

Development of Hollow Cylindrical Tank with Blow Forming of Titanium Sheets

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ABSTRACT

In this paper, manufacturing hollow cylindrical tank was demonstrated with gas forming of titanium sheets. An innovative gas blow forming method to produce a complex shape of hollow cylindrical tank from titanium multi-sheets by low hydrostatic pressure was presented. Finite element analysis on gas blow forming process has been carried out in order to improve the forming process when manufacturing subscale hollow cylinder structure using Ti-6Al-4V multi-sheets. The simulation focused on the reduction of forming time and obtaining final required shape throughout investigating the deformation mode of sheet according to the forming conditions and die geometry. The result shows that the manufacturing method with gas forming of multi-sheets of titanium alloy has been successful for near net shape forming of subscale hollow cylindrical tank of ramjet engine.

INTRODUCTION

Titanium alloys have been extensively chosen for the aerospace application in the last 40 years due to their intrinsic properties of low density, high strength, excellent corrosion resistance, and good high temperature durability. Well known workhorse, Ti-6Al-4V alloy shows superplastic properties that allow large plastic deformation under certain conditions. A combination of superplastic forming and diffusion bonding (SPF/DB) processes of this alloy has been a very attractive method permitting the forming of internally reinforced structural parts in a simple blow forming[1,2]. The present work was concerned with fabrication of titanium hollow cylinder tank for ramjet engine in subscale with blow forming of Ti-6Al-4V sheets. The forming profile of hollow configuration was analyzed and the finite element model was successfully demonstrated

to predict forming behavior. It is notable that the forming of complicated shape of hollow cylindrical tank for ramjet engine is successfully demonstrated with blow forming technology.

EXPERIMENTAL

A commercial Ti-6Al-4V alloy was supplied in the form of rolled sheets of 2mm and 1.6mm by RTI. The chemical composition of Ti-6Al-4V alloy is 6.05Al-3.89V-0.21Fe-0.11O-0.01C-0.007N with less than 0.005 Y and the average grain size is about 10 micron. Ti-6Al-4V alloy is two phase alloy with fine equiaxed alpha phases mixed with transformed beta phase.

The optimum forming condition was obtained by a series of high temperature tensile tests with strain rates ranged from 10^{-4} /sec to 10^{-2} /sec and at several temperatures of 1073K to 1223K. After determining high temperature tensile characteristics of this alloy, the forming profile was prepared from a finite element analysis(FEM) with MARC(MSC Software Corp.).

Based on the optimum condition from tensile tests, diffusion bonding was performed at several different temperatures ranged from 1123 K to 1193 K with 3MPa for one hour in argon gas environment. The pressure was applied for uniform contact of bonded interface by hydrostatic gas pressure. The bonding time of one hour was chosen in order to reduce the parameters and simplify the procedure.

The equipment includes a press and a furnace with top and bottom heating with side heating panels. The upper plate moves downward for pressing the tool evenly and is controlled by a hydraulic cylinder. The lower part of the press is a mobile shuttle which has to allow loading and unloading the tool and parts as shown in Figure 1.

