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(71) , 46908 - 9013, , . 9013 1020

(72) , ,
 , 46901, , 901
 , ,
 , 46901, , 11300
 , ,
 , 46902, , 3500

(74)

:

(54) N i - C r - M o 2 -

12 - 23.5% - - 2 -

, 50
 가 .

1

1 P

12 - 23.5 %

Ni - Cr - Mo , 15 - 24%

가
 1 가 2 가
 (aging) Ni - Cr - Mo
 12% ()
 가
 3,871,928
 가
 가

Ni - Cr - Mo Ni - Mo

HAYNES 242
 Ni - Cr - Mo Ni - Mo
 538 - 871
 2 Ni - Mo 538 - 871
 Ni₃ Mo Ni₄ Mo
 25 - 30%
 16 % 16 % Ni - Cr - Mo
 500 - 1000 Ni₂ (Mo,Cr) Pt₂ Mo
 Ni₂ (Mo,Cr)
 가
 538 - 694
 가
 가

4,818,486 5 - 12% 10 - 30%
 649 - 816 Ni - Cr - Mo
 1000 24
 242 HAYNES 242 HAYNES 242
 가

242

. HAYNES 242 8 % , 20 - 30 % , 0.35 - 0.5 % , 0.006 % , 0.03 % , 0.8 % , 0.8 % , 2 % , 1 % , 0.006 % , 0.03 % ,

Ni - Cr - Mo 5,019,184(Crum) . 19 - 23% 14 - 17.5%
1149 - 1260 5 - 50

INCONEL 686

Ni - Cr - Mo 4,906,437(Heubner) . 22 - 24% 15 - 16.5
% . 가 . VDM NICROFE
R 923 h Mo 59 .

Ni - Cr - Mo 4,129,464 (Matthews) . 13 - 18% 13 - 18%
 . 480 - 593 50
 . 168 . 50 . 168
 . 3 1,2,3 . 1 HASTELLOY C - 276
 2 HASTELLOY C - 4 3 HASTELLOY S

12 - 23.5%

2 -

12 - 23.5%

2 -

31.2 - 35.9 P

$$\begin{aligned} P = & 2.46 \text{ Al} + 0.19 \text{ Co} + 0.83 \text{ Cr} - 0.16 \text{ Cu} + 0.39 \text{ Fe} + 0.59 \text{ Mn} \\ & + 1.0 \text{ Mo} + 0.81 \text{ Zr} + 2.15 \text{ Si} + 1.06 \text{ V} + 0.39 \text{ W} + 0.68 \text{ Nb} \\ & + 0.52 \text{ Hf} + 0.45 \text{ Ta} + 1.35 \text{ Ti} \end{aligned}$$

P 8 , 12 - 20 704
 593 - 718 , 8 , 28 - 36

. 12 - 23.5% 2 Ni - Cr - Mo

242

2 -

10 - 20
2

2 가 가
Ni - Cr - Mo

가

2

가

가

12 - 23.5%

2

8 - 20

691 - 760

, 538 - 718

,

8

24 - 36

가

$P = 2.46 Al + 0.19 Co + 0.83 Cr - 0.16 Cu + 0.39 Fe + 0.59 Mn$
 $+ 1.0 Mo + 0.81 Zr + 2.15 Si + 1.06 V + 0.39 W + 0.68 Nb$
 $+ 0.52 Hf + 0.45 Ta + 1.35 Ti$

1 20 5 Ni - Cr - Mo HA
 STELLOY S , HASTELLOY C - 276 , HASTELLOY C - 4 , Alloy 59 INCONEL
 686 . 1 " n.m" 가 . 1 P .

S	23.89%	H	11.56%	P	22.06%	G	9.91%
34%							0.11 - 0.
	12.7mm		1038 - 1093			30	
					2		
04							

