IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 8, August 2015.
www.ijiset.com
ISSN 2348 – 7968

Age hardening Treatment of Ti-6Al-4V alloy dome for Aerospace Application

Jijo John[1] and Dr. N. M. Nagarajan[2]

[1]Final Year M.Tech in Manufacturing Engineering,
KMCT College of Engineering, Calicut, Kerala
Email: jijojohn31189@gmail.com
Mob: +919995169435
[2] Emeritus professor,ME,
KMCT College of Engineering,Calicut, Kerala
Email: dr.nmnagarajan@gmail.com
Mob: +91 9895281423

***Abstract*— Titanium and Titanium alloys are very much useful for aerospace applications due to their high strength and toughness .They are light in weight, and have extra ordinary corrosion resistance. Also they have ability to withstand extreme temperatures. Its applications include military applications, medical devices, connecting rods on expensive sports cars and consumer electronics, apart from aerospace.**

Titanium and Titanium alloys produce an optimum combination of ductility, machinability, and dimensional and structural ability after heat treatment. Also these are amenable for age hardening heat treatment to produce special properties such as fracture toughness, fatigue strength and high-temperature creep strength.

An attempt is made to improve the mechanical properties of Ti-6Al-4V alloy by age hardening heat treatment process by varying quenching mediums. The test casting selected for this investigation is hemispherical dome used for aerospace application.

The test result reveal that age hardening heat treatment enhances strength of the alloy by transforming primary alpha grains to beta phase. Also ice bath quenching treatment is found increasing the tensile strength of dome compared with water bath.

I. INTRODUCTION

High strength, low density, and excellent corrosion resistance are the main properties that make titanium attractive for variety of applications including aircraft parts, biomedical devices or components in chemical processes. Although Ti has a low strength-price ratio it is used in certain necessary applications. Basically, the price is the consequence of the reactivity of Ti with oxygen during the production process, where vacuum or inert atmosphere is required. The cost of this material has hindered a wider use for example in automotive applications, where aluminium is used instead of Ti. Aluminium is the main competitor in light weight structural applications presenting a higher specific stiffness in bending, but the higher melting temperature of Ti gives an advantage for service at high temperatures. The maximum service temperature for Ti alloys is about 600ºC due to the fast growing of oxide layers and subsequent embrittlement of the surface [1]

Within the family of titanium alloys, the α+β alloys are the most widely used because of the great variety of microstructures and mechanical properties that can be obtained by varying their composition and thermo mechanical treatments [1].One of these α+β alloys has the greatest commercial importance namely Ti-6Al4V, making up more than half of the sales of titanium alloys [2].

During solution treatment, retained beta phases are formed. When the alloy is cooled from the β region α begins to form below β transus. Upon quenching the β phase obtain martensite structure. Also when the alloy is cooled, α begins to nucleate within the β phase [3-10]. The ageing treatment results in the decomposition of retained metastable β phase producing finely divided mixture of α and β phases. α plates are formed in the β matrix and thus restrict the dislocation motion. Therefore, hardness is improved [11].

II.PROCESS DETAILS

In this project Ti-6Al-4V were hot forged, annealed and proof machined and finally converted into hemispherical dome.

A. Raw material inspection

For the experimental investigation, the billets Ti-6Al-4V with size 250 mm ϕ × lengths was taken as the raw material. The billets were visually inspected for any defects and ensured that the billets were defect free. The billets were cut to dimension of 250 mm ϕ × 450 mm using band saw cutting machine.

B. Sequence operation of dome production

Firstly the billets are heated in electrically heated furnace to 950^{0}C and soaked for 3 hrs .The heated billet was then loaded to 16 ton hammer. Forging machine and closed die forging was carried out. The forging dies shall be pre heated to 350 ^{0}C to 400 ^{0}C by forging a requisite mass or by external heating. After each stage of forging skin grinding shall be carried out and Ti 95 glass lubricant shall be

ISSN 2348 – 7968

applied. After forging, a dome was obtained as the end product.

