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Investigation of Mechanical Properties and Grain Structure of Titanium BT20 Alloys under Precisely Controlled Annealed Conditions

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Abstract-**An attempt has been made to investigate the influence of annealing temperature, cooling mode, and microstructure on mechanical properties such as tensile strength, impact strength, hardness, and elongation of the Titanium BT20 alloys under different annealed conditions. Here the material Ti BT20 loss its mechanical properties (impact strength) after the heat treatment in a particular range of temperature. The heat treatment process is carried out in different conditions of temperatures and cooling modes and the mechanical properties are measured in each condition to optimize the material property. The optimum values of mechanical properties in given range of temperature are established in the study.**

Index Terms- **Titanium BT20 alloy, heat treatment, mechanical properties, and microstructure.**

I. INTRODUCTION

Titanium special alloy BT 20 is used for the production of air craft parts. While in the production of certain parts it seems that the impact strength of the material failed in laboratory test after completion of all heat treatment process. That is the final product should have an impact strength at least 39 J/cm^2, for the proper application of the product in required areas. But in laboratory test it seems that the impact strength is less than the critical value (39 J/cm^2). So the product cannot be used for the required application. The major adjustable parameters in heat treatment are austenitizing temperature, soacking time, and cooling mode. This project concentrates on analyzing these parameters and to determine how they depend on the mechanical properties of Titanium BT 20. Hence we can find out an optimum working condition and the reason behind the failure of impact property.

Titanium BT 20 raw materials are coming in long cylindrical form after the extrusion process[5]. We have to find out the dependence of annealing parameters on the mechanical properties of the material (Tensile strength, impact strength, ductility, toughness, etc…). There is mainly two parameters effecting the annealing process.

- Annealing Temperature
- Cooling Mode

Since the Titanium BT 20 is an alpha plus beta alloy, the material should not be heated above the beta transus temperature (882 °C)[4]. The annealing temperature for BT 20 is commonly taken in the range of 700°C to 790°C. In order to determine dependence of annealing temperature on mechanical properties, the temperature is set at various values (700, 730, 750, 770, and 790°C) and the annealing is carried out. After the annealing process, a small portion is cut from the rod and prepared for testing various tests like impact test (charpy test) ,tension test (U T M),Grain structure(optical microscope), chemical composition (emission spectrometer). In annealing process cooling mode can be either furnace cooling or air cooling. The process is carried out in these two ways to find out the effect on material properties.

The present research tests this hypothesis by investigating the variation of grain structure and mechanical properties when Titanium BT20 alloy is subjected to different annealed conditions, by precisely setting the temperature gradient and under controlled environment.

II. METHODS AND MATERIALS

The heat treatment of the alloy was done in a pit furnace with advanced electronic temperature controller attached with digital timer as shown in the figure. The initial temperature of the furnace was set at 735°C and 1 hour per 25mm thickness soaking time as per the standards available for Titanium BT20 alloy. The heat treatment process is repeated by setting the temperature at different states 750, 770 and 790°C.

Figure 1. Charpy testing machine

Figure 2. Specimen machined as per standarad

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Figure 3. Electric Pit Type Furnace

The computer based active closed loop temperature control system of the furnace maintains the temperature uniformity of the chamber and assures isolation of the material from the surroundings. All the work pieces were treated identically in the pit furnace and following two types of annealing process were conducted in this study.

- Air cooling (AC)
- Furnace cooling (FC)

Both this conditions were repeated at different temperatures (735,750,770,790℃). An extensive study on significant mechanical properties - Hardness, Tensile stress, Impact strength and Grain structure analysis of titanium BT 20 alloy were conducted at all the different annealing conditions[1].

The mechanical properties namely proof stress, tensile strength and elongation of the specimen after annealing was investigated in the Universal Testing Machine (UTM) having capacity 400 kN as shown in figure 4. The dial gauge readings obtained from the extensometer mounted on the specimen was used to find the actual elongation and the corresponding strain induced in the specimen under different loading conditions in the experiment[6].

