Mechanical Properties of Weld, Base Metal and Coated Columbium Alloy Cb 752

GTA or EB welding has no significant effect on tensile strength of sheet Cb 752, but markedly reduces ductility. R 512E coating further reduces ductility of the welded Cb 752

BY A. A. TAVASSOLI

ABSTRACT. Bend ductility and elevated temperature tensile properties of sheet Cb752 have been evaluated. Bend tests were conducted from 260 to −184 C (500 to −300 F) and tensile tests up to 1427 C (2600 F).

Gas tungsten-arc welding (GTAW) or electron beam welding (EBW) had no significant effect on tensile strength of sheet Cb752, but markedly reduced ductility. Postweld annealing had no improving effect on elongation and only lowered ductile-to-brittle transition temperature of EB weld material. R512E coating (Si-20Cr-20Fe) on both welded and base metal Cb752 sheet had a uniform thickness and resulted in an equal substrate consumption. However, R512E further decreased tensile elongation of welded Cb752.

In view of the marked reductions in ductility of Cb752 after welding and coating, detailed evaluation of welded columbium alloy panels for the thermal protection system of the space shuttle and the aerobraking system of the space tug is necessary.

Introduction

Silicide slurry coated columbium alloys are the leading refractory metal alloy candidates for application in the thermal protection system (TPS) of space shuttle and aerobraking system of space tug. Although many tests have been conducted on the uncoated and coated properties of the leading columbium alloys (Cb752, C129Y and FS85), little work has been done on their welded properties.[1-3] It was for

A. A. TAVASSOLI, formerly with NASA Marshall Space Flight Center, is now with the Metallurgical Engineering Department, Aria-Mehr University of Technology, Tehran, Iran.

