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REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF NICKEL-BASE AND COBALT-BASE ALLOYS

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DEFENSE METALS INFORMATION CENTER
BATTELLE MEMORIAL INSTITUTE
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REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF NICKEL-BASE AND COBALT-BASE ALLOYS

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INTRODUCTION

This memorandum is a brief summary of recent significant developments in the field of nickel-base and cobalt-base alloys and high-strength superalloys. The information was obtained from data made available to the Defense Metals Information Center during the period January 1 through April 28, 1961.

GENERAL

Research and development in nickel-base and cobalt-base alloys appears to be directed along three channels: (1) the development of new alloys with improved properties, (2) the development of dispersion-hardened alloys by powder metallurgy techniques, (3) the determination of the properties of existing materials. The majority of the work is being carried out under Government contracts.

NEW ALLOYS

Very recently, a new cast nickel-base superalloy was announced by the International Nickel Company.(1)** The composition of this alloy, designated IN-100, is as follows:

	Per Cent
Chromium	8 to 11
Cobalt	13 to 17
Molybdenum	2 to 4
Vanadium	0.70 to 1.20
Aluminum	5 to 6
Titanium	4.5 to 5.5
Carbon	0.15 to 0.20
Boron	0.008 to 0.02
Zirconium	0.03 to 0.09
Nickel	Balance

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**References are listed at the end of this memorandum.

The IN-100 alloy has higher rupture strength at all temperatures up to 1900 F than any other superalloy thus far announced. The International Nickel Company reports a minimum rupture life of 23 hours at 1800 F and 29,000 psi stress with 4 per cent minimum elongation. At 1900 F, a 100-hour rupture strength of about 17,000 psi is reported.

A new cobalt-base casting alloy (No. 152, comprising 0.40 to 0.50 per cent C, 20 to 22 per cent Cr, 10 to 12 per cent W, 1.5 to 2.5 per cent Cb + Ta, 1 per cent max Ni, 1.0 to 2.50 per cent Fe, and balance Co) has been announced by the Haynes Stellite Company.(2) This alloy has a higher cobalt content than does Alloy No. 151 (which is similar), about the same creep strength, and lower rupture strength at temperatures up to 1800 F. Alloy No. 152 is useful for turbine vanes operating above 1800 F in cases where creep-strength requirements are lower but improved fatigue strength, thermal-shock resistance, and oxidation resistance are needed.

A series of nickel-base casting alloys not requiring vacuum melting while still having stress-rupture properties adequate for advanced-temperature applications have been developed at the Lewis Research Center.(3) The alloys investigated were a nickel-6Al-6Cr-8Mo-1Zr base modified by small additions of C, Ti, V, W, and B. The best alloy developed (modified with W, V, and C) had a stress-rupture life of 768 hours at 1800 F and 15,000 psi, as compared with about 370 hours for cast Udimet 700 and 480 hours for Nicrotung. The stress-rupture life of the new alloy at 1900 F and 15,000 psi was about 100 hours.

POWDER-METALLURGY ALLOYS

Nickel-base materials dispersion hardened with alumina have been prepared by a technique involving the hot extrusion of mixtures of nickel powder and partially oxidized spongy, pyrophoric nickel-aluminum powder.(4) The evaluation of the properties of these materials is in progress.

Materials composed of magnesia particles dispersed in a nickel base have also been produced by hot pressing and hot extrusion.(5) Dispersions comparable to those produced in SAP aluminum with respect to particle size and spacing were made. The best as-extruded dispersion-hardened alloy had a strength nearly equal to that of Inconel X for 100 hours' life at 1800 F, while material cold worked 30 per cent was nearly equal to Inconel 700.

Cobalt-base alloys of S-816 composition were made by the liquid-phase-sintered technique to study the influence of carbon and microstructure on stress-rupture properties.(6) Alloys having equivalent or better properties than wrought S-816 were produced. Increasing the carbon generally improved the stress-rupture life. Higher carbon contents, however, give wide scatter in life tests. In the low-carbon range, as-sintered specimens had better life than hot-swaged or heat-treated materials.

