Biomaterials

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Analysis of the fretting corrosion deposits on biomaterials

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Metal implants in living organisms are constantly exposed to degradation of the metal surface. All processes that occur, such as wear, corrosion and damage, are covered by the concept of tribocorrosion. Tribocorrosion is a general term that covers all mechanical (wear) and chemical (corrosion) interactions that cause degradation of materials in relative motion [1]. Fretting corrosion is a type of tribocorrosion that occurs in area of contact of two materials in presence of repetitive relative movement under load. Fretting occurs when the environment takes part in the destruction of the metal. Repeated (frequent) oscillatory motion occurs in orthopaedic implants when the multicomponent implants are placed in the limbs carrying weight, or when the fixation is achieved by screwing a metal plate to a bone in places where connections can become loose [2]. There are small oscillation amplitudes in corrosive environment of bodily fluids, which in the beginning causes strengthening of the contact surfaces and cyclic flow of subsurface. In this case, we have the metal-to-metal contact. The testing in this study was carried out using the device for testing fretting corrosion that was designed at the Department of Production Engineering and G&G. The testing device enables the movable part with the tip in shape of hemispherical pin to perform rotationally oscillating movement along the groove of a fixed sample in the shape of a hemisphere, in order to simulate the behaviour of plate and screw in fixated bone, in case of a loosened screw. The tests were performed in physiological saline containing 9% NaCl (pH 7.4) heated to 37°C to simulate the conditions that exist in a living organism. Test was performed for 21600 cycles for all materials.

Moving part is made of stainless steel 316L, for all cases, and three materials were tested as a fixed sample, stainless steel 316L, CoCrMo alloy of cobalt and titanium alloys TiAl6V4. The chemical composition of the investigated materials is given in Table 1. The tested surfaces were mechanically polished and initial mean roughness (Ra) of stainless steel and cobalt alloy was 0.03 μm, and of the titanium alloy 0.08 μm Metals used for implants are highly resistant to corrosion, due to the creation of the passive oxide layer on the surface, but due to fretting corrosion and cyclic movement of the surface, passive film gets destroyed. Metallic implants are exposed to bodily fluids that are corrosive environment, and so the behaviour of the metals changes significantly and their corrosion resistance reduces [3]. On the surface of the stationary part, a dark brown corrosion deposite was created in all three materials, which has been tested using a scanning electron microscope Jeol JSM 6460LV, with Oxford EDS analyzer instrument, the INCA X-sight program. The test results of EDS analyzer deposite are presented in tables and by energy dispersive X-ray spectrum with peaks of elements present. The tests were conducted for several locations in a sample. The analyzed surface layer of stainless steel consists of oxygen, chromium (14 to 27%), and nickel (7 to 14%.) In one location sulphur appears, up to 1%, and also aluminium Al (4.8%), Fig 1 On the surface of cobalt alloy, corrosion layer had iron present in large amounts (48.96%), which indicates the presence of mechanical wear in moving part made of stainless steel. It also has a layer of nickel (up to 7%), which probably also comes from stainless steel, Fig.2. The surface layer of titanium alloy had small amounts of Cl (0.9%), probably originating from the saline. Chromium (up to 2%), Ni (1.7%) and iron (7%) also occur, indicating again the existence of mechanical wear of moving part made of stainless steel caused by metal to metal contact, Fig.3 The surface layers of cobalt and titanium alloys show presence of iron and nickel, which indicates the highest surface damage of moving stainless steel part.