테스트된 샘플의 조성

합금 No.	조성																		
	Al	B	C	Ce	Co	Cr	Cu	Fe	Mg	Mn	Mo	Nb	Ni	P (Phos.)	S	Si	V	W	"P 75"
A	0.15	0.002	0.003	0.008	0.05	12.79	0.04	1.11	< 0.002	0.33	21.58	n.m.	Bal.	< 0.004	0.001	< 0.01	0.01	0.19	33.3
B	0.15	0.002	0.002	0.007	0.04	15.26	0.01	1.13	< 0.002	0.34	19.92	n.m.	Bal.	< 0.004	0.002	< 0.01	0.02	0.34	33.8
C	0.12	0.003	0.006	0.008	0.05	14.99	0.03	1.05	< 0.002	0.32	18.78	n.m.	Bal.	0.002	0.001	0.01	< 0.01	0.15	32.2
D	0.12	0.005	0.002	< 0.005	0.08	17.36	0.03	1.08	0.003	0.32	17.21	n.m.	Bal.	0.003	0.001	0.02	< 0.01	0.14	32.7
E	0.17	0.003	0.002	< 0.005	0.06	19.88	0.02	1.05	< 0.002	0.32	15.40	n.m.	Bal.	0.005	0.001	0.03	< 0.01	0.14	33.1
F	0.14	0.002	0.003	0.007	0.06	22.18	0.02	1.09	< 0.002	0.31	13.32	n.m.	Bal.	0.002	0.001	0.01	< 0.01	0.14	32.8
G	0.13	0.005	0.002	0.005	0.07	25.48	0.02	1.12	0.003	0.32	9.91	n.m.	Bal.	0.002	0.001	0.02	< 0.01	0.18	32.2
H	0.15	< 0.002	0.003	0.007	0.05	11.56	0.06	1.17	0.003	0.34	19.75	n.m.	Bal..	< 0.004	0.001	0.15	0.02	0.15	30.8
I	0.14	0.002	0.004	0.005	0.06	16.57	0.04	1.08	0.004	0.31	15.60	n.m.	Bal.	< 0.002	0.003	0.07	0.02	0.15	30.6
J	0.14	0.002	0.005	0.004	0.06	21.28	0.04	1.07	< 0.002	0.31	11.79	n.m.	Bal.	< 0.002	0.004	0.07	0.02	0.14	30.7
K	0.16	0.002	0.004	0.009	0.06	12.58	0.04	1.17	0.003	0.30	22.48	n.m.	Bal.	< 0.004	< 0.001	0.15	0.02	0.22	34.4
L	0.13	0.002	0.003	0.004	0.06	17.53	0.04	1.11	0.002	0.31	18.63	n.m.	Bal.	< 0.004	0.003	0.11	0.02	0.15	34.5
M	0.17	0.002	0.006	0.005	0.06	22.28	0.01	1.17	0.002	0.30	14.73	n.m.	Bal.	0.005	0.001	0.16	0.02	0.18	34.7
N	0.14	< 0.002	0.007	0.004	0.05	19.92	0.01	0.98	< 0.002	0.29	17.38	0.03	Bal.	< 0.002	0.001	0.05	0.03	0.13	35.1
O	0.13	< 0.002	0.007	0.003	0.06	21.13	0.01	1.00	< 0.002	0.30	15.62	0.03	Bal.	< 0.002	0.002	0.04	0.03	0.13	34.3
P	0.13	< 0.002	0.006	0.003	0.07	26.06	< 0.01	1.02	< 0.002	0.29	11.82	0.03	Bal.	0.003	0.001	0.06	0.04	0.13	34.6
Q	0.13	< 0.002	0.009	0.002	0.07	23.03	< 0.01	1.02	< 0.002	0.28	16.66	0.03	Bal.	0.003	0.001	0.05	0.03	0.13	36.9
R	0.13	< 0.002	0.007	0.005	0.06	17.92	0.01	1.04	0.002	0.27	20.08	0.03	Bal.	0.005	0.001	0.04	0.03	0.14	36.1
S	0.14	< 0.002	0.006	0.006	0.06	13.45	< 0.01	1.00	0.002	0.27	23.89	0.03	Bal.	0.002	0.001	0.04	0.03	0.15	36.2
T	0.14	< 0.002	0.009	0.002	0.06	23.97	< 0.01	0.99	< 0.002	0.30	13.60	0.03	Bal.	0.003	0.001	0.06	0.04	0.11	34.7
Has-telloy S	0.22	0.008	0.010	n.m.	0.09	15.35	n.m.	1.12	0.03	0.59	14.80	n.m.	Bal.	n.m.	0.005	0.48		0.23	30.0
C-276	0.30	n.m.	0.003	n.m.	0.76	15.76	0.06	5.48	0.05	0.51	15.43	0.09	Bal.	0.007	0.002	n.m.	0.12	3.39	33.3
C-4	0.34	n.m.	0.002	Ti 0.23.	n.m.	15.54	0.02	1.01	0.05	0.18	15.41	n.m.	Bal.	n.m.	n.m.	0.04	0.02	n.m.	30.1
59	0.30	n.m.	0.002	n.m.	0.08	22.75	0.01	0.65	n.m.	0.17	15.45	n.m.	Bal.	0.002	0.002	0.05	n.m.	n.m.	35.6
686	n.m.	n.m.	0.005	Ti 0.07	n.m.	20.17	n.m.	0.21	n.m.	0.23	16.08	n.m.	Bal.	0.002	0.001	0.01	n.m.	3.94	34.7

