RESEARCH MEMORANDUM

THE CRYSTAL STRUCTURE AT ROOM TEMPERATURE OF SIX CAST HEAT-RESISTING ALLOYS

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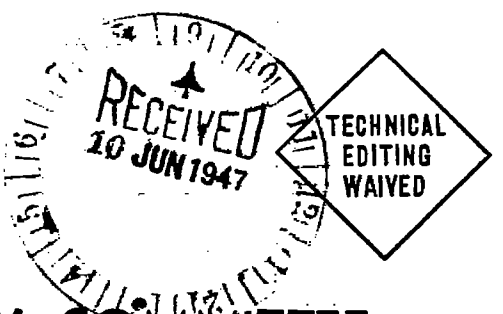

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THE CRYSTAL STRUCTURE AT ROOM TEMPERATURE OF SIX CAST HEAT-RESISTING ALLOYS

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SUMMARY

The methods of X-ray diffraction have been employed to study the crystal structure of six cast high-temperature alloys — 61, X-40, X-50, 422-19, 6059, and Vitallium — that have been or are being considered for use in gas-turbine applications. The predominant phase present in each of the alloys was a solid solution of the face-centered cubic type made up of the principal constituent elements. The lattice parameters of these alloys were found to lie between the values 3.5525 and 3.5662.

INTRODUCTION

Increased emphasis has recently been placed upon the development of improved heat-resisting alloys for use in high-temperature applications such as gas turbines. The length of time over which a material can withstand a certain stress at a given temperature is limited by the physical properties of the material, which depend, in a large measure, upon the arrangement and the distribution of the atoms. Reference 1 shows that the distance between atoms in the slip direction and the size of the unit cell are important factors in establishing the creep properties of an alloy.

Methods of X-ray diffraction have been used at the NACA Cleveland laboratory to determine the crystal structures at room temperature of six cast alloys that are in current use for high-temperature applications. The crystal structure and the lattice parameter of the predominant phase of each alloy are presented.

APPARATUS AND PROCEDURE

Typical chemical compositions of the six cast alloys studied are listed in table I (data from reference 2). Each of the specimens investigated was taken from a precision casting of the alloy.

In order to determine the type of crystal structure of each material, X-ray diffraction patterns of the cast alloys, 61, X-40, X-50, 422-19, 6059, and Vitallium, were obtained with filtered Co Kα radiation in a Debye-Scherrer powder camera 143.2 millimeters in diameter. A wedge-shaped specimen of each alloy was mounted in the camera and oscillated through 20° in the X-ray beam, which was collimated by 0.020- by 0.300-inch slits. Intensities of the lines on the developed film were measured with a Knorr-Albers type automatic recording microphotometer. The line spacings were measured to the nearest 0.1 millimeter.

In order to ascertain more accurate values for the lattice parameters, the back-reflection method, which employs a Sachs type camera, was used. At an absolute pressure of approximately 10 microns of mercury, fine chips, machined from a specimen of each alloy, were annealed at 1900° F for 1 hour and then cooled at a rate that did not exceed 20° F per minute. This annealing operation, performed to relieve internal stresses in the cold-worked particles, resolved the Kα doublet lines on the pattern. Investigations carried out at the University of Michigan have shown that these alloys exhibit an increase in hardness after stress-rupture tests at 1700° and 1800° F. The chips with collodion as the binder were firmly packed into a small drilled hole in a Lucite slide. A gold specimen, similarly mounted, served as a standard for the calibration of each pattern. Diffraction patterns were made with unfiltered Fe radiation at a film-specimen distance of approximately 5 centimeters. The film casette and the specimen were rotated at different speeds to produce a relative motion between them. The X-ray beam was collimated by pinholes of 0.010-inch diameter. The line-to-line spacings were measured to the nearest 0.05 millimeter.

RESULTS AND DISCUSSION

Values of interplanar spacings and of intensities of the lines appearing in the diffraction patterns taken with the Debye-Scherrer camera are listed in table II. Each alloy at room temperature gave a pattern that is characteristic of the face-centered cubic type of crystal structure. The small amount of the shift in the reflections or the lines, observed in a comparison of the patterns of these alloys, which have large differences in chemical composition, indicated that a solid solution of the principal constituent elements exists in each alloy. The smallness of this shift has been previously observed with other high-temperature materials that have been studied at this laboratory (reference 3).

From the patterns taken with the Sachs type camera, the lattice parameter a of each alloy was calculated from the diameter of the

band representing the Fe $K\alpha_1$ reflection of the (222) plane. The relation used was

$$180^\circ - 2 \sin^{-1} \frac{\lambda\sqrt{h^2 + k^2 + l^2}}{2a} = \tan^{-1} \frac{D}{2L}$$

where

a	lattice parameter of face-centered cubic crystal structure, A
D	diameter of diffraction ring representing (222) plane
h, k, l	Miller indices of reflection plane (in this case, (222) plane)
L	film-specimen distance calculated from diffraction pattern of the standard
λ	characteristic wavelength of radiation, A (in this case, $K\alpha_1$ wavelength of iron 1.932076 A)

The lattice parameter, the only unknown in this equation, was determined to four decimal places for each of the alloys (table III). The accuracy of these values, which vary from 3.5525 to 3.5662 A, is believed to be within ± 0.0005 A.

