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TECHNICAL REPORT RD–ST–95–9

MATERIALS ANALYSIS OF FOREIGN PRODUCED FLEX WINGS

Albert S. Ingram
Structures Directorate
Research, Development, and Engineering Center

March 1995

U. S. ARMY MISSILE COMMAND

Redstone Arsenal, Alabama 35898-5000

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A material analysis was performed on two foreign produced flex wings. The steel alloy and fabrication sequence was identified. The mechanical properties of the steel as well as the corrosion resistance of the wing configuration researched. The flex wing was found to be fabricated from a martensitic Precipitation Hardening stainless steel (15–5 PH). The corrosion resistance (as judged from salt fog tests) was deterimined to be excellent. The wing halves were spot welded together after the 900 °F age hardening heat treatment. The flex wing exhibited excellent spot weld quality and a fine martenistic microstructure.

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I. BACKGROUND

The wrap around or flex wing concept for missile applications is an innovative method of providing needed guidance surfaces while allowing designers to take advantage of the additional internal missile body space. With the flex wings deployed on the missile outer diameter, the added internal missile body space may be used for additional electronic hardware or munitions. Past studies into the Alternate Antitank Airframe Configuration (AATAC) missile [1] documented domestic flex wings which were manufactured using 17–7 PH stainless steel (AISI 631). Foreign flex wings are reported to be produced with similar materials though slightly different in size and configuration. As part of a task which characterized foreign missile hardware, several foreign produced flex wings were received for analysis. Examples of the domestic and foreign produced flex wings are shown in Figure 1. As seen in Figure 1, the flex wing depends upon spot welding as the primary means of joining the wing halves.

II. OBJECTIVE

The objective of this project was to perform a materials characterization study of the foreign produced flex wing. All results regarding the steel alloy used and fabrication methods for the foreign flex wing were documented. Any information gained regarding the alloy steel used and fabrication sequence might be advantageous toward improving domestic flex wing production.

III. APPROACH

This task was divided into three main areas of research which included the following:

1. Steel Alloy Characterization

   o Alloy Identification
   o Tensile Testing
   o Rockwell Hardness

2. Fabrication Methods

   o Heat Treatment Used
   o Spot Weld Quality
   o Basic Flex Wing Configuration/Dimensions

3. Corrosion Susceptibility

IV. STEEL ALLOY CHARACTERIZATION

The "as received" flex wing did not have any protective coating such as paint or a plating. The flex wing steel's elemental composition was reported to be very similar to the domestic Precipitation Hardening (PH) alloy 15–5 stainless steel. The elemental analysis was performed using atomic absorption and Energy Dispersive X–Ray (EDXA) analysis. The analysis confirmed the material to be a 15–5 PH type stainless steel (Table 1).

To determine the mechanical properties of the flex wing steel, tensile samples were sectioned from the main body of a wing. Four flat tensile samples with a one inch gage length were tested. The results (Table 2) show the steel was heat treated to a high level of tensile properties with an average ultimate strength of 229,910 psi (1,585 MPa). The nominal thickness of these tensile samples was 0.0114 inch (0.29 mm).

To determine the hardness of the flex wing steel, microhardness measurements (500 g load) were performed on a prepared metallography sample. Hardness measurements were made on the base wing material as well as the spot welds. The hardness test results were as follows:

o Base Material: 44–47 HRC
o Spot Welds: 40–41 HRC

V. FABRICATION METHODS

The subject flex wing is fabricated from a 15–5 PH type stainless steel which is very similar to the domestic 17–4 and 15–5 precipitation hardening stainless steels. Like the domestic versions, the foreign steel would be hardened by a one step hardening operation which is normally done at 900 °F. Since the spot welds are of lower hardness than the base material, spot welding of the wing halves was performed after the 900 °F aging heat treatment. Therefore, it is believed that all forming operations of the wing halves was performed while the steel was in the solution annealed condition (condition A).

The spot weld quality of the foreign flex wing was excellent. As seen in Figure 2, a typical spot weld exhibited good fusion and penetration with no spot weld anomalies. Typically, this particular type of wing has 118 spot welds on the wing halves (59 per side) and 96 spots welds for the base stiffener sections (48 per side). The microstructure of the 15–5 PH type alloy consisted of a very fine martensite with no observed delta ferrite or other inclusions (Fig. 3).