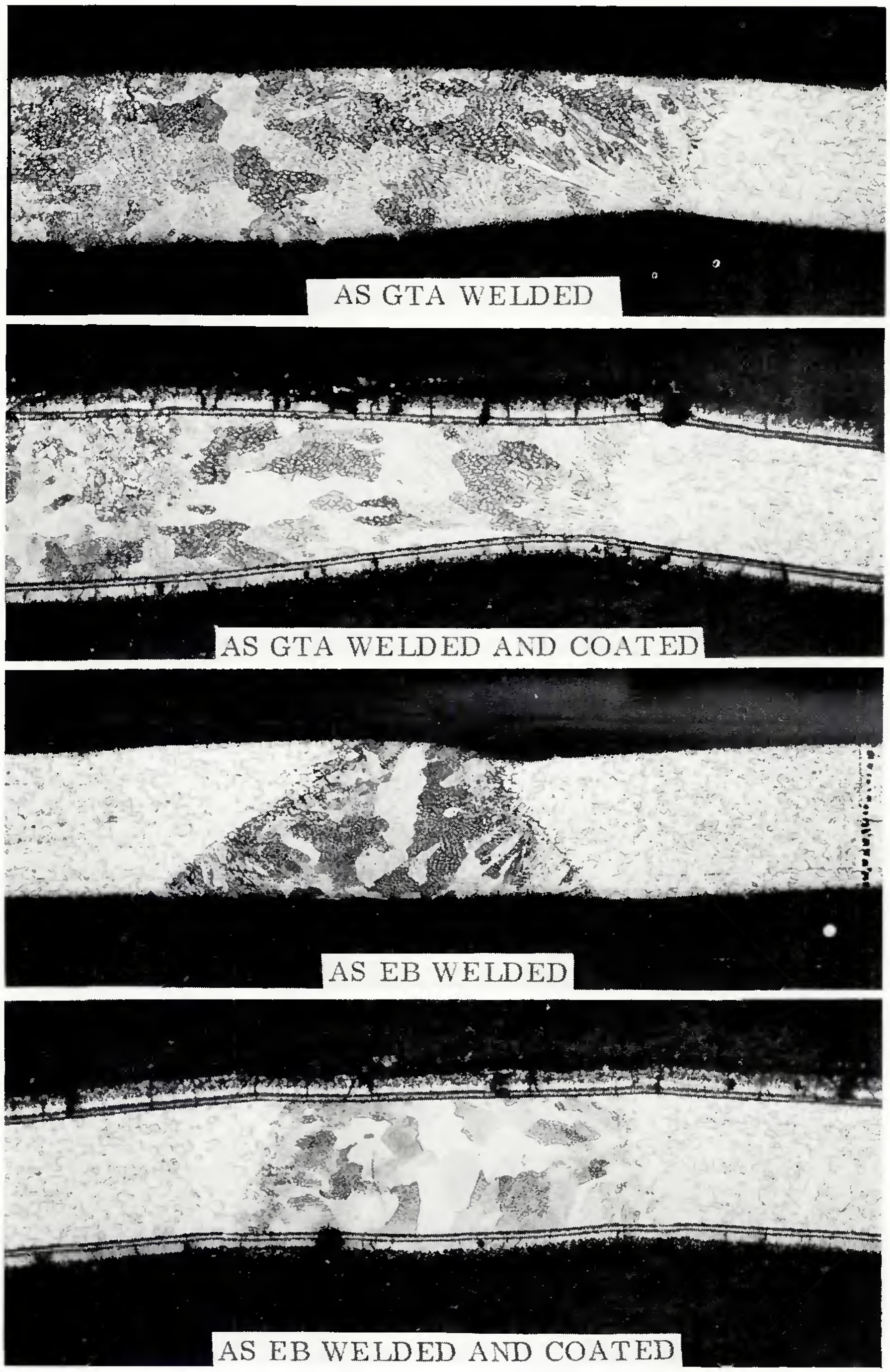

Fig. 1 — Photomicrographs of as-welded and welded-coated sheet Cb752. X50,

Table 1 — Ingot Chemical Composition of Cb752

	Wt %			Parts per million, ppm								
	W	Zr	Ta	C	O	N	H	Ti	Fe	Si	Hf	Mo
Recrystallized, heat No. 86D-2915	9.20	2.30	.02	27	64	45	5−	50−	50−	100	100	100

Table 2 Welding Conditions Used for Sheet Cb752 [a]

Parameter	Unit	GTAW	EBW
Current	A	80	3.5×10^{-3}
Voltage	V	10	75×10^{3}
Speed	cm/min	101.6	86.4
	in./min	40	34

(a) GTA chamber gas and shielding gas was argon, and electrode EWTh-2 ground to pencil sharpness was 0.238 cm (3/32 in.) in diam.

Table 3 — Bend Transition Temperature for Sheet Cb752[a] in Three Conditions

	As received or welded				1 hr at 1093 C (2000 F)				1 hr at 1316 C (2400F)			
	Longitudinal		Transverse		Longitudinal		Transverse		Longitudinal		Transverse	
Specimen	C	F	C	F	C	F	C	F	C	F	C	F
Base metal	<−184	<−300	<−184	<−300	<−184	<−300	−129	−200	<−184	<−300	<−180	<−300
GTA welded	−101	−150	−101	−150	>−129	>−200	− 46	− 50	—	—	—	—
EB welded	21	71	21	71	—	—	—	—	−101	−150	−101	−150
Coated	−101	−150	−101	−150	—	—	—	—	—	—	—	—
GTA-Coated	−101	−150	− 73	−100	−101	−150	− 46	− 50	—	—	—	—
EB-Coated	—	—	−101	−150	—	—	—	—	21	71	−101	−150

(a) Bend radius 1t where t. thickness, = 0.0381 (0.015 in.)

Table 4 — Diamond Pyramid Hardness for Sheet Cb752 (1 kg load) Before and After Anneal

	Before anneal			After anneal		
Specimen	Base metal	HAZ	Weld	Base metal	HAZ	Weld
Base metal	178	—	—	177	—	—
GTA welded	182	184	209	182	182	192
EB welded	182	203	226	182	180	184
Coated	171	—	—	—	—	—
GTA-Coated	172	180	182	—	—	—
EB-Coated	172	184	180	—	—	—

this need that the present work was initiated. Mechanical properties of uncoated and R512E coated gas tungsten arc (GTA) and electron beam (EB) welds of Cb752 are presented in this report. R512E (Si-20Cr-20Fe) was selected for this work because it is the prime coating choice for Cb752 in the metallic TPS.