D. Heat treatment of hemispherical dome

All forged domes were proof machined before solution treatment operation. The solution treatment is carried out 700^0C and subsequently the sample temperature is raised to 955^0C for 1 hour soaking time. After, the Sample is quenched into it. After waiting 45minutes the dome is kept for ageing at pit furnace at 510^0C with soaking time of 8hours and is air cooled to room temperature.
The quenching is done by two medium. One dome is in water and other is in ice cubes.

1. Water as quenching medium

The solution treatment is carried out 700^0C and subsequently the sample temperature is raised to 955^0C for 1 hour soaking time..The sample is quenched in water at an average temperature of 28^0C.After waiting for 45minutes the dome is kept for ageing in pit furnace at 510^0C with soaking time for 8 hours and is air cooled to room temperature

2. Ice cubes are quenching medium

The solution treatment is carried out 700^0C and subsequently the sample temperature is raised to 955^0C for 1 hour soaking time..The sample is quenched in 10% ice brine solution with 10% salt with ice cubes at an average temperature of 18^0C.After waiting for 45minutes the dome is kept for ageing in pit furnace at 510^0C with soaking time for 8 hours and is air cooled to room temperature

E .Chemical composition of Ti-6Al-4V

Al	V	C	Fe	H	O	N	Balance
6.29	4.10	0.01	0.02	0.006	0.1970	0.0017	Ti

F. Mechanical Test

In this project work, the tensile properties are to be evaluated by taking specimens from top, middle and bottom region of the dome. The mechanical properties of the test bar such as uniaxial tensile strength and hardness have been evaluated. The test specimen prepared as per ASTM E8/E3.

1. Ultimate Tensile Strength found out using Universal testing machine (UTM)

Tensile properties helps in determining tensile properties such as tensile strength, yield point,% elongation,% reduction in area and modulus of elasticity.

2. Brinell hardness number is fund out using Brinell hardness tester.Brinell hardness number is given

$$BHN=2P/\pi D \setminus (D \setminus \sqrt{D^2 - d^2}\;)$$

Where p= Load applied (100kg)
D=Ball diameter (10mm)
This gives the resistance of test bar to plastic deformation.

G. Microstructure analysis

The specimen were prepared as per ASTM E3/E8.these specimen were polished using different grit size papers and finally etched using Keller's reagent for 8-15 sec. The etched samples were then viewed through the optical microscope.

III. RESULTS & DISCUSSIONS

Hemispherical dome for the aerospace vehicle is strengthened by age hardening heat treatment in the project work. Heat treatment is performed for the purpose of changing the mechanical properties and the metallurgical structure. After precipitation hardening heat treatment process, the strength of hemispherical dome is tested using the Universal Testing Machine (UTM).The Brinell hardness number is also measured by using Brinell hardness apparatus and the microstructure is analyzed using optical microscope.

Tensile testing

The tensile properties such as ultimate tensile strength, proof stress and % of elongation were determined for the dome quenched in water and ice cubes. They are tabulated in table 3.1 & 3.2.from the tensile test it was observed that the heat treated dome which was obtained by quenching in ice cubes had more UTS of 1129Mpa.this is higher while compared to the UTS of the dome obtained by quenching in water. The comparison between the ultimate tensile strength of the domes are shown in fig 3.1.the percentage elongation of the dome quenched in ice was lower than the doe quenched in water. The comparison of proof stress and % of elongation of the both domes are shown in fig 3.2& 3.3.The Brinell hardness value of the two domes where also determined. There was a slight increase in hardness number for dome quenched in ice.