The basic dimensions of the received flex wing are listed in Figure 1. The wing halves were manufactured from 0.0114–inch (0.29 mm) thick sheet steel while the base stiffener sections were manufactured from 0.027–inch (0.68 mm) thick sheet steel.

VI. CORROSION SUSCEPTIBILITY

The corrosion susceptibility of this flex wing was evaluated by performing salt spray exposure tests on u–bend strip samples and on a complete flexed wing. Three 1 inch wide strip samples, which had been sectioned from a flex wing, were stressed to 100 ksi in a u–bend fixture and placed in a salt spray chamber (per ASTM B117). There were no failures after 1040 hours of salt spray exposure. To test the flex wing configuration, a complete flex wing was installed in a loading fixture (Fig. 4) to simulate actual stowage conditions. This assembly was then placed in a salt spray chamber; the flexed wing was monitored for corrosion and cracking. After 120 hours, there was no evidence of cracking with some isolated areas of minor surface staining.

VII. CONCLUSIONS

The examined flex wing has excellent material qualities; particularly with regard to corrosion susceptibility during long term stowage. This explains why no protective coating was found on any examined foreign flex wing. The fine martensitic structure (e.g., lack of coarse grain boundaries) as well as the absence of delta ferrite indicates that this steel alloy was vacuum melted during the ingot refinement and, subsequently, cold worked (rolled) to the required thickness.

The spot welding quality of the examined flex wing is excellent. All examined spot welds had good fusion and penetration with no spot weld anomalies. The microstructure of the basic alloy (15–5 PH) was free of any metallurgical anomalies.

The alloy used for manufacture of the examined flex wing is a 15–5 PH type stainless steel which is a martensitic PH stainless steel and is very similar to the domestic 17–4 PH and 15–5 PH stainless steels. Heat treatment response testing (Table 3) confirmed that this alloy hardens from the same basic heat treatment procedures as used on domestic 17–4 PH and 15–5 PH type steels. In comparison, current domestic flex wings use 17–7 PH stainless steel which is a semi-austenitic PH stainless steel.

Based on the microhardness and microstructural examination of the base metal and spot welds, the foreign flex wing assembly was spot welded together after the age hardening heat treatment.

VIII. RECOMMENDATIONS

Future fabrication of domestic flex wings can utilize 15–5 PH stainless steel (and vacuum melted 17–4 PH steel) as a very acceptable alternative to 17–7 PH steel. All domestic 15–5 PH stainless steel is vacuum melted to eliminate delta ferrite inclusions. Depending upon material availability in the required thickness, either of these two alloy types (martensitic 15–5 or semiaustenitic 17–7 PH steels) can be used for flex wing structures.

Table 1. Foreign Flex Wing Steel Element Analysis

ELEMENT	WEIGHT PERCENT
Chromium	15.17
Nickel	5.17
Copper	2.43
Silicon	0.66
Titanium	0.19
Iron	Balance

Table 2. Foreign Flex Wing Steel Mechanical Properties

Sample	Yield Strength	psi (MPa)	Ultimate Strength	psi (MPa)	Percent Elongation *
1	226,785	(1,564)	232,142	(1,600)	3.2
2	221,429	(1,527)	226,786	(1,564)	4.3
3	228,571	(1,576)	230,357	(1,588)	4.6
4	225,000	(1,551)	230,357	(1,588)	3.3
Average	224,446	(1,547)	230,357	(1,588)	3.8

* A 1 inch gage length was used. The average thickness of all samples was 0.0114 inch (0.29 mm). Test speed was 0.05 inch per minute (1.27 mm per minute).

Table 3. Foreign Flex Wing Response to Heat Treatment Hardness Test @

"As Received" Hardness, HRC	**Solution Anneal * At 1900 °F, HRC**	**Age Hardening At 900 °F, HRC**
44–47	28–37	39–46
Average 45	32	41 $

* Air cool after solution anneal. Age hardening time was one hour. Heat treatment per MIL–H–6785 for 15–5 PH steel.

