CR-54627
Centaur 10-10
170
206

[redacted]

[redacted]

GENERAL DYNAMICS

Convair Division

[redacted]

A2136-1 (REV. 5-65)

GPO PRICE $ _____

CFSTI PRICE(S) $ _____

Hard copy (HC) 4.00

Microfiche (MF) .50

ff 653 July 65

MECHANICAL PROPERTIES OF TYPE 202 STAINLESS STEEL AT CRYOGENIC TEMPERATURES

MRG-298

March 12, 1962

Prepared by: J.L. Christian

GENERAL DYNAMICS/CONVAIR

MRG-298

12 March 1962

SUBJECT: Mechanical Properties of Type 202 Stainless Steel at Cryogenic Temperatures

ABSTRACT: Type 202 is an anstenitic stainless steel containing chromium, manganese and nickel as the major alloying elements. The purpose of this investigation was to determine the applicability of this alloy for structural uses at cryogenic temperatures. Tensile and notched (K_t = 6.3) tensile properties of the parent metal were determined from 78° to -423°F. The alloy was evaluated in two tempers: 55% and 75% cold worked.

The test data indicate that type 202 stainless steel possesses yield and tensile strength and elongation comparable to type 301 or 302 stainless steels. However, the notched tensile data indicated increasing notch sensitivity with decrease in testing temperature, and the resulting notched/unnotched tensile ratios indicated a lack of toughness for structural applications at -320°F and -423°F. Based upon the data obtained in this investigation, type 202 stainless steel is not recommended for structural uses at -320° or -423°F. The notched tensile properties of type 202 stainless steel are compared with the properties of types 301, 301-N, 302, 304 ELC, 310 and AM-355 stainless steels.

Prepared by J. L. Christian
J. L. Christian

Approved by A. Hurlich
A. Hurlich
Research Group Engineer
Materials Research Group

AH:JC:jn

Distribution:

W. F. Radcliffe	595-0	C. Pruckner	541-3
K. A. Ehricke	100-0	H. Steele	593-1
G. D. Davis	510-1	K. Hogelan	593-1
R. S. Shorey	597-3	J. Comber	541-3
A. Hausrath	597-3	W. Gross	563-1
D. Collins	541-1	V. A. Babits	592-0
L. Munson	534-0	E. R. Foor	290-2
A. E. Miken	290-3	W. E. O'Brien	597-3

MRG-298

12 March 1962

TO: Distribution

FROM: Materials Research Group, 592-1

SUBJECT: Mechanical Properties of Type 202 Stainless Steel at Cryogenic Temperatures

INTRODUCTION:

The chromium (17-19%) - manganese (7.5-10%) - nickel (4-6%) type 202 is a new anstenitic stainless steel which possesses desirable mechanical and physical properties. The room temperature properties of 202 are comparable to those of 302 stainless steel. The purpose of this investigation was to determine the mechanical properties of type 202 stainless steel at room and cryogenic temperatures in order to evaluate the alloy for structural applications for cryogenic fueled missiles and space vehicles.

MATERIALS AND PROCEDURE:

Two 0.045" thick sheets of type 202 stainless steel were supplied by Allegheny-Ludlum Steel Corporation. The alloy was supplied in 55% and 75% cold rolled tempers. The properties as supplied by the producer, of the 55% and 75% cold rolled material, with and without being stress relieved, are given in Table I. The material was tested in this investigation in the "as-received" condition. Tensile specimens were machined per print MRG-D-1, and notched tensile specimens were machined per print MRG-D-10, notch "A". Tensile tests were performed at 78°F (room temperature), -320°F (by immersion in liquid nitrogen) and -423°F (by immersion in liquid hydrogen). Strain rates were 0.001 in/in/min. until 0.2% offset yield then 0.15 in/min. until failure. Strain measurements were made by use of extensometers and continuous stress-strain recorders.

