

CORROSION BEHAVIOR OF METALLIC SURGICAL IMPLANT REX 734 - CoCr ; PITTING, CREVICE AND GALVANIC CORROSION EVALUATION

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INTRODUCTION The corrosion behavior of combinations of materials used in orthopedic implant REX 734 stainless steel and CoCr alloy has been investigated. This couple of alloys is quite often used in hip prosthesis, where a ball head of CoCr is tapered inter operatively on a hip stem made of REX 734 steel.

The resistance against pitting or crevice corrosion of two alloys REX 734 and CoCr was evaluated according to the standard ASTM F746-87 (re-approved 1994). The galvanic corrosion of coupled REX / CoCr was evaluated by the direct measurement of the corrosion current of the couple and by prediction of the galvanic current using mixed potential theories and potentiodynamic polarization curves (ASTM G71-81).

MATERIALS and METHODS: Nominal compositions in % weight of the alloys studied are

a) CoCr alloy ISO 5832-12: C 0.085, N 0.15, Cr 27.5, Mo 6.20, Mn 0.7, Si 0.75, Fe < 0.65, Ni < 0.85, Co balance, and

b) REX 734 steel ISO 5832-9: Nb 0.25-0.8, N 0.25-0.5, Cr 19.5-22, Mo 2-3, Mn 2-4.25, Ni 9-11, Si max 0.75, C max 0.08, S max 0.01, P max 0.025, Cu max 0.25, Fe balance.

a) Pitting and crevice corrosion evaluation : The samples for the REX 734 were cut from an orthopedic prosthesis; the samples for CoCr were taken from a bar of diameter 8 mm. The samples were not subjected to any special treatment such as heat treatment, hot or cold working, or passivation treatment. The surface of sample cylinders were metallographically polished with 600-grit paper. The collar used to create the crevice was machined from polytetrafluoroethylene of medical devices purity. The total exposed surface area A_T of the specimen before placement of the collar was 168.8 mm². The crevice area A_C (area on the internal surface of the collar) was 39.3 mm².

b) Galvanic corrosion evaluation : The test samples were in the form of small discs (diam. 8 mm), connected to a central stem in order to

establish the electrical contact. They were metallographically polished with diamond

paste (2 μ m). The ratio of anode surface to the cathode surface was equal to one.

Test milieu: 9 g/l NaCl in de-ionized water (18 M Ω .cm); temperature 37° \pm 1°C. The pH before and after the test was 5.7 \pm 0.2.

Test equipment: the electrochemical setup was controlled by an EG&G PAR model 273A in autoexecute running experiments Model 352/252 SoftCorr II (EG&G Instruments). The current versus time in the galvanic coupling measurement was controlled by an EG&G PAR model 273A potentiostat, which was modified according to the supplier's instructions to be used as a zero resistance ammeter. This modification permitted measurements of the current variation down to 100 pA.

RESULTS:

a) Crevice and pitting corrosion: From the analysis of electrochemical parameters measured and the optical examination of the surfaces below the collar we deduce the pitting or crevice potentials to be 450 mV vs. SCE for the CoCr alloy and, respectively, 500 mV vs. SCE for the REX 734. The REX 734 specimen showed traces of corrosion below the collar. The CoCr alloy revealed a discoloration of the surface.

b) Galvanic corrosion : The coupled REX 734 / CoCr materials exhibit negligible galvanism ; the current generated by the galvanic cell remained low (of the order of nA). There is no risk of triggering the phenomenon of crevice corrosion (crevice potential of the alloys : 450 and 500 mV SCE and couple potential : 10 mV SCE). The values of i_{couple} and E_{couple} were calculated according to the mixed potential theory. The data for predicting galvanic parameters from potentiodynamic polarization curves for REX 734 steel and CoCr alloy (by rotating electrode technique) are also very low (of the order of nA).

DISCUSSION & CONCLUSIONS: Table 1 summarizes the results of the galvanic coupling as obtained by the various measurement techniques. All the different techniques lead to the same conclusion that the galvanic currents (whether measured or calculated) are low.

Table 1. Summary of electrochemical parameters, galvanic current and potential coupling.

Techniques, Methods	$E_{couple\ corr}$	$i_{couple\ corr}$
	<i>mV SCE</i>	<i>nA/cm²</i>
Direct measurement	-	6
	1	.
	0	5
		0
Application of the mixed potential theory	+	3
	2	2
	1	.
		6
		4
Polarization curves; (fix electrode)	-	9
	2	6
	3	.
	7	6
		2
Polarization curves; rotating electrode	-	2
	2	4
	1	.
	1	3
		6

With 500 mV for the CoCr and 450 mV for REX 734, the crevice potential of both materials examined are very high. In consequence, there is no risk for a crevice corrosion caused or amplified by the galvanic coupling.