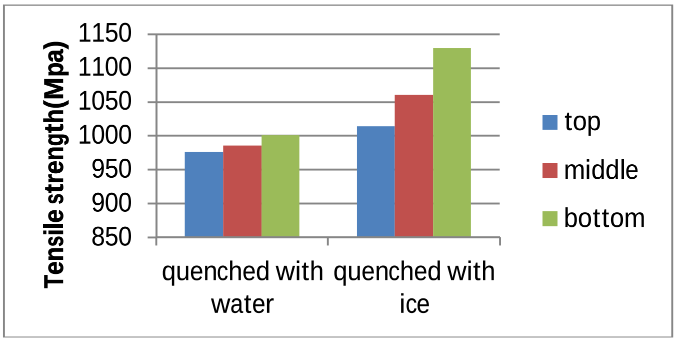


Fig 3.1 Tensile strength of water and ice quenched

ISSN 2348 – 7968

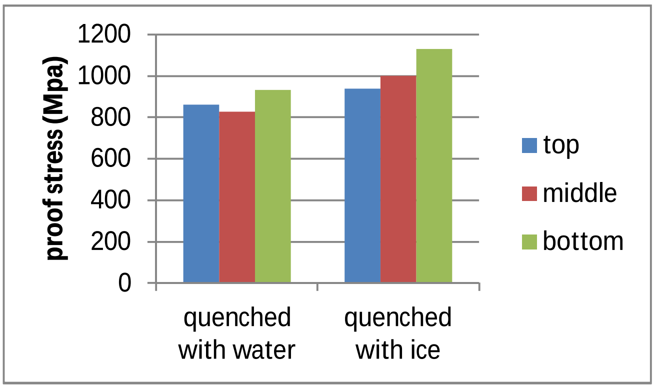


Fig 3.2 Proof stress in water and ice quenched

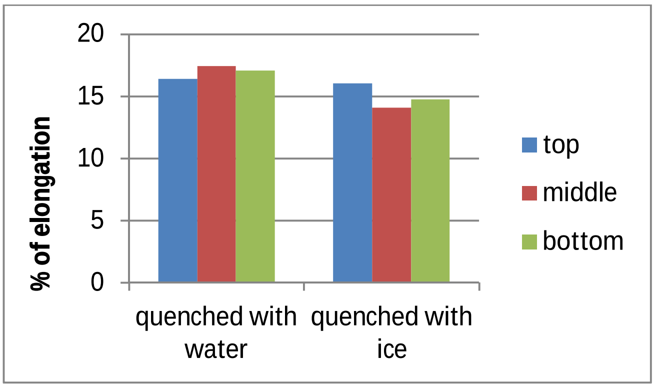
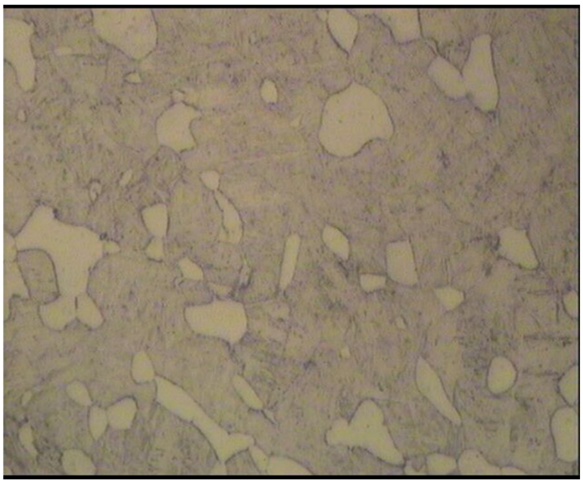