Materials and Experimental Procedures

Cb752 material was received in the form of a 0.0381 cm (0.015 in.) thickness sheet. The ingot chemical composition and final heat treatment for Cb752 are given in Table 1. The as-received sheet was initially sheared into blanks and 7.62 × 25.4 cm (3 × 10 in.) strips. The strips were electrical discharge machined in two 3.81 × 25.4 cm (1.5 × 10 in.) strips and were GTA and EB welded along the machined edges. The welding conditions used are presented in Table 2. All specimens were then prepared by electrical discharge machining. Bend specimens were 2.54 × 6.55 cm (1 × 2.5 in.) in size and tensile specimens were 15.55 cm (6-1/8 in.) long with 6.35 (2.5 in.) gage length and 0.635 cm (0.25 in.) gage width. R512E was applied by the dipping technique at the rate of 5.08 cm/min (2 in./min). The coated specimens were fired for 1 hr in vacuum at 1416 C (2580 F). GTA and EB welded specimens were postweld annealed along with the as-received specimens in vacuum for 1 hr at 1093 C (2000 F) and 1316 C (2400 F) respectively

Bend tests were conducted with the crosshead speed of 2.54 cm/min (1 in./min) on a 2.54 cm (1 in.) span fixture from 260 to −184 C (500 to −300 F). The weld lines for transverse direction specimens were perpendicular and for longitudinal direction specimens parallel to the main axis of the bend punch.

Apart from room temperature tests all tensile tests were carried out in a vacuum of 1.33 to 7.99 × 10^{-3} N/m^2 (1 to 6 × 10^{-5} torr) and at the rate of 0.127 cm/min (0.05 in./min). Test temperature was automatically approached in 5 to 15 min by resistance heating of a tungsten mesh element