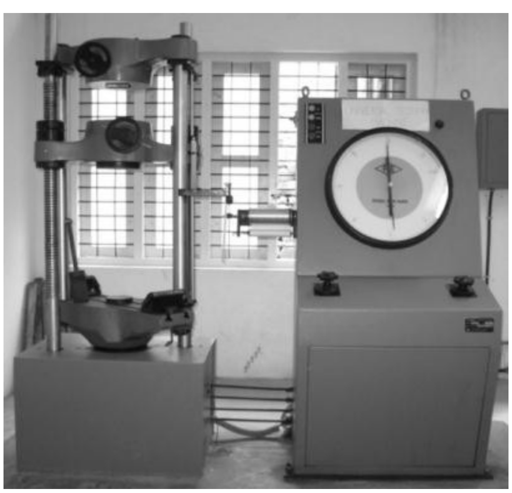
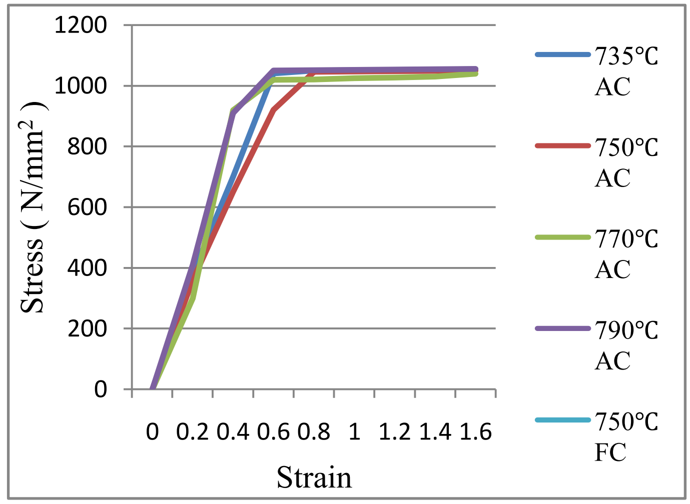


Figure 4. Universal Testing Machine (UTM)

Yield point of the Titanium BT 20 alloys was found to be difficult to capture in the tensile test, hence corresponding proof stress was evaluated at 0.2% of the gauge length from the line of proportionality[3]. The stress- strain graphs for the different annealed conditions were plotted in Graph 1.



Graph 1 Stress vs Strain graph at different annealed Temperature

The impact stress of the specimen was tested in the charpy testing machine as shown in the figure 1. The specimen is fixed in the horizontal position and the hammer strikes the specimen on the unnotched face. The impact strength can be directly read from the gauge.

The hardness of all the four specimens was tested in the Brinell hardness tester. A steel ball indenter of diameter 10mm under 1000 kg force is applied for 10 seconds. The diameter of the indentation'd' was measured by optical microscope. The corresponding Brinell hardness number was calculated using the following expression.

$$HBS = \frac{2P}{\pi D\left[D - \sqrt{D^2 - d^2}\right]}$$

The specimen is then prepared for microstructure analysis. Alloy was cut and the distorted material was removed by wet grinding followed by fine polishing with the aid of 24 micron abrasive powder. Using optical microscope (200X), the grain structure of the Titanium BT 20alloy at different annealed conditions were explored in the present work.

III. RESULTS AND DISCUSSIONS

The influence of different annealing conditions on various mechanical properties was quantified in terms of tensile strength, impact strength and hardness of the BT 20 specimen. Their performance variations are shown in Fig. 6(i), 6(ii), and 6(iii) respectively.

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The results obtained from 200X optical microscope exhibit the grain sizes for the annealing at 735, 750, 770 and 790°C found to be challenging. Their grey scale grain images are shown in figure 7(i), 7(ii) and 7(iii) respectively.

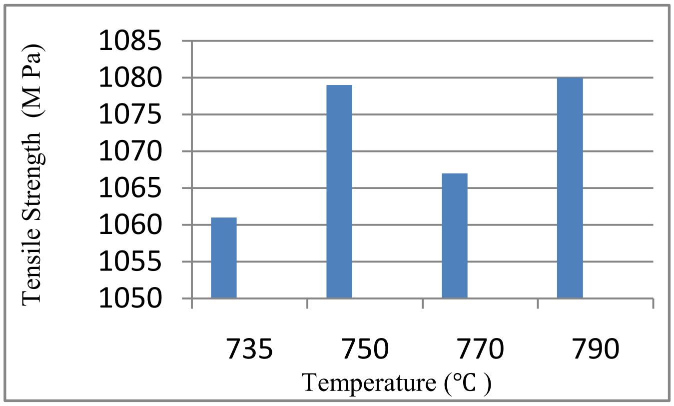

Figure 6(i)

