of materials of different content, and the other factors varied for the optimization purposes of technological solutions. The tribotechnical tests were carried out according to the "plane-plane" scheme on a modified friction machine MFK -1, which allows controlled heating of the friction zone and measurement of the average value of the friction coefficient. Steel 40X9C2 (HRC 75-80) was chosen as the counterbody material to study the possibility of using a TiCN-(Ni-Fe) composite in a seat-valve friction pair. Two types of modes were investigated: at a constant temperature T=const, to study the effect of the composite composition on the binder and refractory component, and the composite composition C=const, to study the effect of temperature in the tribocontact zone on the wear rate and friction coefficients, respectively.

To study the effect of the ratio of metal binder (Ni-Fe) and refractory component TiCN, materials of three contents were synthesised and the technological features of the formation of these materials under vacuum sintering conditions were determined.

The results of tribotechnical tests of composite materials at a constant component content showed that with an increase in temperature, the wear rate changed its behaviour for different cases of composite composition. Thus, in the operating temperature range for the inlet valve (450°C), the best characteristics of 11.2 μm were shown by sample 2, and for the outlet valve (900°C), the minimum wear values of 8.4 μm were also shown by sample 2, which contains 50% of the binder.

The friction coefficients of the composite materials tested vary from 0.14 to 0.29 depending on the temperature in the friction zone. For the selected materials, in the case of the exhaust valve, the friction coefficient in the test modes is 0.23, and for the exhaust valve, the friction coefficient is 0.12, which indicates that the materials will operate in the antifriction zone, and this will not lead to significant scoring, adhesion and distortion of the sealed surface.

Tests of samples made of composite material at a constant temperature in the tribocontact zone showed a qualitative effect on the tribotechnical characteristics of changes in the composition of the composite material components (which can occur, for example, in the event of their burnout). Thus, with an increase in the metal bond content, the wear rate passes through the minimum at any test temperature. This graph finally allows us to choose the composition of the composite material: for the inlet valve operating at 450°C, the minimum value is at the point of 50% bonding, and for the outlet valve operating at 900°C, the minimum value is also at the point of 50% bonding.

The friction coefficients during the tests at constant temperatures under tribological contact conditions show the following: for the inlet valve, a friction coefficient of 0.23 will be provided at a binder content of 50%, and for the outlet valve, a friction coefficient of 0.12 will be provided at the same binder content of 50%. The wear intensity of the counterbody during the tests did not exceed 10 μm for a test base of $5 \cdot 10^5$ cycles.

A general view of the friction surfaces at a magnification of 50, obtained with a laser scanning microscope LSM, which has digital surface relief processing and automatically calculates the amount of wear. It also provides high-quality images for visual analysis of friction surfaces.

Analysing these results, the following conclusions can be drawn. It shows a friction track of a material containing 50% metal bonding and tested at a temperature of 900°C. Under these conditions, it showed a wear rate of 8.4 μm for $5 \cdot 10^5$ fretting cycles. It is worth noting the formation of free carbon inclusions on the surface of the sample due to the release of TiCN from the carbide part, which leads to a decrease in the friction coefficient to 0.12. and it shows the friction track of a sample that also contains 50% of a metal bond and 50% of a refractory component. The sample of this particular composition showed the lowest value of fretting wear intensity 11.2 μm for $5 \cdot 10^5$ fretting cycles at a test temperature of 450°C. The friction surface is also saturated with the release of free carbon due to tribochemical transformations. This leads to the release of carbon, which is known to have high antifriction properties and reduces the friction coefficient to 0.23. To find out the mechanisms for improving the wear resistance of this sample, its friction surface was additionally examined by micro-X-ray spectral analysis. It is worth noting that the surface quality after the tests was not lower than class 4, which is considered satisfactory for the seat-valve of ICE of AGE sealing zone for its tightness.

The rest of the friction tracks shows either too worn or has too many adhesion areas that distort the surface quality of ICE of AGE and decrease it`s resource. To explain the results obtained, the friction surfaces of the samples made of the developed composite materials were examined using РЭМ-106И electron microscope. The structure of the friction zone of the composite materials at a magnification of 200 is a surface of heterogeneous morphology without significant damage, which has two characteristic areas: continuous films covered with a network of microcracks, and areas of the original structure of the composite, where these films have already peeled off.

These island areas were examined more closely and it was found that the film structure is a continuous complex oxide film containing titanium, nickel and iron oxides. This is evidenced by the results of elemental micro-X-ray spectral analysis.

This ternary oxide system of amphoteric metals in a certain stoichiometric ratio creates a higher oxide compound with free oxygen exchange between the metals participating in this system. This structure has a strong adhesive bond and is reliable as a "third body", protects against adhesive interaction and minimises wear [3].

In those places where there is a deviation from the stoichiometric composition of the three-component oxide system, it loses its amorphous properties and peels off from the surface and the original components of the composite are observed there: the refractory component and the bond. Such a wear mechanism is described in scientific works [4, 5], it belongs to the oxidation type and is favourable from the point of view of the wear resistance of the friction pair, since the interaction products in the form of released carbon play the role of a solid lubricant [6].

Conclusion. Thus, as a result of the synthesis of the composite material and its testing for wear resistance under conditions close to the operation of ICE of AGE, its composition was determined to be such that it intensifies the oxidative wear mechanism and is optimal for its surface strength, it corresponds to 50% of the binder. This applies to exhaust valves operating at temperatures close to 900°C, and for inlet valves, the amount of binder can be increased to 80% to save the refractory component. So, described strengthening of working surfaces of ICE of AGE provides it`s resource increasing during operation.

References

1. L. B. Pryimak, A. G. Dovgal Technologies of Resource Management for Aircraft Ground Support Equipment and Airport Equipment / Guide to Laboratory Works. – K.: NAU, – 2019. – 40 p.

2. О. А. Тамаргазін, А. Г. Довгаль, Л. Б. Приймак Моделювання зносостійкості композиційного покриття для поверхонь поршнів ДВЗ авіаційної наземної техніки. // Двигатели внутреннего сгорания. – Всеукраинский научно-технический журнал., – № 1. – 2018. – С. 67–73.
3. L. B. Pryimak, A. G. Dovgal, O. A. Tamargazin Fundamentals of Tribology Studies of Aircraft Ground Support Equipment and Airport Equipment/ Guide to Laboratory Practical Works. – К.: NAU, – 2018. – 36 p.
4. Енергетична концепція стабілізації стану трибосистем / Свирид М.М., Кравець І.А., Приймак Л.Б., Занько С.М., Паращанов В.Г. Проблеми трибології. – 2008. – №4 (50). – С. 13-18.
5. Л. Б. Приймак, А. Г. Довгаль, В. В. Варюхно Дослідження зносостійкості нових композиційних матеріалів на основі оксиду алюмінію спеціального триботехнічного призначення, Надтверді матеріали, 2022, № 5, С 39-47.
6. А. Г. Довгаль, В. В. Варюхно, Л. Б. Приймак Влияние структурообразования композитов системы $SiC–Al_2O_3$ с различными активационными добавками на их прочность и твердость. // Сверхтвердые материалы, - 2020, - № 2.- С 57-64.