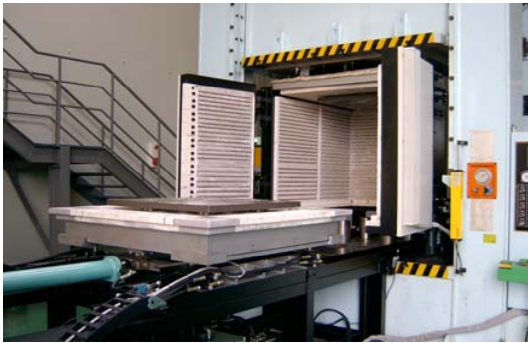


Figure 1. Press used for blow forming operations

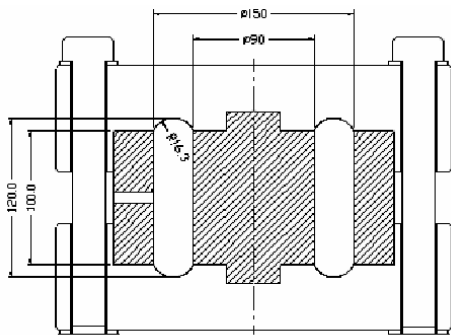


Figure 2. Cross-sectional view of forming tool

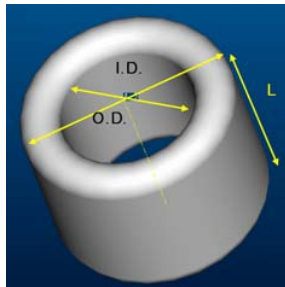


Figure 3. Schematic shape of hollow cylinder tank

Since the forming temperature is above 1073K, corrosion resistant steel (CRES) is chosen for tool material. The detailed forming fixture is described in Figure 2. It is important to drill a hole for gas supply. In the figure, the gas inlet hole is located at the left side of the tool. The hydrostatic gas pressure was applied inside of the tank for final forming. The inner and outer sheets were diffusion bonded and the specimen was located inside of the forming tool (Figure 2) and inert gas was applied.

The schematic shape of the hollow cylinder tank is shown in Figure 3. The outer diameter is 150mm and inner diameter is 90mm in subscale. The design drawing of hollow cylinder tank is in Figure 4.

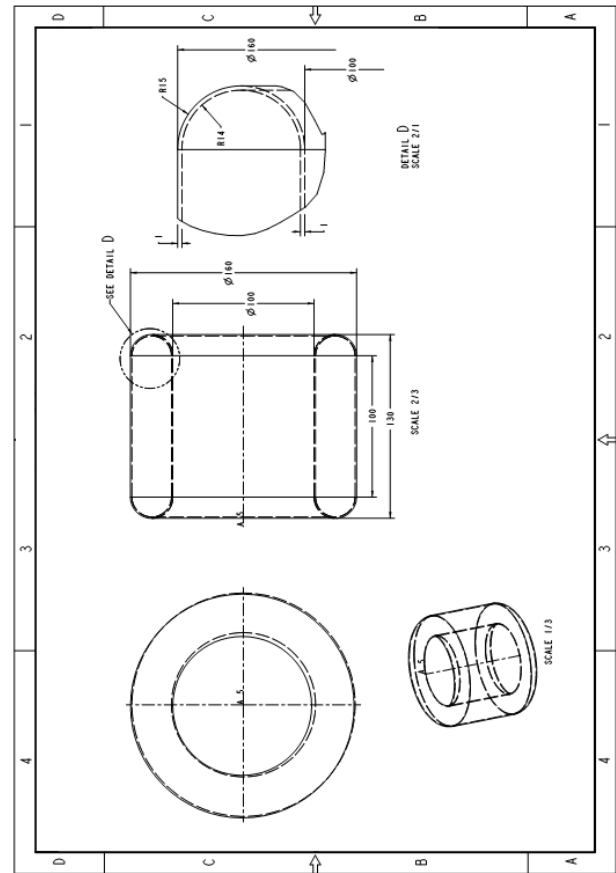


Figure 4 Design drawing of hollow cylinder tank

RESULTS AND DISCUSSION

The typical microstructure of specimen is shown in Figure 5, with average grain size of 10 micron. The flow stress for high temperature behavior was obtained from a series of tensile tests with strain rates ranged from 10^{-4} /sec to 10^{-2} /sec and at several temperatures of 1073 K to 1223 K. The typical flow stress curve is shown in Figure 6. The maximum elongation was obtained at the strain rate of 10^{-3} /sec and 1123 K.

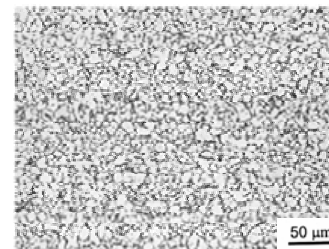


Figure 5. Initial microstructure