ASTM E - 8

실온 인장성질

제작	0.2% 향복 강도		최종 인장 강도		성장률
	MPa	ksi	MPa	ksi	
A	816	118.3	1306	189.4	40.1
B	823	119.3	1300	188.5	40.7
C	723	104.8	1229	178.3	43.4
D	709	102.9	1222	177.3	43.5
E	690	100.0	1198	173.7	44.1
F	508	73.7	962	139.5	47.6
G	324	47.0	738	107.1	61.8
H	359	52.0	841	122.0	65.1
I	341	49.5	806	116.9	64.3
J	304	44.1	743	107.8	64.1
K	822	119.2	1338	194.0	41.1
L	659	95.6	1170	169.7	47.9
M	663	96.1	1166	169.1	45.8
N	644	93.4	1158	168.0	47.3
O	629	91.2	1145	166.1	47.3
P	343	49.8	761	110.4	60.7
Q	747	108.4	1227	177.9	34.5
R	809	117.4	1305	189.3	32.4
S	962	139.5	1473	213.6	28.0
T	409	59.3	825	119.7	57.8
HASTELLOY S	465	67.5	918	133.1	47.1
C-276	369	53.5	803	116.4	56.7
C-4	497	72.1	947	137.4	47.6
Alloy 59	594	86.2	1066	154.6	47.3
INCONEL alloy 686	682	98.9	1169	169.6	45.0

가 Fe 3% .

1	P	.	가	.	가	.	가
.	X	2 -	.	1	가	12 - 23.5%	31.2 - 35.9 P
가	.	.	.	.	.	.	.

SM2060 Mo	MAT - 21	UNS	Ni - Cr - Mo	C - 2000	, C - 22
1.25% , 0.04% , 0.03% , 0.75%	0.5% , 0.015% , 0.02% , 2.2%	, 2.5% , 2.0% , 0.35% , 0.7%	, 3.0% , 1.5% , 4.5%		

2	가	M	.	20.0	C(Rc)	가	가	가
3	.	.	.	가 20.0	.	.	.	M
3	691 - 760	.	2	24	538 - 691	.	927	1
1	가 2	.	.	.	.	927	1	가
	1	.	.	가 760	.	.	.	.

				Ni ₂ (Mo,Cr)			
가		가		가		가	
.	.	.	.	2	.	.	1
.	.	.	.	2	.	.	2
1	가	538	2	3	M	16	704
1	가	16	760	1	가	538	621
가		621				2	732

M		1		16		704			N	O		
593	, 621	, 649		2		.	1	8	16	760	, 16	32
	732	, 16		704			K	593	621		8,12,16,32	
2		.		4		.	N	O	593	621		2
	가			649		가		.	N	O	621	
	M					M			N	O		

K M,N,O . 4 K 8,16,32
704, 732, 760 . 2 가 732 가 704 718 40

760 8 1 가
8 2 가 .
 가 2
 8

. 1 가 732 32 704

. 가 32 - 40

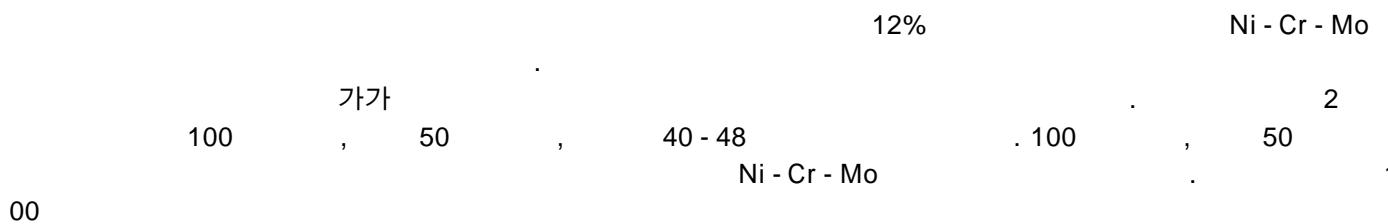
- - . 12 - 23.5% 31.2 - 35.9 P
1 가 691 - 760 8 , 2 가 538 - 718 8 .
 가

