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TECHNIQUE OF TESTING ON FRETTING AT THE SPHERE-TO-PLANE CONTACT

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The methodology of conducting tests on fretting at the sphere-to-plane contact was developed for the wing mechanization unit, namely for screw-nut pair with intermediate balls. Wearability tests were conducted on a modified installation МФК-1, the feature of which is the designed holder that allows testing with real balls. It was found that at the dry contact of ШХ-15 and 30Х2НВФА materials, surface microcracks are formed due to welding of microasperities areas and their rupture under the influence of vibration.

Keywords: fretting, mechanization units of aircraft wing, sphere-to-plane contact, topography of surfaces, wearability, ШХ-15, 30Х2НВФА.

Розроблено методику проведення випробувань в умовах фретинг-корозії при контакті куля – площина для вузла механізації крила, а саме для пари гвинт-гайка з проміжними кульками. Описано випробування на зносостійкість, які проводили на модифікованій установці МФК-1. Розглянуто розроблений утримувач, який дозволяє проводити випробування з реальними кульками. Установлено, що при сухому контакті матеріалів ШХ-15 та 30Х2НВФА на поверхні утворюються мікротріщини внаслідок зварювання ділянок мікронерівностей та їх розриву під дією вібрації.

Ключові слова: вузли механізації крила літаків, зносостійкість, контакт куля–площина, топографія поверхонь, фретинг-корозія, ШХ-15, 30Х2НВФА.

Introduction

At present, research in the field of tribology and mechanics of contact fracture of elements and units at variable load modes represents current direction. It causes significant amount of operational failures of technical objects of various purposes.

Fretting takes up to 50% of wear of aircraft parts.

According to [1], among the main operational defects in domestic and foreign aircraft gas turbine engines (GTE), fretting takes up to 60% of all types of wear. Fretting develops in GTE in various elements of connection:

– bolted;
– spline;
– dowel joints;
– in different press fittings of elements, hinged places of locking connections;
– on contact surfaces of shroud flanges of blades, fittings of turbine and compressor blades, including fittings of fan blades.

Destruction due to fretting is observed in the form rubbing, dents, caverns, microcracks and pits filled with powder-like products of wear. All materials in almost all kinds of environment and conditions are subjected to the influence of fretting.

One of the most important aircraft units are aircraft wing mechanization units, which are designed to create additional lift at such responsible stages of flight as takeoff and landing.

Flap and slat actuators, that are wing mechanization units, are used to move flaps and slats after takeoff and before landing. The actuator is a screw-nut pair with intermediate balls which are used to transmit force from the screw drive to the nut attached to flap assembly bracket. The bracket is moved with the help of wing mechanization rail and moves flap on a certain trajectory. Failure of any actuator in flight leads to a special situation.

Structurally, friction pair rail-roller and screw-nut transmit the same force necessary for extension and retraction of wing mechanization. Therefore it is interesting to analyze the work and damage of flap actuator unit, especially because the friction pair rail-roller is subjected to significant damage as a result of vibration during its operation.

Analysis of researches and publications

Recently, much of modern literature [1, 2, 3, 4, 5] is dedicated to the questions of development of methodologies of conducting tests on wearability of different coatings and metals. Improvement of existing and creation of new methodologies of testing of various structural materials for friction and wear is one of the important directions of improvement of tribotechnical reliability of various machines and mechanisms.

Thus, authors [6] use friction machine Setta-Shell, which allows conducting tests in the mode of sliding friction as well as rolling friction with the usage of liquid and plastic lubricants. Friction force, scoring index, critical load, welding load and other parameters are measured at testing.

Also, analysis of sources showed that the authors [4] use the installation using reciprocating rotational movement at the sphere-to-chamfer scheme. Installation is made on the basis of table drilling machine. Due to radii difference of position of fingers of traction on the pulley, rotational movement of pulley using traction is converted to reciprocating motion, placed on the spindle of the installation unit. The load on the friction unit is transmitted through the lever by means of cargo. Installation allows testing of steel, alloys and composite materials in a wide range of loading conditions.

According to [2], for the fretting research (alternating dry friction) special friction machine was made (contact – cylinder – cylinder). This friction machine allows for the following test conditions on fretting:

– contact pressure of 1 GPa;
– frequency up to 50 Hz;
– amplitude from 0.1 to 2 mm;
– temperature of environment from 20 to 8000°C.

Value of wear was determined by measuring the chord of wear on a cylindrical contact surface of the sample.

In its turn, authors [6] developed a microtribometer of reciprocating type, operating at low loads. They have chosen sphere-to-plane scheme that allows to accurately calculate the area of contact spots and the values of contact pressure and to prevent the inevitable effects of inclination of indenter and plate on geometry of contact. Testing with high frequency and small amplitude of sample motion gives an opportunity to study dynamics of fretting.

The authors [5] studied the phenomenon of fretting on electrical contacts of low current circuits of modern digital equipment [7]. The main subject of investigation here was the impact assessment of additional thickness of the contact pair coating and contact pressing force on the rate of resistance growth at fretting.