RESULTS AND DISCUSSION:

The results of tensile and notched tests on 202 stainless steel at 78°, -320° and -423°F are reported in Table II. The tensile data at 78° and -320°F verify the results obtained by the producer (see Table I). The yield and tensile strengths increase and elongations (over a two inch gauge length) decrease with reduction of testing temperature from 78° to -320°F. Tensile tests were not conducted at -423°F due to insufficient material. The tensile values compare quite favorably with 60% C.R. 301 or 75% C.R. 310 stainless steels. The notched tensile strengths, however, increased only slightly from 78° to -320°F and decreased sharply from -320° to -423°F for both

the 55% and 75% C. R. Materials. These data indicate an increase in notch sensitivity at cryogenic temperatures, particularly at -423°F.

The notched/unnotched tensile ratio is used as an index to toughness or resistance to brittle fracture. The notched/unnotched tensile ratios obtained on the 55% C. R. 202 stainless steel indicate a high degree of toughness at 78°F but insufficient toughness for structural applications at -320° and -423°F. The notched/unnotched tensile ratios reported at -423°F were calculated from the smooth tensile strengths at -320°F, and therefore, are expected to be conservative since the tensile strengths at -423°F should be considerably greater than at -320°F. The notched/unnotched tensile ratios of the 75% C.R. material indicate a lack of toughness at each of the testing temperatures (78°, -320° and -423°F.)

It should be noted that the properties reported in Tables I and II are for the transverse direction (parallel to the direction of rolling.) In general, the notched tensile strengths and resulting notched/unnotched tensile strengths are lower in the transverse direction for the cold worked stainless steels. In order to compare the notch sensitivity and toughness of type 202 with other stainless steels, Table III was prepared. As may be seen from Tables II and III the relative toughness of 202 as compared to other stainless steels (transverse direction) at -423°F is quite poor, as shown below in order of decreasing toughness:

310	S. S.	40% C. R.
310	S. S.	60% C. R.
304	ELC S.S.	50% C. R.
310	S. S.	75% C. R.
304	ELC S. S.	70% C. R.
302	S. S.	60% C. R.
302	S. S.	40% C. R.
301	S. S.	42% C. R.
301	N. S. S.	60% C. R.
301	S. S.	60% C. R.
*202	S. S.	55% C. R.
*202	S. S.	75% C. R.
301	S. S.	78% C. R.
AM-355	S. S.	CRT

In order to determine the reason for the poor toughness of the 202 material at cryogenic temperatures magnetic measurements were made on the fractured tensile specimens. A Magne-gage, calibrated to read directly the per cent martensite present in stainless steels,

was used for these measurements. Both the 55% and 75% C. R. materials were found to be completely anstenitic (no martensite) in the "as-received" condition and also after room temperature tensile testing. However, the tensile specimens tested at -320°F nad 10% martensite present for the 55% C. R. material and 43% martensite present for the 75% C. R. material. It is believed that the martensite which transforms during the tensile test at cryogenic temperatures is quite brittle due to the presence of a large amount of carbon (up to 0.15%) and nitrogen (up to 0.25%) present in the 202 stainless steel. The embrittling effects of carbon and nitrogen on the semi-anstenitic stainless steels have been previously shown (e.g. 301 vs. 301-N, 304 vs. 304 ELC, etc.). It is therefore believed that the ductile-to-brittle transition of 202 stainless is caused by the formation of brittle martensite at cryogenic temperatures.

SUMMARY:

Tensile and notched tensile tests were performed on type 202 stainless steel at 78°, -320 and -423°F. Tensile properties at 78° and -320°F are comparable to those of cold worked 301 or 302 stainless steels. Notched tensile data and resulting notched/unnotched tensile ratios indicate severe embrittlement of the 55% and 75% C. R. type 202 stainless steel at cryogenic temperatures. This low temperature embrittlement is believed to be due to the formation of strain induced martensite (containing large amounts of carbon and nitrogen) at cryogenic temperatures.