A program of basic research directed to the study of the mechanism by which second-phase dispersion-hardening particles strengthen alloys has been reported.(7) The two alloy systems studied were (1) precipitated Ni_3Al in nickel and (2) Al_2O_3 particles dispersed in nickel, as produced by internal oxidation of a nickel-aluminum alloy. The nature of the interactions of slip lines and dislocations with the particles and the effect of the particles on yield, work hardening, and recovery were investigated.

PROPERTIES OF EXISTING MATERIALS

Temperature and time parameters significantly affect the selection of materials for high-speed aircraft and space vehicles. The criteria for including these factors in the selection of materials are clarified in a report by the Douglas Aircraft Company.(8) Two materials, Inconel 718 and Haynes Alloy 25, were evaluated for repeated exposure to a typical hypersonic re-entry glide trajectory, and a detailed analysis of the metallurgical characteristics of the materials is given.

Additional work in this area is covered in an investigation of the effects of rapid loading and of elevated temperatures on the mechanical properties of compression members.(9) The short-time tensile-creep properties of René 41 and Haynes Alloy 25 sheet were determined, and forced-creep-rate tensile tests were made. The yield and ultimate strengths of Haynes 25 alloy are sensitive to strain rate at all temperatures.

REFERENCES

(1) Bieber, C. G., and Kihlgren, T. E., "A New Cast Alloy for Use at 1900 F", Metal Progress, pp 97-99 (April, 1961).

(2) "Haynes Alloy No. 152", Haynes Stellite Company, Intra-Company Sales Technical File (December, 1960).

(3) Freche, J. C., Waters, W. J., Riley, T. J., "A New Series of Nickel-Base Alloys for Advanced Temperature Applications", preprint of paper presented at 42nd Annual Convention of ASM, Philadelphia, Pennsylvania, October 17-21, 1960, No. 214.

(4) Fiesel, D. H., Westinghouse Research Laboratories, Pittsburgh, Pennsylvania, preliminary work under a Navy contract.

(5) Schafer, R. J., Quatinetz, M., and Wheeton, J. W., "Strength and High-Temperature Stability of Dispersion-Strengthened Ni-MgO Alloys", Lewis Research Center, Cleveland, Ohio, NASA paper, prepared transcript, AIME E-1123 (March, 1961).

(6) Clarkin, P. H., Wheeton, J. W., and Sikora, P. F., "Effects of Variations in Carbon Content, Heat Treatment, and Mechanical Working on the Stress-Rupture Properties of a Liquid-Phase-Sintered High Temperature Alloy", Lewis Research Center, Cleveland, Ohio, for NASA, prepared for AIME presentation, E-149 (October, 1960).

(7) Guard, R. W., "Research on Dispersion Hardening", General Electric Research Laboratory, Schenectady, New York, ARL Technical Report 60-288, USAF, ARDC, Contract AF 33(616)-6406 (October, 1960).

(8) Davis, J. E., et al., "Investigation Into 'More Complete Use of Structural Materials' Through a Study of the Stress-Temperature-Time Conditions of a Re-Entry Vehicle", Douglas Aircraft Company, Santa Monica, California, TR-60-363 for WADD Contract AF 33(616)-6680 (May, 1960).

(9) The Marquardt Corporation, Van Nuys, California, preliminary information under an Air Force contract.

LIST OF DMIC MEMORANDA ISSUED (CONTINUED)

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A list of DMIC Memoranda 1-61 may be obtained from DMIC, or see previously issued memoranda.