It is interesting that in this work there was no investigation of fretting, depending on the forms of contacting surfaces.The contact group represented itself as a sphere-to-plane pair, which, after the beginning of testing was actually reduced to a contact on plane. And the current [8] requires to conduct research of tangent planes (fig. 1).

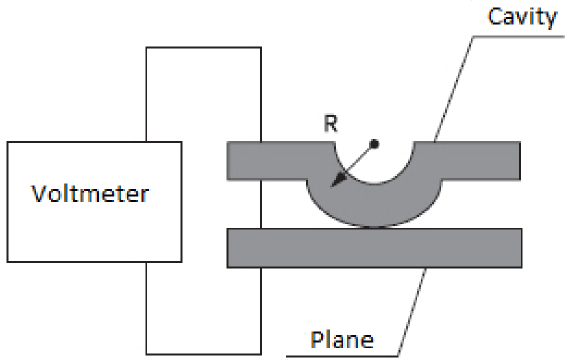


Fig. 1. A scheme of testing on fretting taking into account changing of electrical contacts of low current circuits

It is important to consider the size and cost of installation at the development of friction machine. Samples for friction must have a smaller size, but also be sufficient in dimensions for the required type of friction, which installation realizes. When beginning a research, the development of methodology should be conducted in accordance with two requirements. On the one hand, the simulation of sliding friction in the laboratory should maximally correspond to conditions in real structures. On the other hand, methodology should enable comparison of obtained results with data from other works [9].

The aim of work is to develop methodology of conducting tests on fretting at the sphere-to-plane contact.

Methodology of testing on wearability

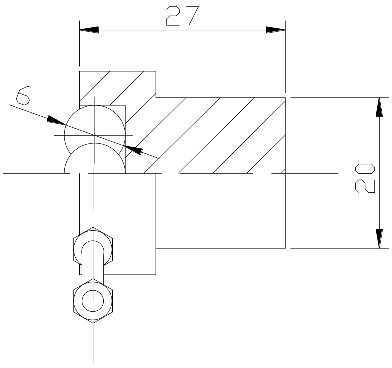
Wearability tests were conducted on a modified installation imitating vibration МФК-1. The essence of the method is that the movable counter sample which touches the immovable cylindrical sample by its end face at a given load is driven by reciprocating rotary motion at specified amplitude and frequency.

The installation allows conducting comparative tests of steel, alloys, coatings, composite materials in process of sphere-to-plane contact in a wide range of loading conditions:

– frequency 25–35 Hz;
– loading N=10–200 kg;
– amplitude 25–500 mcm.

The peculiarity of the installation is the developed holder, which allows conducting tests with real balls.

Holder *3* is a cup-like sleeve, which by means of screws *2* rigidly fixes three balls *1* (fig. 2).



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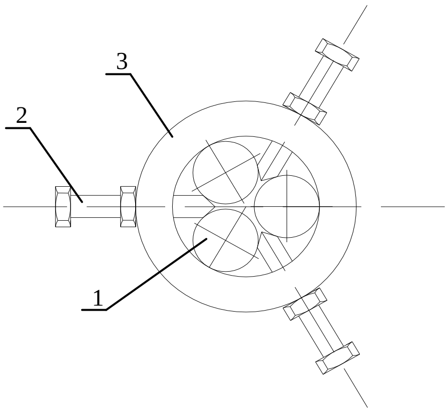


b

Fig. 2. Countersample scheme for testing:
a – side view;
b – front view.
1 – ball;
2 – screw;
3 – holder

Thus, sphere-to-plane contact is formed at which three balls are simultaneously involved in testing on fretting.

The linear wear of immovable sample using optimeter IKB of vertical type was determined. The criterion of wear resistance was the maximum averaged depth of point contact.

Wearability tests

Sample was made of the same material as the screw (steel 30Х2НВФА using further nitriding in accordance with the requirements for the product).

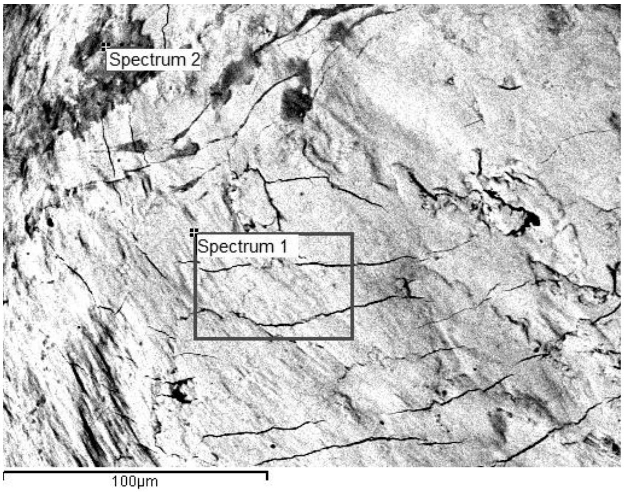
Counter sample in fig. 2 is represented by three balls 6 mm in diameter, made of steel ШХ-15.

