Some property data for nickel-cobalt electrodeposits

Nickel–cobalt deposits have been shown to be suitable for use in high strength electrojoining applications. Earlier work described the process of electrojoining in detail and included some property data and application information [1, 2]. As part of a continuing study aimed at determining the suitability of nickel–cobalt deposits for use as structural members of a plated joint, Poisson's ratio was needed. This information could not be found in the literature; therefore, data were obtained in our laboratory. Concurrently, a number of other mechanical properties were obtained and the influence of heating the deposits was also evaluated.

The composition and operating conditions of the plating solution are presented in Table I. Composition of the deposits produced using these conditions was 40 to 50% cobalt, and the remainder was nickel. Earlier work showed that mechanical properties were constant in this range [1].

TABLE I Nickel–cobalt solution formulation and operating conditions

Nickel (as nickel sulphamate	73.5 $g l^{-1}$
Nickel (as nickel bromide)	3.7 $g l^{-1}$
Cobalt (as cobalt sulphamate)	8.0 $g l^{-1}$
Boric acid	30.0 $g l^{-1}$
Surface tension	26–31 dyn cm^{-1}
Temperature	49° C
Current density	268 A m^{-2}

Solution volume was 105 litres. For more detail on operation of the solution see [1].

Tubes were electroformed by plating on aluminium rods 12.1 mm (0.475 ins.) in diameter, machining to size and then dissolving the aluminium in caustic solution. Length of the finished electroforms was 102 mm (4 in.); wall thickness was 1 mm (40 mil) on the ends except for a 38 mm ($1\frac{1}{2}$ in.) reduced section in the middle which was 0.5 mm (20 mil) thick.

Uniaxial and biaxial tension tests were run by threading adaptors into the ends of electroformed tubes and applying an axial force for the uniaxial tests and internal oil pressure and axial force for the biaxial tests. By applying a prescribed combination of axial load and internal oil pressure, five different axial to hoop tension stress ratios were obtained. The outside surface strains at the centre of the specimens were measured by means of four biaxial strain gauges spaced 90° apart around the circumference. The data were processed by using a special program on a CDC 6600 computer. This program averaged the four axial strain gauge readings and also the four hoop strain gauge readings and computed the ratio of the two averages. In the case of one-dimensional loading, i.e. only axial or hoop, this was Poisson's ratio.

Some specimens were heated at around 300° C and also included in the room temperature test program. In addition, other specimens were heated for varying periods of time at temperatures above 500° C and then tested only axially at room temperature.

Data presented in Table II show that the properties were essentially the same in the axial and tangential directions for as-plated Ni–Co alloy. The strength in the axial direction was 1560

TABLE II Room temperature properties of nickel–cobalt electrodeposits*

Test type	No. of	Modulus of elasticity		Poisson's	Yield strength‡		Ultimate strength	
	tests†	(MN m^{-2} × 10^4)	(psi × 10^6)	ratio	(MN m^{-2})	(psi)	(MN m^{-2})	(psi × 10^3)
Axial	4	197	28.5	0.32	993	143 600	1560	225.8
Hoop	4	192	27.8	0.31	930	135 000	1410	204.3
1AX:2H§	2	–	–	–	–	–	728/1450	105.5/211
1AX:1H	3	–	–	–	–	–	1415/1415	205/205
2AX:1H	2	–	–		–	–	1428/689	206.8/100
After heating at 288°C for 72 h								
Axial	4	206	29.8	0.31	884	128 000	1284	186
Hoop	2	196	28.4	0.32	860	122 500	923	133.5

*Electroformed tubes 102 mm (4 in.) long with a wall thickness of 0.51 mm (20 mil). Deposit was 40 to 50 wt% Co.
†Reported data are the average values.
‡Determined by 0.2% offset method.
§Stress twice as high in hoop direction as axial.

TABLE III Axial property data for heated Ni–Co tubes*

Temperature	Time	Tensile strength†	
(°C)	(min)	($MN m^{-2}$)	(psi × 10^3)
540	80	614	89
540	255	592	85.9
540	480	592	85.9
620	60	562	81.4
620	270	549	79.5

*Electroformed tubes 102 mm (4 in.) long with a wall thickness of 0.51 mm (20 mil). Deposit was 40 to 50 wt % Co.

†All tensile tests were run at room temperature. Average of two tests for each value reported.

$MN m^{-2}$ (226 000 psi) and this agreed quite well with previously reported data [1]. Strength in the hoop direction was slightly lower at 1410 $MN m^{-2}$ (204 300 psi) but close enough to the axial data to be within experimental error of the test. This information coupled with data from variable axial to hoop tension tests (also in Table II) led to the conclusion that the material was isotropic in the as-plated condition.

Some specimens were heated at 288° C in an attempt to rid the material of some of the stress resulting from deposition [1]. As can be seen from Table II, heating at this temperature for 72 h provided more than a stress relief anneal since the properties dropped substantially. The reduction was particularly noticeable in the hoop direction where strength was originally 1410 $MN m^{-2}$ and then 923 $MN m^{-2}$ after heating. Comparison of the hoop and axial properties of the heated specimens also showed that the material was no longer isotropic.

Samples heated at 540° C and 620° C before being tested axially at room temperature showed reasonable strengths (around 550 $MN m^{-2}$) even after over 4 h at temperature (Table III). This indicates that nickel–cobalt electrodeposits would be suitable for some high temperature applications.

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