Data enumerated in table IV, which give the lattice parameters and the types of crystal structure of the main alloying elements, were taken from reference 4.

SUMMARY OF RESULTS

The six cast high-temperature alloys – 61, X-40, X-50, 422-19, 6059, and Vitallium – were examined by X-ray diffraction methods and yielded diffraction patterns typical of face centered cubic materials

with lattice parameters in the range between 3.5525 and 3.5662 A. The principal phase of each alloy seemed to consist of a solid solution of the main alloying elements.

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REFERENCES

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2. Cross, Howard C., and Simmons, Ward F.: Progress Report on Heat-Resisting Metals for Gas Turbine Parts (N-102). OSRD No. 4717, Ser. No. M-477, NDRC, OSRD, War Metallurgy Comm., Feb. 20, 1945.

3. Kittel, J. Howard: The Crystal Structure at Room Temperature of Eight Forged Heat-Resisting Alloys. NACA TN No. 1102, 1946.

4. Sproull, Wayne T.: X-rays in Practice. McGraw-Hill Book Co., Inc., 1946, pp. 576-586.

TABLE I

TYPICAL COMPOSITIONS OF SIX CAST HEAT-RESISTING

ALLOYS STUDIED BY X-RAY DIFFRACTION METHODS
[Data from reference 2.]

Alloy	Chemical composition, percent								
	C	Mn	Si	Cr	Ni	Co	Mo	W	Fe
61	0.43	0.28	0.57	24.21		Bal		5.38	
X-40	.48	.64	.72	25.12	9.69	55.23		7.23	0.55
X-50	.76	.58	.52	22.57	20.05	40.7		12.17	
422-19	.40		.51	24.75	15.92	Bal	6.06		.65
6059	.39			24.61	33.5	33.55	5.34		
Vitallium	.242			28.7		Bal	5.57		

TABLE II

X-RAY DIFFRACTION DATA ON SIX CAST HEAT-RESISTING ALLOYS
[Filtered Co Kα radiation was used to obtain diffraction patterns; d, interplanar spacing (A); I, peak intensity of a diffraction line; I/I_1, relative intensity of a diffraction line where I_1 is the intensity of the strongest line.]

Cast Alloy											
61		X-40		X-50		422-19		6059		Vit.	
d	I/I_1	d	I/I_1	d	I/I_1	d	I/I_1	d	I/I_1	d	I/I_1
2.05	1.00	2.05	1.00	2.05	1.00	2.06	1.00	2.05	1.00	2.05	0.93
1.78	.76	1.78	.39	1.78	.41	1.79	.35	1.77	.45	1.78	.63
1.26	.33	1.26	.22	1.26	.29	1.26	.19	1.26	.24	1.26	.53
1.07	.68	1.07	.32	1.08	.62	1.08	.31	1.07	.29	1.07	1.00
1.03	.41	1.03	.37	1.03	.15	1.03	.19	1.03	.05	1.03	.34

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TABLE III

LATTICE PARAMETERS OF SIX CAST

HEAT-RESISTING ALLOYS
[Accurate to ±0.0005 A.]

Alloy	Lattice parameter, a (A)
61	3.5525
X-40	3.5591
X-50	3.5613
422-19	3.5619
6059	3.5622
Vitallium	3.5662

TABLE IV

CRYSTAL STRUCTURE AND LATTICE PARAMETERS OF ELEMENTS

PRESENT IN RELATIVELY LARGE AMOUNTS IN

SIX CAST HEAT-RESISTING ALLOYS
[Data from reference 4.]

Element	Crystal structure	Lattice parameters, A	
		a	c
α-Chromium	Body-centered cubic	2.878	
β-Chromium	Hexagonal close-packed	2.717	4.418
α-Cobalt	Face-centered cubic	3.554	
β-Cobalt	Hexagonal close-packed	2.514	4.105
α-Iron	Body centered cubic	2.861	
γ-Iron	Face-centered cubic	3.63	
α-Nickel	Hexagonal close-packed	2.66	4.29
β-Nickel	Face-centered cubic	3.517	

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ABSTRACT

The methods of X-ray diffraction have been employed to study the crystal structure of six cast high-temperature alloys - 61, X-40, X-50, 422-19, 6099, and Vitallium - that have been or are being considered for use in gas - turbine applications. The predominate phase present in each of the alloys was a solid solution of the face-centered cubic type made up of the principal constituent elements. The lattice parameters of these alloys were found to lie between the values 3.5525 and 3.5662.

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