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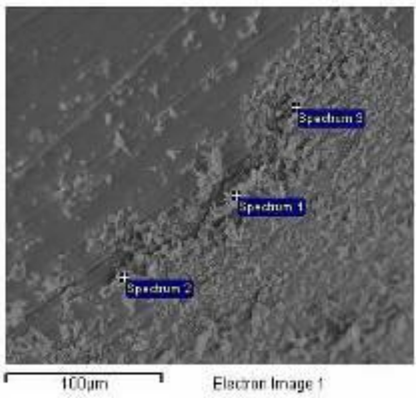
Sastav	C	Cr	Ni	Si	Mn	Mo	Co	Fe	Al	V	Ti
316L	0,02	17,67	14,3	0,50	1,87	2,72	0,027	Bal.			
CoCrMo	0,43	27,2	1,50	0,92	0,8	5,23	Bal.				
TiAl6V4	0,02							0,14	6,08	4,04	Bal.

Table 1. Chemical composition of tested materials



Sp1	C	O	Al	Cr	Fe	Ni
Wt%	19.55	10.20	4.80	26.86	31.66	6.93

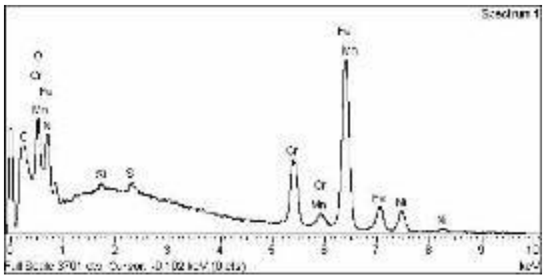
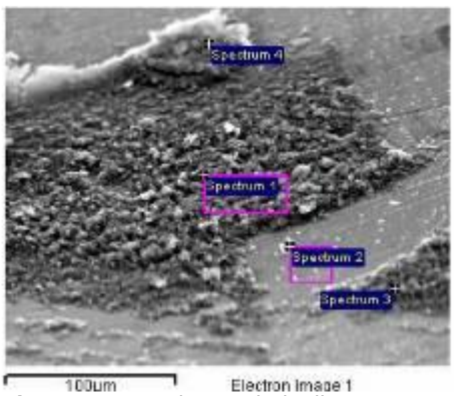


Figure 1. Deposit on stainless steel



Sp 4	C	O	Cl	Cr	Fe	Co	Ni	Mo
Wt%	12.25	21.0	0.22	20.10	30.3	3.86	7.16	3.99

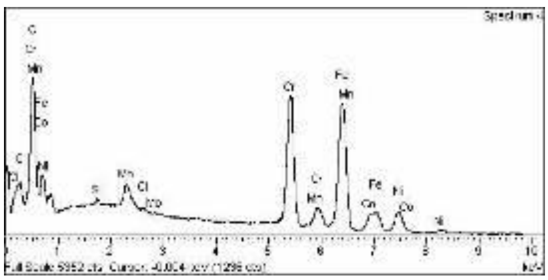
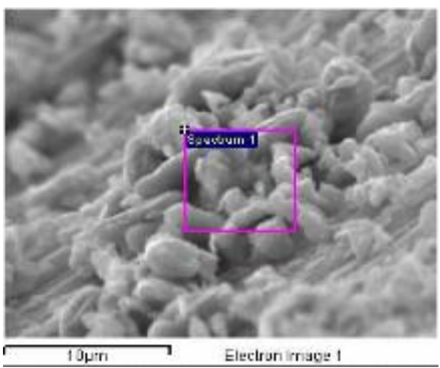


Figure 2. Deposit on cobalt alloy



	C	O	Al	Ti	V	Cr	Fe	Ni
Wt%	6.96	13.68	4.29	60.97	2.80	2.11	6.95	1.68

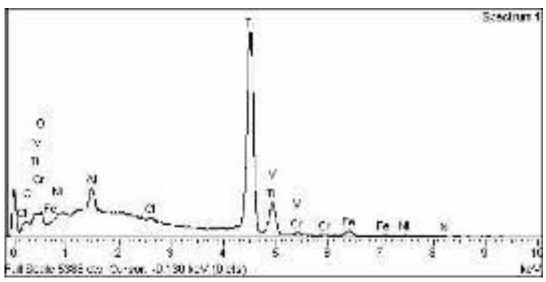


Figure 3. Deposit on titanium alloy