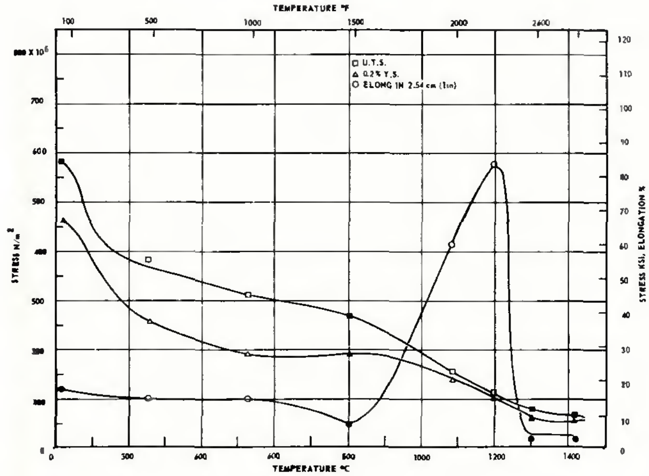

Fig. 2 — Tensile properties vs. temperature for GTA welded Cb752 sheet

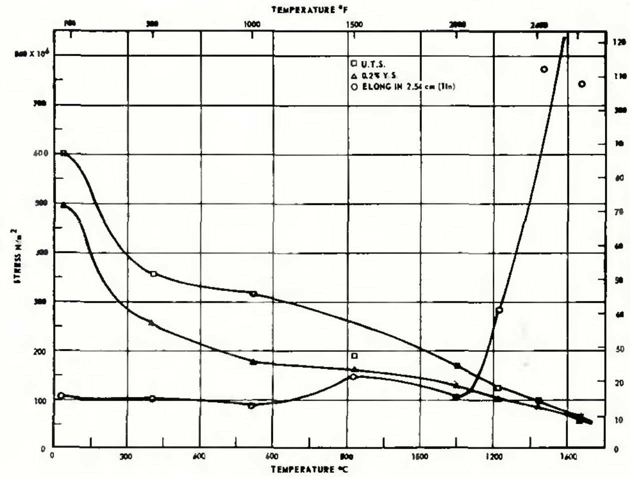

Fig. 3 — Tensile properties vs. temperature for EB welded Cb752 sheet

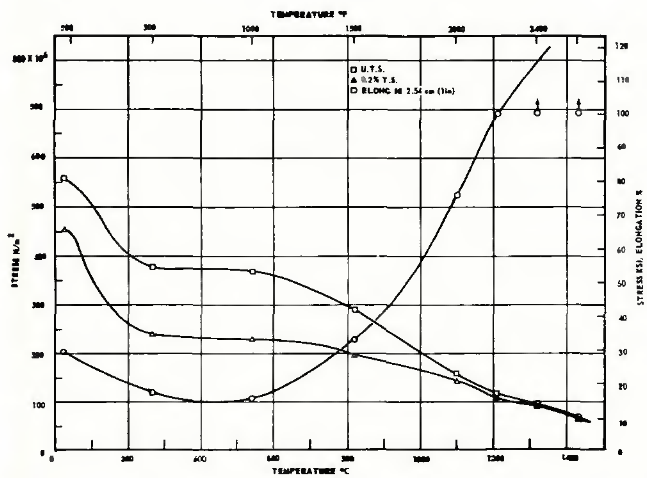

Fig. 4 — Tensile properties vs. temperature for Cb752 sheet annealed 1 hr at 1093 C (2000 F)

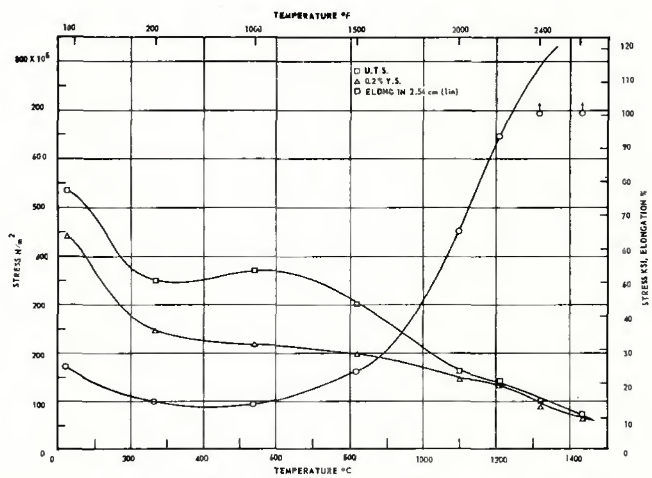

Fig. 5 — Tensile properties vs. temperature for Cb752 sheet annealed 1 hr at 1316 C (2400 F)

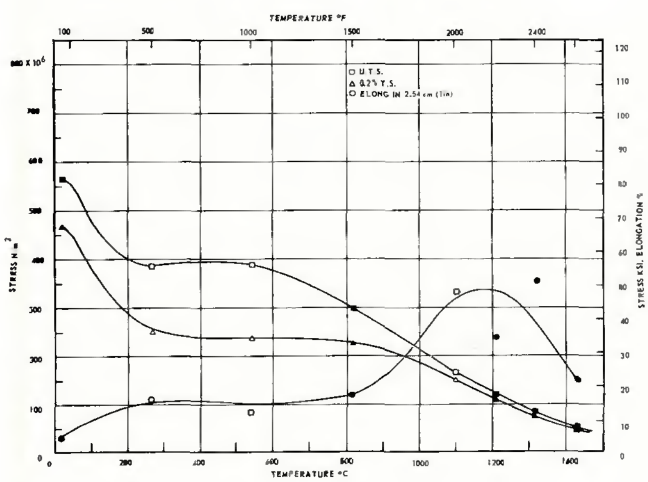

Fig. 6 — Tensile properties vs. temperature for postweld annealed GTA welded Cb752 sheet

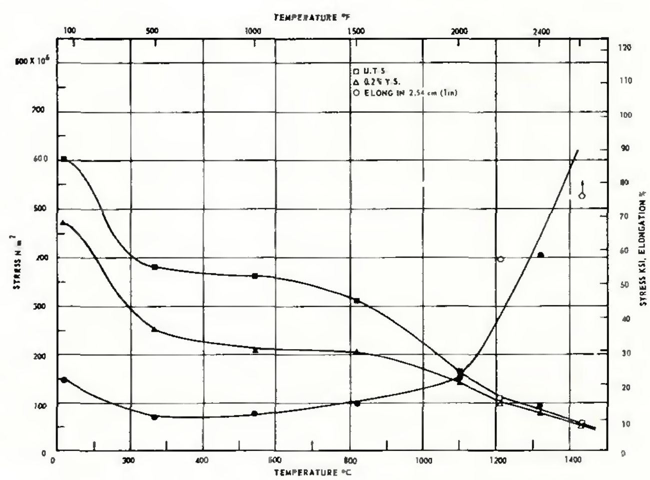

Fig. 7 — Tensile properties vs. temperature for postweld annealed EB welded Cb752 sheet