TABLE I

MECHANICAL PROPERTIES OF TYPE 202 STAINLESS STEEL*

0.045" Sheet, Heat No. FJ-81-A3, A-L Steel Corp.

Condition**	Test Temp.	Hardness (at RT)	0.02% Yield Strength (Ksi)	0.2% Yield Strength (Ksi)	Tensile Strength (Ksi)	El. %
55% C.R.	Room	43.0	102	171	212	6.8
55% C.R.	-320°F	****	202	259	314	2.3
75% C.R.	Room	46.0	115	195	243	5.0
75% C.R.	-320°F	****	217	287	340	2.0
55% C.R. & Stress Relieved	Room	47.0	137	192	225	7.0
75% C.R. & Stress Relieved	Room	51.0	160	225	262	3.8

* As supplied by Allegheny-Ludlum Steel Corporation, letter dated 1 March 1960.

** Material tested transverse to the direction of rolling.

MECHANICAL PROPERTIES OF TYPE 202 STAINLESS STEEL*

0.045" Sheet, Heat No. FW-81-A3, Allegheny Steel Corp.

% Cold Work	Test Temp. (°F)	Fty (Ksi)	Ftu (Ksi)	El. (%)	Notched (K_t = 4.3) Tensile Strength (Ksi)	Notched/Unnotched Tensile Ratio
55	78	174	212	6.0	222	
55	78	-	-	-	232	
Average		174	212	6.0	227	1.07
55	-320	273	316	4.0	232	
55	-320	-	-	-	226	
Average		273	316	4.0	229	0.72
55	-423	-	-	-	158	
55	-423	-	-	-	154	< 0.49
Average		-	-	-	156	
75	78	189	238	5.0	198	
75	78	-	-	-	211	0.86
Average					205	
75	-320	288	348	4.0	225	
75	-320	-	-	-	254	0.69
75	-320	-	-	-	242	
Average		288	348	4.0	240	0.86
75	-423	-	-	-	169	
75	-423	-	-	-	165	
Average		-	-	-	167	< 0.48

* Tested as received (no stress relief) in transverse direction only.

TABLE III

NOTCHED TENSILE PROPERTIES OF STAINLESS STEEL (TRANSVERSE DIRECTION)

Alloy	Temper	Heat No.	Test Temp. (°F)	Notched (K_t =6.3) Tensile Strength (Ksi)	Notched/Unnotched Tensile Ratio
301	42% C.R.	133019	78	207	1.09
			-100	210	0.92
			-320	243	0.82
			-423	197	0.72
301	60% C.R.	38358	78	237	1.01
			-100	242	0.91
			-320	268	0.86
			-423	252	0.75
301	60% C.R.	48081	78	216	0.97
			-320	276	0.87
			-423	227	0.68
301	60% C.R.	48112	78	216	0.97
			-320	276	0.87
			-423	227	0.68
301	78% C.R.	157573	78	144	0.46
			-100	181	0.56
			-320	189	0.48
			-423	169	0.42
301-N	60% C.R.	31131	78	222	0.97
			-320	232	0.80
			-423	152	0.49
302	40% C.R.	327250	-423	242	0.81
302	60% C.R.	84204	-423	258	0.82
304 ELC	50% C.R.	33251	78	208	1.09
			-100	242	1.12
			-320	300	1.18
			-423	320	1.05
304 ELC	70% C.R.	W23215	78	205	0.95
			-100	249	1.06
			-320	307	1.11
			-423	330	1.03
310	40% C.R.	84074	-423	294	1.11
310	60% C.R.	84074	-423	308	1.08
310	75% C.R.	84074	-423	301	1.01
310	75% C.R.	43631	78	193	0.97
			-100	236	1.05
			-320	292	1.07
			-423	328	1.03
AM-355	CRT	38174	78	231	0.81
			-100	243	0.77
			-320	172	0.50
			-423	126	0.37

GENERAL DYNAMICS

Convair Division