Investigation was done at axial load of 100 kg and amplitude, equal to 200 microns. Frequency was equal to 30 Hz. The base of test was $3{\cdot}10^5$ cycles. Temperature of conducting tests – 293 K. The tests were carried out in the air and with the usage of plastic lubricant ЭРА.

The results of these tests show that at dry friction wearability of nitrided steel 30Х2НВФА is in 8.5 times lower than when using lubricant ЭРА.

Topographies of damaged surfaces at tests without lubricant and with lubricant ЭРА are represented on fig. 3.

As it can be seen, at dry friction entire surface of steel is covered with microcracks that are formed due to cold welding of balls with 30Х2НВФА surface.



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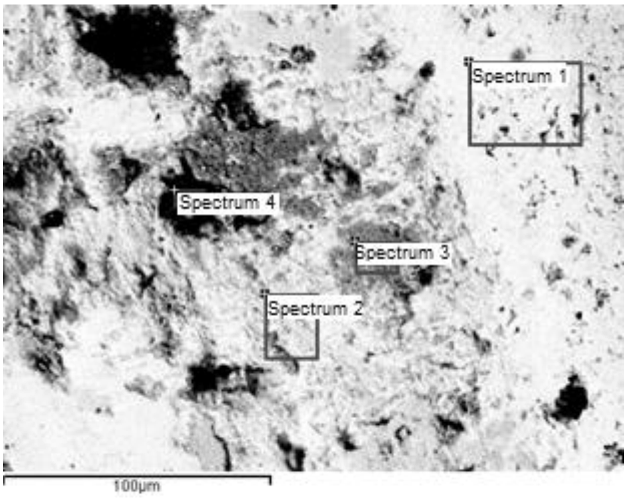

b

Fig. 3. Topography of damaged surface of nitrided steel 30Х2НВФА at testing without lubricant (*a*) and with lubricant ЭРА (*b*)

Topography of surface at testing with lubricant ЭРА looks smoother without crack formations. There are several specific areas on the surface where elemental composition was determined.

Elemental composition was determined by scanning the surface of friction paths on bitmap, scanning electron microscope CamScan 4D with the help of microspectral x-ray analyzer INCA 200 Energy. Secondary and reflected back electrons were used in the analysis.

Tables 1 and 2 show that dark spots on the friction surface are probably products of oxidation of steels 30Х2НВФА and ШХ-15. However, in these areas there is an increased amount of carbon about 50%, which indicates possible formation of compounds with lubricant or insufficient cleaning of friction surface.

Lightest areas in fig. 3, *b* correspond to material that is most close to the primary steel before testing on friction. Intermediate gray spots Spectrum 2 and Spectrum 3 correspond to an intermediate material between the primary and oxidation, which has undergone. In these areas there is change of chemical elements (such as Cr, Fe, Ni, W) toward oxidation.

Conclusions

1. The methodology of testing in conditions of fretting in process of sphere-to-plane contact is developed.
2. The tests were conducted for the friction pair screw-nut of the element of wing mechanization of modern airplanes of Antonov type.
3. The tests show that at dry friction the wearability of nitrided steel 30Х2НВФА is in 8.5 times less than with the usage of ЭРА lubricant.
4. The topography of surfaces show the appearance of cracks on nitrided steel 30Х2НВФА surface at tests without ЭРА lubricant at sphere-to-plane contact in conditions of fretting.
5. One should regularly check for lubricant on the working surface of screw pair and periodically renew it. Insufficient lubrication of friction surfaces or lubricant drying out may lead to the contact of friction pairs without lubricant which causes cold welding on the surface as the result of high contact stress and consequently formation of microcracks.

Table 1. **Chemical composition of friction surface when testing without lubricant, %**

Spectrum	N	O	Si	Cr	Fe	Ni	W	Total
Spectrum 1	9,1	0	0,39	1,85	85,47	1,5	1,67	100
Spectrum 2	3,54	23,1	0	1,42	69,73	1,24	0,96	100
Maximum	9,1	23,1	0,39	1,85	85,47	1,5	1,67	-
Minimum	3,54	0	0	1,42	69,73	1,24	0,96	-

Table 2. **Chemical composition of friction surface when testing with lubricant ЭРА, %**

Spectrum	C	N	O	Si	P	Ca	Cr	Mn	Fe	Ni	W	Total
Spectrum 1	15	5,8	6,62	0,44	0,61	0	1,55	0	68,87	1,12	0	100
Spectrum 2	22,13	2,33	5,36	0	0	0	1,42	0	66,98	1,03	0,75	100
Spectrum 3	21,09	1,32	12,22	0	0,38	0	1,1	0,36	62,7	0	0,81	100
Spectrum 4	53,42	1,02	16,7	0	0,42	0,17	0,72	0	27,55	0	0	100
Maximum	53,42	5,8	16,7	0,44	0,61	0,17	1,55	0,36	68,87	1,12	0,81	-
Minimum	15	1,02	5,36	0	0	0	0,72	0	27,55	0	0	-

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