다양한 예이징 처리가 합금M의 경도에 미치는 효과

제1단계 온도	제1단계 시간	제2단계 온도	제2단계 시간	경도 (RC)
두-예이징	---	---	---	< 20.0
649°C/1200°F	16	538°C/1000°F	32	< 20.0
649°C/1200°F	16	566°C/1050°F	32	< 20.0
649°C/1200°F	16	593°C/1100°F	32	< 20.0
649°C/1200°F	16	621°C/1150°F	32	< 20.0
649°C/1200°F	16	649°C/1200°F	32	< 20.0
677°C/1250°F	16	538°C/1000°F	32	< 20.0
677°C/1250°F	16	566°C/1050°F	32	< 20.0
677°C/1250°F	16	593°C/1100°F	32	< 20.0
677°C/1250°F	16	621°C/1150°F	32	< 20.0
677°C/1250°F	16	649°C/1200°F	32	< 20.0
704°C/1300°F	16	538°C/1000°F	32	< 20.0
704°C/1300°F	16	566°C/1050°F	32	20.7
704°C/1300°F	16	593°C/1100°F	32	28.6
704°C/1300°F	16	621°C/1150°F	32	< 20.0
704°C/1300°F	16	649°C/1200°F	32	< 20.0
732°C/1350°F	16	538°C/1000°F	32	< 20.0
732°C/1350°F	16	566°C/1050°F	32	27.4
732°C/1350°F	16	593°C/1100°F	32	31.2
732°C/1350°F	16	621°C/1150°F	32	< 20.0
732°C/1350°F	16	649°C/1200°F	32	< 20.0
760°C/1400°F	16	538°C/1000°F	32	24.9
760°C/1400°F	16	566°C/1050°F	32	26.6
760°C/1400°F	16	593°C/1100°F	32	28.4
760°C/1400°F	16	621°C/1150°F	32	< 20.0
760°C/1400°F	16	649°C/1200°F	32	< 20.0
816°C/1500°F	16	593°C/1100°F	32	31.0
871°C/1600°F	16	593°C/1100°F	32	30.4
927°C/1700°F	16	593°C/1100°F	32	27.8
704°C/1300°F	4	593°C/1100°F	4	< 20.0
704°C/1300°F	4	593°C/1100°F	8	< 20.0
704°C/1300°F	4	593°C/1100°F	16	< 20.0
704°C/1300°F	4	593°C/1100°F	44	< 20.0
704°C/1300°F	8	593°C/1100°F	4	< 20.0
704°C/1300°F	8	593°C/1100°F	8	< 20.0
704°C/1300°F	8	593°C/1100°F	16	< 20.0
704°C/1300°F	8	593°C/1100°F	32	20.1
704°C/1300°F	8	593°C/1100°F	40	29.4
704°C/1300°F	16	593°C/1100°F	4	< 20.0
704°C/1300°F	16	593°C/1100°F	8	< 20.0
704°C/1300°F	16	593°C/1100°F	16	< 20.0
704°C/1300°F	16	593°C/1100°F	24	20.4

다양한 예이징 처리가 합금N 및 O의 경도에 미치는 효과

합금	제1단계 온도	제1단계 시간	제2단계 온도	제2단계 시간	경도 (Rc)
K	Unaged	---	---	---	< 20
K	740°C/1300°F	16	593°C/1100°F	32	36.7
K	740°C/1300°F	16	649°C/1200°F	32	40.3
K	732°C/1350°F	16	677°C/1250°F	16	37.0
K	732°C/1350°F	32	704°C/1300°F	8	37.0
K	732°C/1350°F	16	704°C/1300°F	12	36.9
K	760°C/1400°F	16	704°C/1300°F	32	37.9
K	760°C/1400°F	8	704°C/1300°F	40	36.9
K	760°C/1400°F	16	718°C/1325°F	32	< 20
K	760°C/1400°F	8	718°C/1325°F	40	30.7
K	760°C/1400°F	16	732°C/1350°F	32	< 20
K	760°C/1400°F	8	732°C/1350°F	40	< 20
N	Unaged	---	---	---	< 20
N	704°C/1300°F	16	593°C/1100°F	32	30.7
N	704°C/1300°F	16	621°C/1150°F	32	32.7
N	704°C/1300°F	16	649°C/1200°F	32	< 20
O	Unaged	---	---	---	< 20
O	704°C/1300°F	16	593°C/1100°F	32	30.2
O	704°C/1300°F	16	621°C/1150°F	32	23.9
O	704°C/1300°F	16	649°C/1200°F	32	< 20



(57)

1.

