HOT PRESS FORMING 7' DIAMETER

HEMISPHERES OF HEAVY SECTION ALLOY TITANIUM PLATE

Lab. Project 930-107
Technical Memorandum 1

S 4636, Task 12625

July 18, 1969

MATERIAL SCIENCES DIVISION

Approved: R. J. Wolfe
Acting Associate Technical Director

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FIGURE 2 – TWO 7′ DIAMETER Ti–621/0.8MO ALLOY HEMI–HEADS.

ADMINISTRATIVE INFORMATION

Ref: (a) NASL Program Summary S 4636, Task 12625 of 1 May 1969
(b) NASL Program Summary SF 51-541-004, Task 12385 of 1 May 1969
(c) NASL Program Summary SF 51-541-005, Task 12392 of 1 May 1969
(d) Fabrication, Welding and Inspection of Ti-621/0.8 Mo Alloy Titanium "ALVIN/AUTEC" Submersible Hulls, February 1969

FIGURES:

1 - Press Forming 7' Diameter Hemi-Heads of Alloy Titanium, Photo No. L-21760.

2 - Two 7' Diameter Ti-621/0.8 Mo Alloy Hemi-Heads, Photo L-21760-1.

1. An investigation to develop production forming techniques for heavy section alloy titanium plates and shapes is being conducted at the Naval Applied Science Laboratory (NASL) as outlined in reference (a). This work is in support of a Naval Ship Systems Command RDT & E Program to develop and evaluate titanium alloys for potential deep diving submersible applications.

2. Procedures for forming heavy section alloy titanium were developed at NASL under related tasks, references (b) and (c). This memorandum covers the application of these forming parameters to the production of heavy walled 7 foot diameter hemispheric heads. Two of the heads formed during this operation were of the Ti-621/0.8 Mo alloy and are intended for use in the ALVIN/AUTEC submersibles, under Project Titanes.

3. Two 3 3/8 inch thick Ti-621/0.8 Mo plates and one 4 inch thick Ti-6Al-4V plate were produced by Reactive Metals, Inc. and machined to 118 inch diameter at Lukens Steel Company in preparation for the forming operations.

4. All three plates were non-destructively inspected, either under the supervision of, or directly by, qualified NASL personnel, before they were committed to being formed.

5. A centering pin of matching alloy, 2 1/2 inches long by 2 inches in diameter, was welded on one side of each plate at the geometric center. A full fillet weld was placed around the periphery of each pin by the TIG process to retain the pin in place throughout the heating and forming operations.

6. The forming procedure, proposed by the Forming Group of the Titanium Program at NASL and agreed upon beforehand by technical personnel of Reactive Metals, Inc. and the Lukens Steel Company, was to coat the plates with an oxidation retardant coating, heat to 1800 ± 25°F, and then form as rapidly as possible at temperatures not lower than 1600°F.

7. Since the formed hemisphere height and required die heights exceeded the maximum daylight opening capacity of the largest press at Lukens Steel Company, an innovation in die use was proposed by the die design group at Lukens Steel

Company. The plate would be formed to approximately half its finished height with the bottom die in its lowest position. The upper die would then be backed away and the lower die raised and locked approximately two feet higher. Forming would then be completed by pressing the preformed plate through the lower die. This procedure was adopted even though rapid manipulation of the very massive lower die would be required to avoid working the titanium plate below 1600° F.

8. The three titanium plates were charged into a gas fired furnace maintained at 1825°F. and heated for approximately two hours while the dies were being placed in the press. Photographs of the plate charging and die placement operations are shown in Figure (1).

9. The Ti-6Al-4V plate was removed from the furnace at 1780° F. and formed with the lower die in the down position. The shape thus achieved is shown in Figure (1). The temperature loss during the time required to raise the lower die was excessive and the preform was returned to the furnace without further forming. On reaching a uniform temperature of 1800° F. the preformed Ti-6Al-4V plate was again removed from the furnace and placed in the dies. No forming was accomplished during this cycle due to misalignment of the dies that occurred when the lower die was moved to its high position. The preform was placed aside in favor of forming a Ti-621/0.8 Mo head at that time.

10. The first Ti-621/0.8 Mo head was removed from the furnace at a uniform temperature of 1800° F. and formed initially with lower die in the down position. The die was raised without removing the preformed head and, although the temperature was slightly lower than desired, pressing continued until the head was fully formed. During this forming the press was operated at near maximum load capacity.

11. After removal from the dies the hot hemispheric head was visually examined for cracks. Only one, apparently minor, hot tear was found on the outer surface near the equator of the head. A photograph of the tear is shown in Figure (1). The head was far too hot for close examination, but it is believed that the tear is shallow and will be removed during the normal machining operation required to achieve the final dimensions of the head.

12. The second Ti-621/0.8 Mo. plate was heated to 1820° F. and formed in a manner similar to that used for the first head. Die manipulation was accomplished more rapidly and the preformed blank was approximately 40° F. hotter, going into final forming, than the first Ti-621/0.8 Mo head was at the same stage.

13. No cracks or tears were observed in this second head after it was removed from the dies. Again, no very close examination could be conducted because of the high heat conditions but the head appeared to be well formed with no flat, bulged, or thin areas.

14. The Ti-6Al-4V preformed blank was again charged into a furnace and heated to a uniform 1820°F. The cycle of loading the preform into the dies, raising and securing the lower die, and pressing to finished contour was repeated.