$ The decrease in age hardened hardness (45 versus 41) is believed to be due to the recrystallization of the cold worked structure and/or possibly imperfect heat treat temperatures for this specific foreign alloy.

@ All hardness measurements were made using superficial (15N scale) hardness tester.

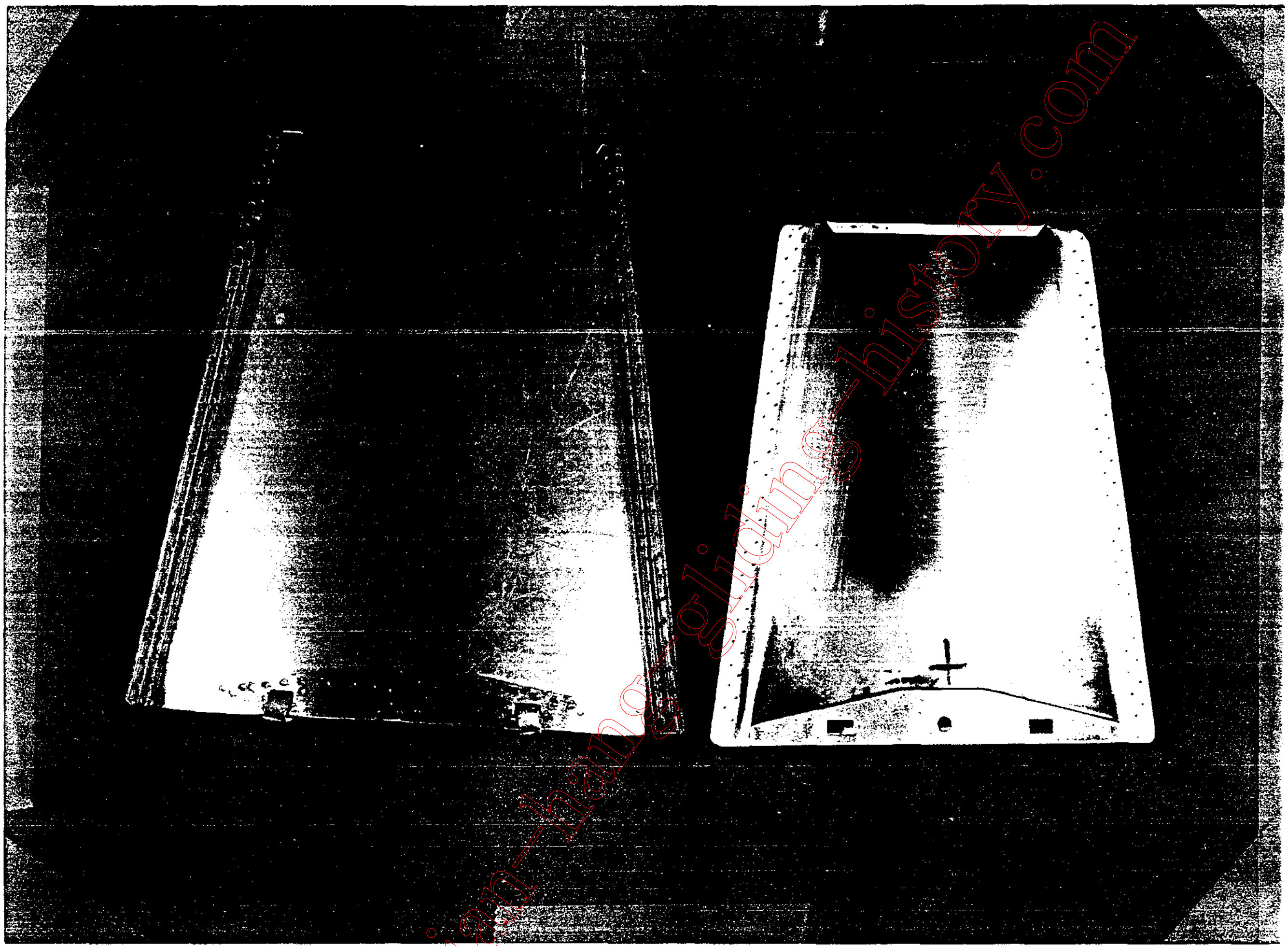

Figure 1. Photograph Showing Foreign Flex Wing (Left) and Domestic Counterpart (Right). The Basic Dimensions for the Foreign Flex Wing are: Height = 5.310 Inches (134.87 mm), Width at Base = 4.910 Inches (124.71 mm), Width at Top = 3.340 Inches (84.84 mm), Skin Thickness = 0.0114 Inch (0.29 mm), Base Stiffness Thickness = 0.027 Inch (0.68 mm)