12 - 23.5% ;

13 - 23% ;

3% ;

, , , , , , , , , , ,
;

;

P 31.2 - 35.9

$P = 2.46Al + 0.19Co + 0.83Cr - 0.16Cu + 0.39Fe + 0.59Mn + 1.0Mo + 0.81Zr + 2.15Si + 1.06V + 0.39W + 0.68Nb + 0.52Hf + 0.45Ta + 1.35Ti$

691 - 760	8	538 - 718	8
	2		-

2.

1	, 2	가	16	704 - 760	593 - 621
32					

3.

1	,	가	:	
---	---	---	---	--

0.1% ;

2.0% ;

1.25% ;

0.04% ;

0.75% ;

0.03%

2.2% ;

0.7% ;

0.035%

4.

1	,		
---	---	--	--

5.

1	,	
---	---	--

12 - 23.5% ;

13 - 23% ;

0.12 - 0.2% ;

0.002 - 0.006% ;

0.30 - 0.34% ;

1.0 - 1.7% ;

0.05 - 0.8% ;

0.10 - 0.34% ;

0.002 - 0.005%

6.

5 ,

0.005 - 0.009% ;

0.01 - 0.06% ;

0.001 - 0.004% ;

0.002 - 0.005% ;

0.001 - 0.004% ;

0.01 - 0.02%

7.

1 , 가 : :

0.5% ;

0.02% ;

1.5% ;

3% ;

2.5% ;

4.5% ;

0.015%

8.

1 , 1.25% 0.015%

9.

- 718 , 538 - 718 가 538
가

10.

, 50 2

11.

12 - 23.5% ; 13 - 23% ; 3% ; 0.5% ; 0.015% ; 0.02% ; 2.5
% ; 1.5% ; 4.5% ; 1.25% ; 0.75% ; 2.2% ; 0.7%
;

P 31.2 - 35.9

$P = 2.46Al + 0.19Co + 0.83Cr - 0.16Cu + 0.39Fe + 0.59Mn + 1.0Mo + 0.81Zr + 2.15Si + 1.06V + 0.39W + 0.68Nb + 0.5$
2Hf + 0.45Ta + 1.35Ti

691 - 760 8

538 - 718

8

12.

11 , 50 2

13.

11 , 704 - 760 593 - 621 32

14.

11 , 538 - 718

15.

11 , 538 - 718 가 538 - 718
가

16.

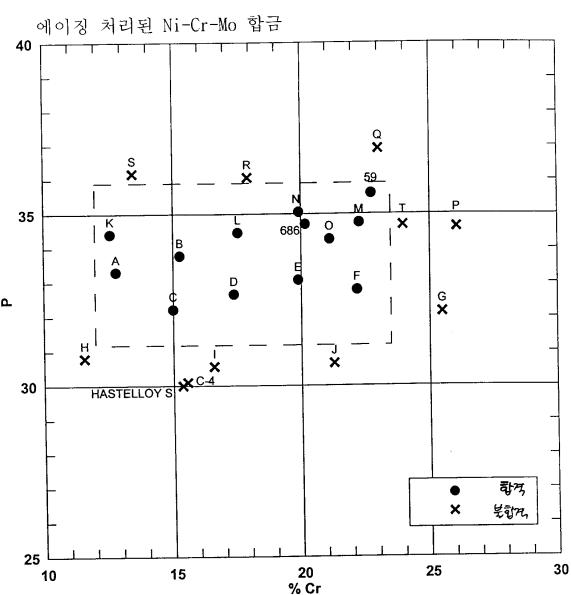
11

1.25%

0.015%

1

704°C/16h/FC-593°C/32h/AC(1300°F/16h/FC-1100°F/32h/AC)에서



$$P = 2.64 \text{ Al} + 0.19 \text{ Co} + 0.83 \text{ Cr} - 0.16 \text{ Cu} + 0.39 \text{ Fe} + 0.59 \text{ Mn} + 1.0 \text{ Mo} + 0.81 \text{ Zr} \\ + 2.15 \text{ Si} + 1.06 \text{ V} + 0.39 \text{ W} + 0.68 \text{ Nb} + 0.52 \text{ Hf} + 0.45 \text{ Ta} + 1.35 \text{ Ti}$$

부록 부록: $12.0 < \text{Cr} < 23.5$ and $31.2 < P < 35.9$