15. On the press backstroke, used to strip the finished Ti-6Al-4V head from the dies, three hold-down turnbuckles on the bottom die fractured followed, in short order, by the fracture of all the the bolts used to secure the male die to the upper press platen. This situation precluded mechanical stripping of the head from the die so the entire upper die assembly was removed and allowed to cool to ambient temperature off the press. The assembly was charged into a furnace and heated until the head became loose on the dies and could be readily removed.

16. Visual examination of the Ti-6Al-4V head revealed a hot tear on the outside surface, near the equator, similar to that found in the first Ti-621/0.8 Mo head. This tear is believed to be shallow but will be fully explored when the head is non-destructively tested at NASL.

17. Figure 2 shows the two 7 foot diameter Ti-621/0.8 Mo hemispheric heads, at NASL, in position for non-destructive inspection. Both these and the Ti-6Al-4V head will be inspected in accordance with the requirements of reference (d).

18. In summary, the 3 3/8 inch thick Ti-621/0.8 Mo plates and the 4 inch thick Ti-6Al-4V ELI plate were successfully hot press formed to 7 foot diameter hemispheres. Difficulties encountered in the forming operations were due mainly to the narrow hot forming temperature range of the material and the massiveness of the plates which required that the press be operated at near maximum capacity. Hot surface tears at the rim areas of two heads may be attributed to local cold spots and high surface stresses in those areas in contact with the lower die. These tears appear to be shallow and it is expected that they will be removed when the heads are machined to their finished size.

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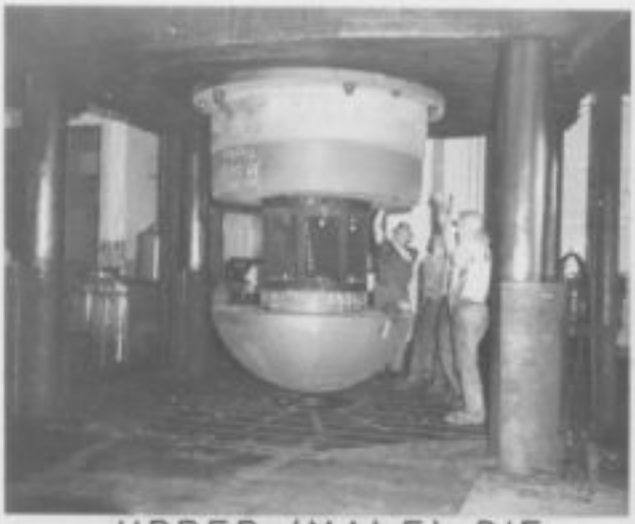
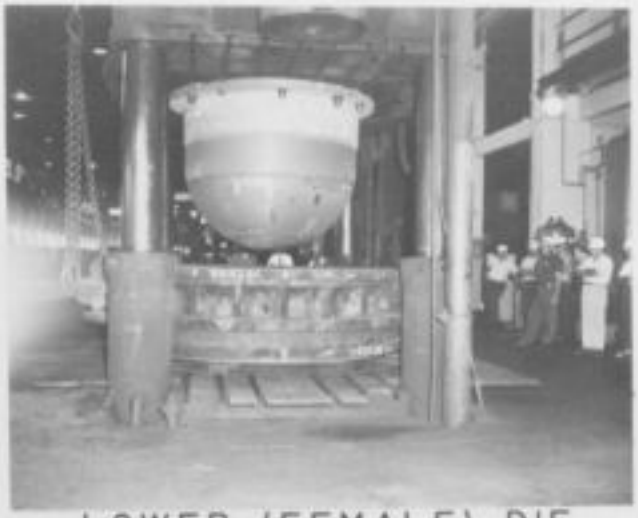
Frank J. Lengenfelder
Senior Task Leader

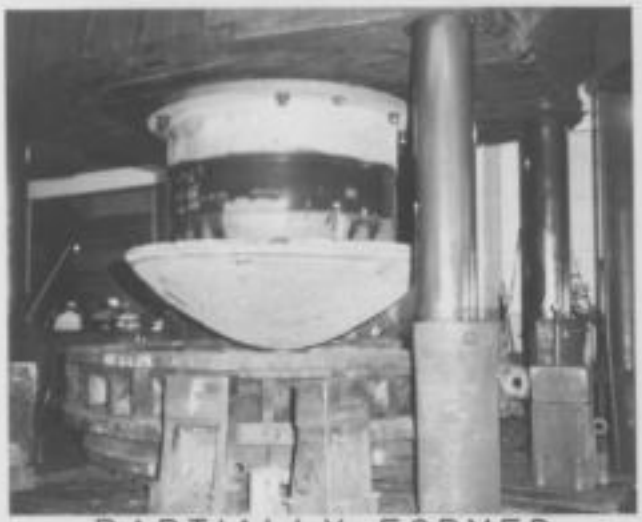


UPPER (MALE) DIE PLACEMENT



LOWER (FEMALE) DIE PLACEMENT

CHARGING TITANIUM DISC INTO FURNACE



PARTIALLY FORMED Ti-6Al-4V HEAD

AS-FORMED HEAD (ARROW INDICATES SURFACE CRACK)

FIGURE I. PRESS-FORMING 7' DIAMETER HEMI-HEADS OF ALLOY TITANIUM

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LAB PROJECT 930-107
TECH MEMO NO 1
PHOTO NO 21760