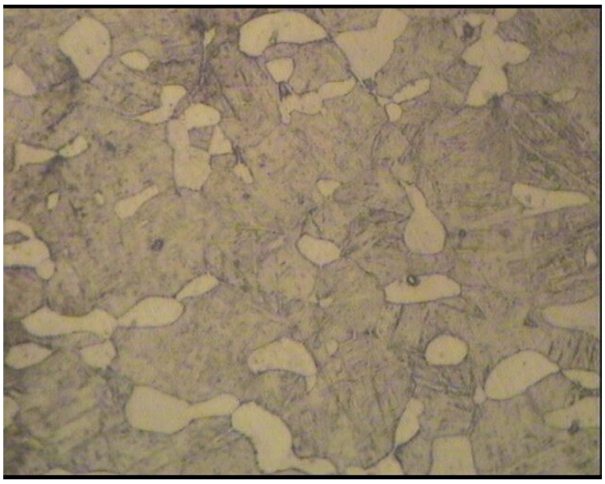
Fig 3.3 % of elongation in water and ice quenched

Microstructure analysis

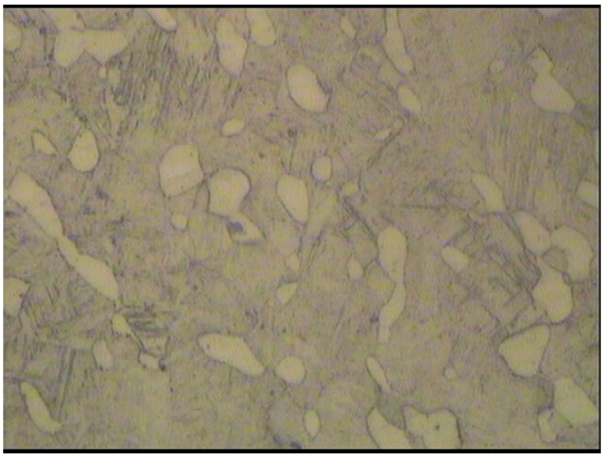
The samples were taken from the top, middle and bottom of the hemispherical dome and the microstructure analysis was carried out using optical microscope. Microstructure of the water and ice quenched domes are showed in fig 3.4 & 3.5



Top 400X (A)



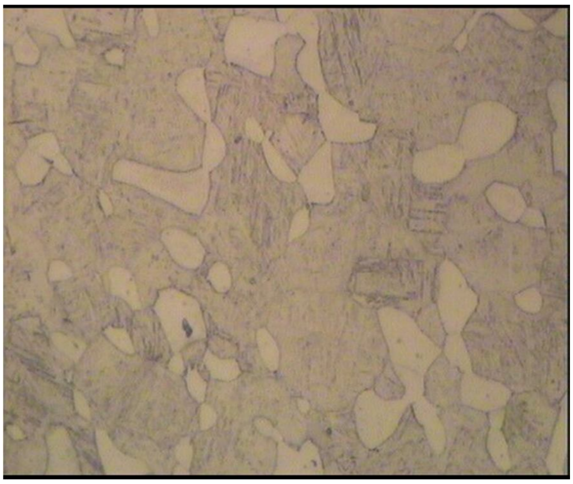
Middle 400X (B)



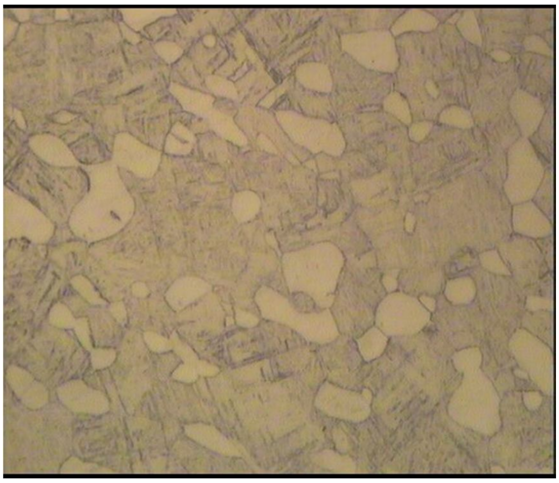
Bottom 400X (C)

Fig 3.4 Microstructure of Ti-6Al-4V hemispherical dome after solution treatment and ageing in water.