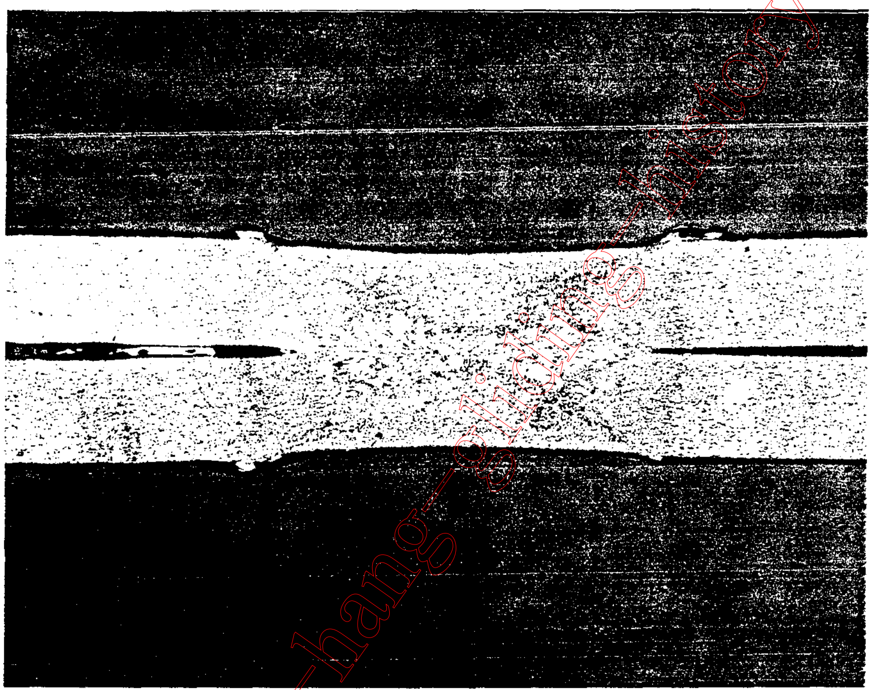

Figure 2. Typical Spot Weld in Foreign Flex Wing Assembly. Mag. 50x. Fry's Reagent Etch.