furnace. A soak time of 5 min at test temperature was allowed. A high temperature extensometer which satisfied Class B-2 of ASTM-E83-57T was used. Due to large thermal expansion and elongation, some elevated temperature tests were stopped before failure and their positions are marked by an arrow on the figures. All tensile specimens were pulled in the transverse direction relative to the rolling direction of the as-received sheet.

Results

Microstructure

GTA and EB welds were generally uniform and of good appearance. There was a small grain growth in the heat affected zones (HAZ) of the welds, but microstructure of base metal was unchanged (Fig. 1). No significant microstructural change other than a slight grain growth was observed at up to 500X after postweld annealing or coating. R512E coating covered base metal, HAZ and weld metals with a uniform thickness. Substrate consumption by coating also was the same for HAZ and base metal of GTA and EB welds.

Bend Ductility and Hardness

Ductile to brittle transition temperature (DBTT) of the as-received material was sharply increased after GTA or EB welding (Table 3). The response of the GTA and EB welds to postweld annealing differed. For instance, DBTT of GTA welded specimens after PWA sharply increased from −101 C to −46 C (−150 F to −50 F), but it decreased for EB welded specimens from room temperature to −101 C (−150 F). This difference in response to PWA is probably due to inclusions in GTA weld metal or surface notches. In general, from Table 3 it can be concluded that welded and coated sheet Cb752 have a DBTT at −101 C (−150 F).

Table 4 shows that no significant change in hardness of Cb752 occurs after welding and coating.

Tensile Properties

Tensile properties versus temperature for as GTA and EB welded Cb752 specimens are presented in Figs. 2 and 3. Open symbols represent specimen failure in base metal and solid symbols in weld or HAZ.

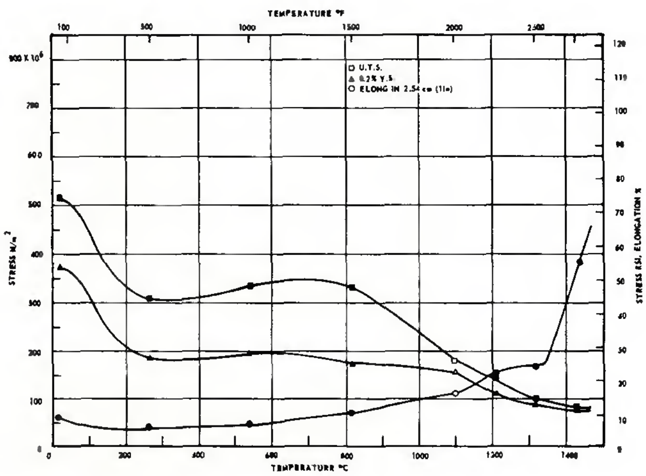

Fig. 8 — Tensile properties vs. temperature for GTA welded and R512E coated Cb752 sheet

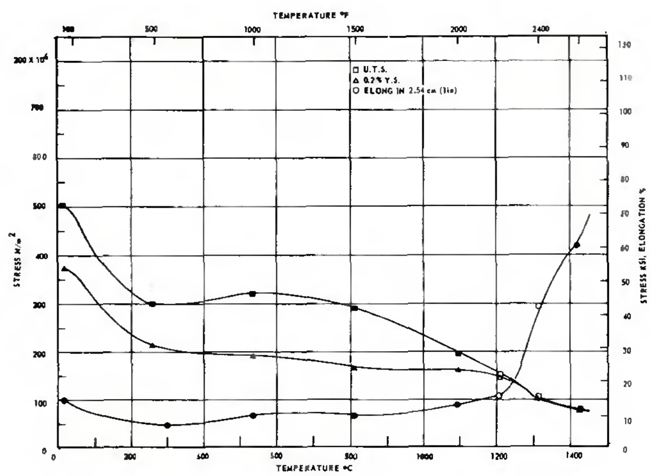

Fig. 9 — Tensile properties vs. temperature for EB welded and R512E coated Cb752 sheet