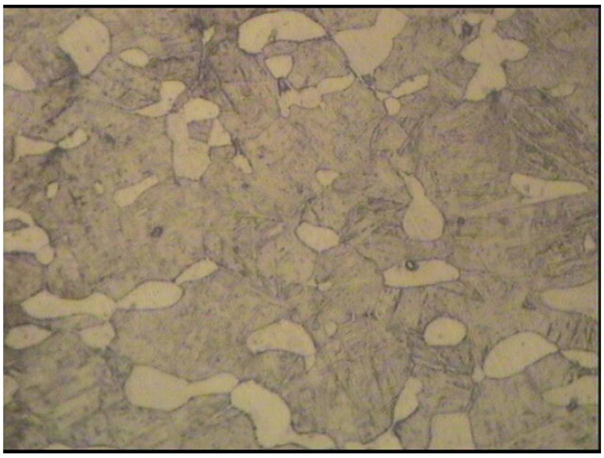
ISSN 2348 – 7968



Top 400X (A)



Middle 400X (B)



Bottom 400X (C)

Fig 3.5 Microstructure of Ti-6Al-4V hemispherical dome after solution treatment and ageing in ice blocks.

The microstructure results of both quenched in ice and water bath are shown in the above figure. The results reveal the primary alpha grains are distributed to transformed beta matrix. The dome before heat treatment has a tensile strength 900Mpa. After solution treatment, precipitation hardening and ageing enhanced the strength 1129 Mpa. Hence 26 percentage increase strength is obtained by the age hardening heat treatment.

From the above results, it is noted that precipitation hardening treatment gives more strength. After the age hardening these domes are used in aerospace application to withstand sufficient strength during operation.

V.CONCLUSION

From the present investigation the following are the conclusions:

1. Ti-6Al-4V alloy taken for the investigation is best suited for precipitation hardening heat treatment and the strength is enhanced by 26 percentages from the initial value.
2. The dome quenched in ice cubes after solution treatment gives better mechanical properties than the dome quenched in water.
3. Micro examination reveals that the primary alpha grains are distributed to transformed beta matrix in precipitation hardening resulting enhances strength.

REFERENCES

1.”Titanium Alloy Handbook” by R. A wood and R.J Favor; Report MCIC-HB, Battelle Memorial institute, Columbus, OH, Dec 1972

2. Effect of heat treatment on mechanical properties of Ti-6Al-4V B.D Venkatesh, D.I, Chen ,S .D Bhole .Department of mechanical and industrial engineering Ryerson University,350 Victoria street, Toronto ,Ontario M5B 2K3,Canada.

3. E8 M-08 standard test method for tension testing of metallic materials, ASTM Annual Book of standard West Conshohocken 65-88

4.”Properties and processing Ti-6Al-4V”Timet Apr 1980

5. How to descale Titanium by A.E .Durkin : Materials and method Vol,38,oct 1953 107-109

6. Properties and structure of titanium after 30Min heating at 1200 to 2000^0Fby E. Walden &L. A, Dixon metal progress vol 64, Aug 1953 p88-89

7. Residual stress, Stress relief and annealing of Titanium and Titanium alloys: by D .J. Moykuth .DMIC Report s-23, July 1968

8. D. Eylon, ’High Temperature Alloys – Review’, Journal of Metals,1984,55-61 Titanium and its alloys : principles of alloying titanium, ed .J L .Walter ,M .R .Jackson and C .T. Sims, ASM Internationals, Metal Park,1988

ISSN 2348 – 7968

9.'Titanium – A technical Guide ' ,ASM International Metals Park,USA,1988.
10.O.M.Ivasishin,. G. Lutjening 'Influence of Grain Size and Cooling rate on the Fatigur performance of Titanium alloys ',Proc. Titanium '99,vol.1,363-374
11. G. Lutjening , 'Influence of processing on Microstructure and mechanical properties of (alpha +beta) titanium alloys ',Material Science and engineering A243, 1998,32-45