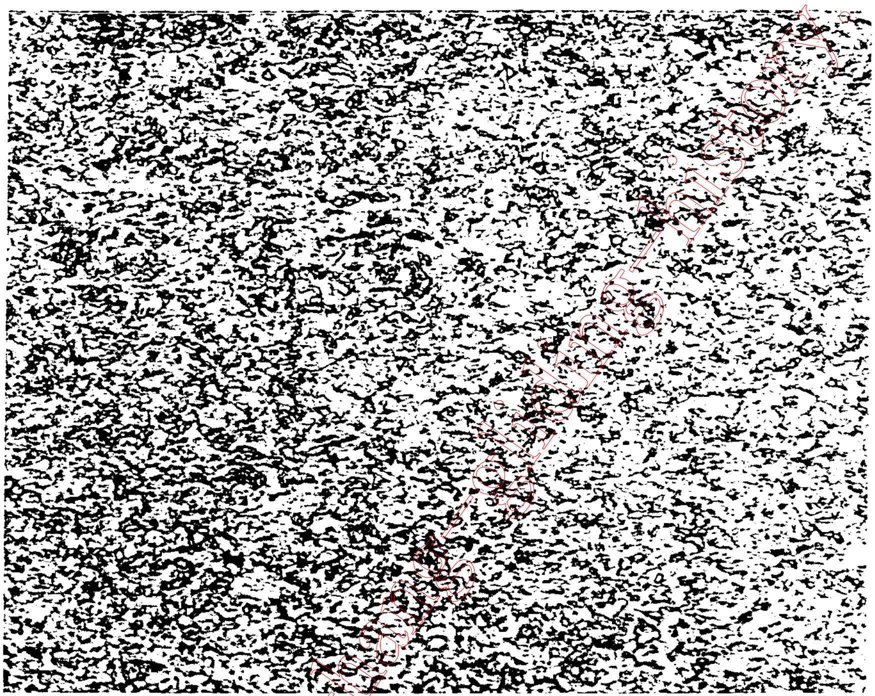

Figure 3. Typical Microstructure of Foreign Flex Wing Steel. Mag. 500x Fry's Reagent Etch

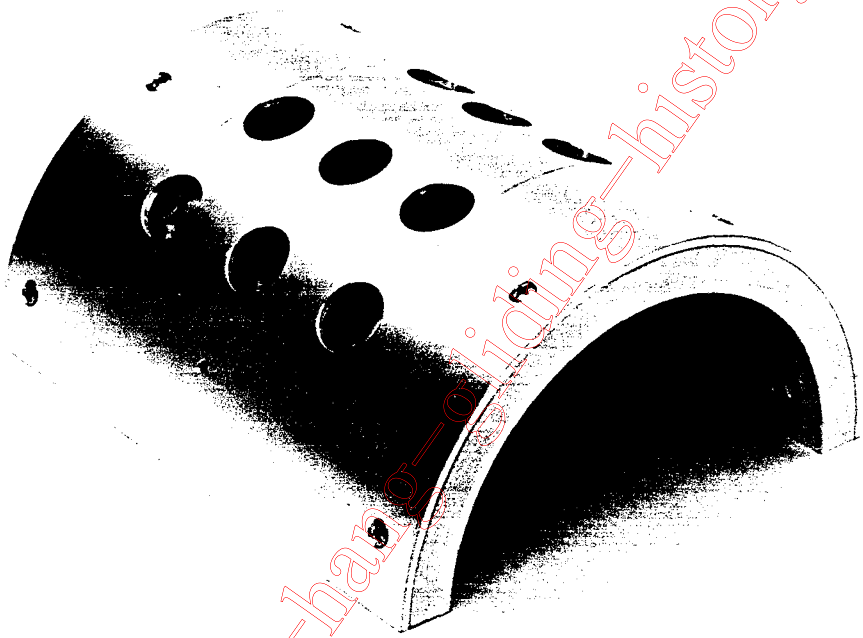

Figure 4. Photograph of Flex Wing Loading Fixture. The Wing Attached and "Flexed" Around the Assembly Before the Perforated Outer Shell was Installed

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AD B252433, Pilot's Handbook for the Flexible Wing Aerial Utility Vehicle XV-8A, March 1964, 52 pp

AD B200629, Flex Wing Fabrication and Static Pressure Testing, by Larry D. Lucas. June 1995, 80 pages

AD B198352, Materials Analysis of Foreign Produced Flex Wings, by Albert Ingram, march 1995, 16 pp.

AD B131204, Active Flexible Wing Technology, by Gerald D. Miller, Feb. 1988, 256 pages

AD B130217, Producibility Analysis of the Alternative Antitank Airframe Configuration Flex Wing, June 1988, 112 pages

AD B126450, From Delta Glider to Airplane, June 1988, 5 pages

—AD B803668, Sailwing Wind Tunnel Test Porgram, September 1966, 125 pages

AD 477 482, An Evaluation of Flex-Wing Aircraft in Support of Indigenous Forces Involved in Counterinsurgency Operations by R.A. Wise, Feb 1965, 74 pages

—AD 461202, XV-8A Flexible Wing Aerial Utility Vehicle, H. Kredit, Feb. 1965, 100 pages

—AD 460405, XV-8A Flexible Wing Aerial Utility Vehicle, Final Report. Feb. 1965, 113 pages

—AD 431128, Operational Demonstration and Evaluation of the Flexible Wing Precision Drop Glider in Thailand, by William R. Quinn, November 1963, 22 pages.

AD 430150, Comparative Evaluation of Republic Bikini Drone System, Final Report, 1943?

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