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Report No. 316/25
Watertown Arsenal

June 7, 1935

Low Chromium 46 Steels

Object

To study the properties of semi-corrosion resisting steels containing 4 to 6% chromium.

Conclusions

Low chromium 46 steels of correct analysis respond satisfactorily to heat treatment. When exposed to the atmosphere or to salt spray, rust appears equally as fast on low chromium 46 steels as on ordinary steels.

The alloy possesses moderate properties and excellent ductility and impact resistance. Its corrosion resistance is not such as to recommend it for ordnance purposes.

Introduction

The oil industry is using considerable quantities of 5% Cr steels because of their resistance to sulphide corrosion and high temperature oxidation.

The value of this material to ordnance was studied and the results are given in this report.

Material

The Allegheny Steel Company, Brackenridge, Pa., supplied this Arsenal with steel of the following analysis:

Analysis of Test Material Supplied by Allegheny Steel Company, 46 steel, Marked 56A9, Report No. 316/44

Element	%
C	.085
Mn	.46
Si	.330
S	.020
P	.014
Ni	.12
Cr	5.55
Cu	.45
Al	.64

Heat Treatment

The material was heat treated as follows:

Piece A

Heated to 815°C, 2 hrs., furnace cooled
" " 870°C, 2 " oil quenched
" " 700°C, 2 " air cooled.

Piece B

Heated to 815°C, 2 hrs., furnace cooled
" " 870°C, 2 " oil quenched
" " 400°C, 2 " air cooled.

Physical Properties

The properties observed are:

Heat Treatment	870°C O.Q. 700°C A.C.		870°C O.Q. 400°C A.C.		
Specimen Number	A1T	A2T	A2L	BL1	BL2
Direction	Transverse		Long.	Longitudinal	
P. L. 1000 p.s.i.	34.2	32.5	26.0	56.0	54.0
Johnson's E.L.1000 psi	44.1	43.6	38.0	66.0	66.0
T.S. 1000 p.s.i.	71.5	71.5	71.6	112.8	112.0
Elongation %	29.0	35.2	38.0	24.0	24.0
Red. of Area %	73.1	74.0	79.0	64.8	62.4
Break	outer third	-	middle third	-	
Test Spec.dia. in.	.125	.125	.252	.252	.252
B H N	134			209	
$150^{R}c$	7			17	
Sq. Charpy Ft. Lbs.	A1L 60.2 A2L 58.7				

Machinability

In the softened condition difficulty was encountered in threading. The stock was tough but otherwise was machinable.

Corrosion Resistance

The behavior of this material when exposed to the atmosphere and to salt spray was observed and compared with mild steel. No benefit was detected

by adding 5.55% Cr to steel to retard either the initial period for rusting to be observed or the initial corrosion which occurred.

Discussion

The low chromium 46 steels are commercially available in various grades, viz:

Chromium 4 - 6 %

Carbon .21 to .25%: .16 to .20%: .11 to .15%: .10% max.

Molybdenum .40 to .60%: .61 to 1.0%: 1.01 to 2.0%

Silicon 1. to 2.%

Titanium .5 to .7%

Tungsten .75 to 1.25%

The other common elements are nominal, for instance; Mn 0.5 max; P 0.04 mx; S 0.04 mx; Si 0.50 mx unless special.

The physical properties of such steels are given on the accompanying tables. A wide range in properties are available. This Arsenal has been supplied with castings of this type analysis for pintle stock.

The addition of more than 2 - 3% Cr reduces the corrosion rate of steel in aerated water, HCl, H_2SO_4, NaCl, NaCl + H_2S, when corroded over long periods of time. The resistance to oxidation is also increased To enhance the corrosion resistance to acid media, the addition of 0.5 to 1.0% Cu is advocated. To enhance the corrosion resistance to oxidation at high

temperatures, the addition of 0.5 to 1.0% Al is advocated. The addition of 0.5% Mo or of 1.0% W increases the strength at high temperaturesand also tends to raise the corrosion resistance. Adding five to eight times as much Titanium as there is carbon causes the steel to lose its air hardening properties so that tensile strength of only 60,000 to 65,000 p.s.i. are obtainable. However, the high temperature strength is not impaired. The tying up of carbon in the form of TiC relieves that much more Cr for enhancing corrosion resistance such as resistance to high temperature oxidation. The alloy finds its usefulness in commerce for its high temperature properties and resistance to oxidation and resistance to crude oils at high temperatures.

For ordnance material the Ordnance Department is interested in ferrous materials which have low <u>initial</u> rates of corrosion rather than low rates of corrosion over long periods of time. The fact that the 5% Cr steels rusted as quickly as plain steels in the atmosphere or salt spray would indicate that this material is not of interest from the corrosion point of view.

Respectfully submitted,

P. R. Kosting

Physical Properties of Low Chromium 46 Steels

Analysis %Cr	%C	Special	Heat Treatment	Y.P. 1000 p.s.i.	T. S. 1000 p.s.i.	El. %	R.A. %	Izod Impact ft.lbs.	Charpy Impact ft. lbs.	B.H.N.
5.21	.10		875°C A.C. no draw	108.9	181.4	15.5	53.2	23.3	18.5	
			drawn 550°C	128.9	169.5	16.5	57.4	8.1	19.1	
			607	102.2	114.1	20.0	71.0	76.4	44.9	
			650	86.8	100.1	23.0	73.2	96.4	51.2	
			700	76.8	91.8	25.0	76.2	102.6	55.6	
			750	67.3	84.8	28.0	77.9	100.6	60.4	
			875°C F.C.	27.3	66.0	37.5	75.6	76.8	47.0	
5.19	.21		875°C A.C. no draw	114.0	212.3	9.0	18.5	23.4	15.6	
			drawn 550°C	138.0	194.8	14.5	45.5	16.6	12.5	
			607	119.9	137.6	18.5	58.7	35.7	39.0	
			650	95.1	115.4	22.5	69.4	81.8	45.7	
			700	83.4	104.7	23.0	68.0	85.9	54.4	
			750	72.0	95.6	27.5	71.5	80.2	57.4	
			800	60.7	94.6	29.0	70.2	88.3	62.4	
			875°C F.C.	32.3	75.7	32.0	75.0	84.1	66.6	
5.27	.30		875°C A.C. no draw	117.3	221.8	13.5	31.7	16.9	15.4	
			drawn 550°C	144.3	196.0	14.5	47.2	13.3	14 5	
			607	116.8	137.4	18.0	60.5	59.1	35.6	
			650	97.0	120.2	21.0	66.7	76.5	41.4	
			700	83.1	108.1	24.0	69.6	85.1	46.9	
			750	73.8	99.7	28.0	72.0	77.0	60.6	
			800	59.6	96.8	30.0	74.1	72.5	55.6	
			875°C F.C.	33.4	79.0	33.5	75.6	79.9	79.4	
4/6	.14	1/2 Mo.	Annealed	31.2	62.1	37.6				
4/6	.14	1 W	Annealed	34.1	70.2	35.2				
5.41	.11	.75 Ti	"As rolled"	37.0	65.0	32	70	30		163
			750°C A.C.	28.0	61.0	37	78	63		112
			900°C A.C.	29.0	62.0	44	79.5	112		112