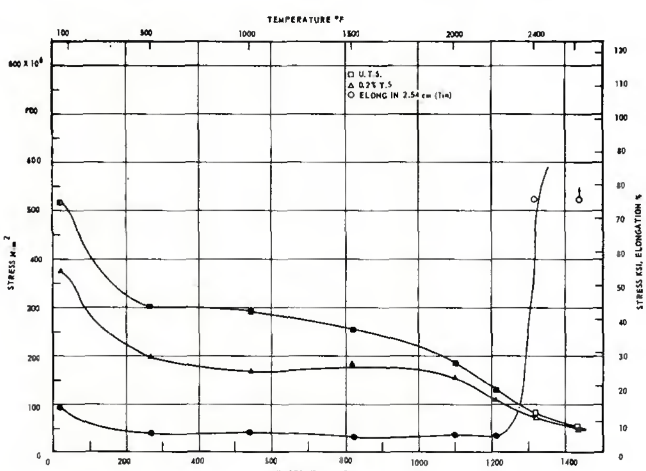

Fig. 10 — Tensile properties vs. temperature for GTA welded R512E coated and postweld annealed Cb752 sheet

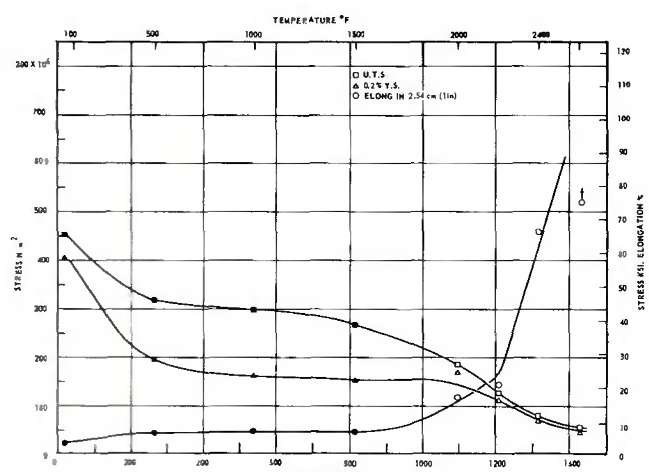

Fig. 11 — Tensile properties vs. temperature for GTA welded, R512E coated and postweld annealed Cb752 sheet

Half-filled symbols indicate that both types of failure were observed. The uncoated and coated tensile properties of as-received Cb752 have been reported elsewhere.[4,5] However, tensile properties of 1 hr annealed specimens (Figs. 4 and 5) are not significantly different from the properties of the as-received Cb752. It can be seen that, although tensile strength or 0.2% yield stress is not affected by welding, elongation is markedly reduced. PWA, unlike its improving effect on DBTT of the EB weld, further decreases tensile elongation of GTA and EB welded specimens (Figs. 6 and 7). There was a substantial increase in the number of HAZ and weld metal failures for EB welded specimens. R512E coating further decreased elongation of welded specimens (Figs. 8-11). It should be noted that the coated strength data are based on before coating dimensions and hence the low temperature strength loss is mainly due to base metal consumption by coating.

Conclusions

Based on the following conclusions detailed evaluation of welded Cb752 panels for application in the TPS of space shuttle and aerobraking system of space tug is necessary.

1. GTA or EB welding has no significant effect on elevated temperature tensile strength of sheet Cb752.
2. GTA or EB welding has a marked reducing effect on bend and tensile ductility.
3. Postweld anneal does not improve tensile elongation.
4. R512E coating further reduces ductility of welded Cb752 material.

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SWIFT and ROGERS . . .

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Conclusion

Stress relief embrittlement in 2¼-Cr-1Mo steel is irreversible. It appears to be due to the formation of precipitates inherent in the alloy system and does not primarily result from the presence of residual elements. The main cause, the precipitate Mo_2C, is partially coherent with the matrix. The coherency strains cause a reduction in the notch toughness. Once the precipitates have grown to a size where coherency strains can no longer be accommodated by the matrix, the notch toughness improves. Therefore, once the weld has been stress relieved at temperatures above the stress relief embrittlement range, it cannot be reembrittled by the same mechanism although classical temper embrittlement can occur.

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