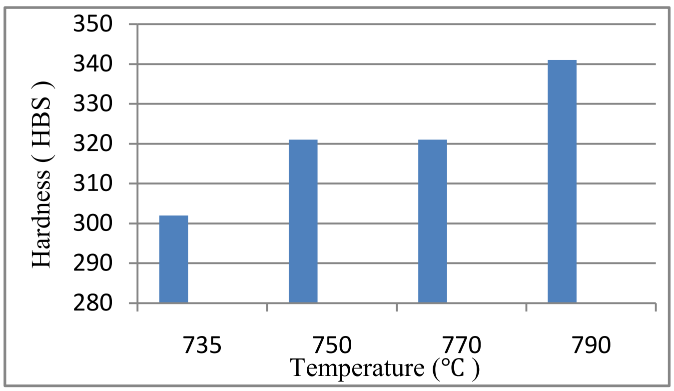

Figure 6(ii)

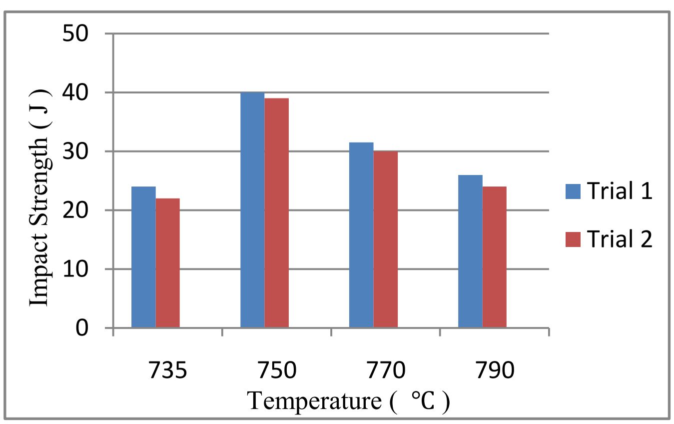

Figure 6(iii)

Figure 6. The variation of mechanical properties at different conditions

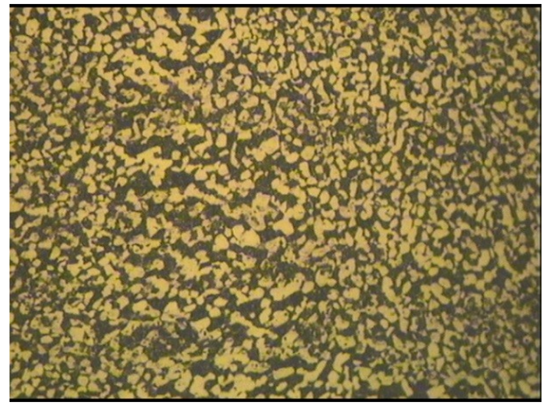

Figure 7 (i)

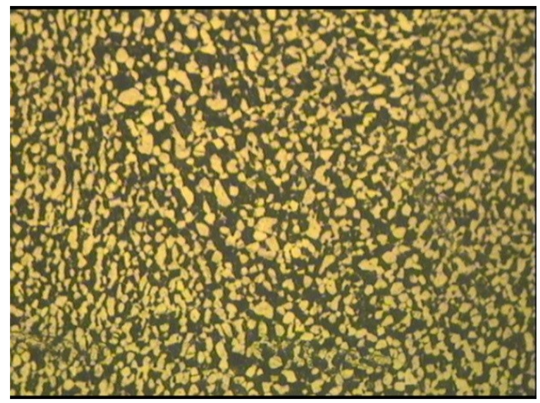

Figure 7(ii)

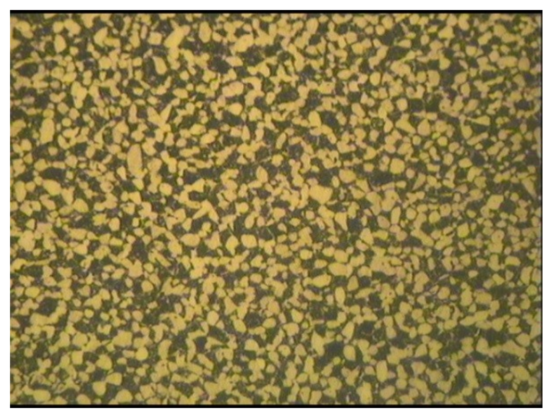

Figure 7(iii)

Figure 7(i), 7(ii) & 7(iii): the grain structure of air cooled specimens at200X magnification.

IV. CONCLUSIONS

- The annealing carried out at 750°C followed by air cooling improves the impact strength significantly.
- The optimum α – β concentration is obtained at 750°C. Temperature Above and below 750°C, there is a deviation for the – β ratio.

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- The hardness and tensile strength are improved significantly with increase in annealing temperature.
- The optimum values of mechanical properties were obtained when annealing at 750℃ followed by air cooling.

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NOMENCLATURE

AC - Air cool
FC - Furnace cool
UTM - Universal Testing Machine
ASTM - American Society for Testing and Materials

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