DMIC Memorandum Number	Title
62	Effects of Rate of Heating to Aging Temperature on Tensile Properties of Ti-2.5Al-16V Alloys, August 18, 1960, (PB 161212 $0.50)
63	Notes on Large-Size Electrical Furnaces for Heat Treating Metal Assemblies, August 25, 1960
64	Recent Developments in Superalloys, September 8, 1960, (PB 161214 $0.50)
65	Compatibility of Rocket Propellants with Materials of Construction, September 15, 1960, (PB 161215 $0.50)
66	Physical and Mechanical Properties of the Cobalt-Chromium-Tungsten Alloy WI-52, September 22, 1960, (PB 161216 $0.50)
67	Development of Refractory Metal Sheet in the United States, September 20, 1960, (PB 161217 $0.50)
68	Some Physical Properties of Martensitic Stainless Steels, September 28, 1960, (PB 161218 $0.50)
69	Welding of Columbium and Columbium Alloys, October 24, 1960, (PB 161219 $0.50)
70	High Velocity Metalworking Processes Based on the Sudden Release of Electrical Energy, October 27, 1960, (PB 161220 $0.50)
71	Explosive Metalworking, November 3, 1960, (PB 161221 $0.50)
72	Emissivity and Emittance--What are They?, November 10, 1960, (PB 161222 $0.50)
73	Current Nickel-Base High-Temperature Alloys, November 17, 1960, (PB 161223 $0.50)
74	Joining of Tungsten, November 24, 1960, (PB 161224 $0.50)
75	Review of Some Unconventional Methods of Machining, November 29, 1960
76	Production and Availability of Some High-Purity Metals, December 2, 1960
77	Rocket Nozzle Testing and Evaluation, December 7, 1960
78	Methods of Measuring Emittance, December 27, 1960
79	Preliminary Design Information on Recrystallized Mo-0.5Ti Alloy for Aircraft and Missiles, January 16, 1961
80	Physical and Mechanical Properties of Some High Strength Fine Wires, January 20, 1961
81	Design Properties as Affected by Cryogenic Temperatures (Ti-6Al-4V, AISI 4340, and 7079-T6 Alloys), January 24, 1961
82	Review of Developments in Iron-Aluminum-Base Alloys, January 30, 1961
83	Refractory Metals in Europe, February 1, 1961
84	The Evolution of Nickel-Base Precipitation-Hardening Superalloys, February 6, 1961
85	Pickling and Descaling of High-Strength, High-Temperature Metals and Alloys, February 8, 1961
86	Superalloy Forgings, February 10, 1961
87	A Statistical Summary of Mechanical-Property Data for Titanium Alloys, February 14, 1961
88	Zinc Coatings for Protection of Columbium from Oxidation at Elevated Temperatures, March 3, 1961

LIST OF DMIC MEMORANDA ISSUED
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DMIC Memorandum Number	Title
89	Summary of Present Information on Impact Sensitivity of Titanium When Exposed to Various Oxidizers, March 6, 1961
90	A Review of the Effects of Starting Material on the Processing and Properties of Tungsten, Molybdenum, Columbium, and Tantalum, March 13, 1961
91	The Emittance of Titanium and Titanium Alloys, March 17, 1961
92	Stress-Rupture Strengths of Selected Alloys, March 23, 1961
93	A Review of Recent Developments in Titanium and Titanium Alloy Technology, March 27, 1961
94	Review of Recent Developments in the Evaluation of Special Metal Properties, March 28, 1961
95	Strengthening Mechanisms in Nickel-Base High-Temperature Alloys, April 4, 1961, (PB 161245 $0.50)
96	Review of Recent Developments in the Technology of Molybdenum and Molybdenum-Base Alloys, April 7, 1961, (PB 161246 $0.50)
97	Review of Recent Developments in the Technology of Columbium and Tantalum, April 10, 1961, (PB 161247 $0.50)
98	Electropolishing and Chemical Polishing of High-Strength, High-Temperature Metals and Alloys, April 12, 1961, (PB 161248 $0.50)
99	Review of Recent Developments in the Technology of High-Strength Stainless Steels, April 14, 1961, (PB 161249 $0.50)
100	Review of Current Developments in the Metallurgy of High-Strength Steels, April 20, 1961,(PB 161250 $0.50)
101	Statistical Analysis of Tensile Properties of Heat-Treated Mo-0.5Ti Sheet, April 24, 1961, (PB 161251 $0.50)
102	Review of Recent Developments on Oxidation-Resistant Coatings for Refractory Metals, April 26, 1961, (PB 171621 $0.50)
103	The Emittance of Coated Materials Suitable for Elevated-Temperature Use, May 4, 1961, (PB 171622 $0.50)

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