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Cause and Effect Analysis for Reheating the Titanium alloys while forging operation- A case study

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Abstract:- Titanium alloys usually reheated in the electrical furnace during the forging operations, the factors for reheating were noted and analyzed with the help of cause and effect diagram. During the forging operations, the temperature range usually preferred for the titanium alloy lies between 850°c and 930°c. If the temperature of the alloy is decreased, during the preheating stage it should be reheated in the electrical furnace, to obtain the forging temperature. The reheating of the titanium alloy in the furnace results in more power consumption and time loss which may results in lower profit. In this paper the different factors that results the reheating of the titanium alloy, Ti6Al4V while the forging operations is identified. The temperature while forging the titanium is recorded using the optical pyrometer and the factors for the temperature variation is analyzed using the managerial tool.

Indexterms:- Titanium alloys, Ti6Al4V, Cause and effect diagram, forging, control charts, 10 Tonne hammer

I. INTRODUCTION

Titanium and its alloys have attractive engineering properties. They are about 40 percentages lighter than steel and 60 percentage heavier than aluminium. Titanium alloys have highest strength to weight ratio of any other metals, roughly 30 percentage greater than aluminium and steel. Other properties of titanium include high corrosion resistance, low thermal conductivity, high melting point than iron, low coefficient of expansion and high electrical resistivity. The presence of a thin, tough oxide surface film provide excellent resistance to atmospheric and organics containing chlorides. Titanium alloys can be classified in to different allotropic phases such as alpha, beta and alpha-beta alloys. Titanium's mechanical properties are closely related to these allotropic phases[1]. At room temperature, it has a closed packed structure, designated as alpha phase. At around 885ºc, the alpha phase transforms to a body centered cubic structure, known as beta phase, which is stable up to titanium's melting point of about 1680ºc.

Alpha alloys contains elements as aluminium, tin ,chromium, zirconium, vanadium and molybdenum in amounts varying from about 1 to 10 percent. They are nonheat- treatable, having good stability between 540ºc and 220ºc. Beta alloys have exceptionally high strengths-over 14085 kg/cm^2 having low toughness and low fatigue strength limits their use. Alpha- Beta Alloys are most widely used group of titanium alloys, having their behavior falls in a range between the two single- phase alloys. These alloys are heat treatable and formable than other type of alloys.

All the titanium forging alloys are double or triple melted, they rarely contain segregations of other materials that might cause wide variations in forgeability. Initial breakdown forging of titanium alloys can be done at temperatures above the β transus because the body-centered cubic structure is more ductile and forging pressure requirements are generally lower. The main contribution of isothermal forging is to eliminate the influence of die chilling and material strain hardening, as a result number of forging operations and machining cost can be minimised.[2]

The present research highlights the main factor that lead to the reheating of the titanium alloy in the electrical furnace with the help of cause and effect diagram under controlled environment.

II. METHODS AND MATERIALS

The characterization of the alloy billet was carried out in German made, foundry master spectrometer connected with Wasag Lab Software is shown in figure 1. It was identified the major constituents of alloy as 6.75% Al and 4.5% V by weight.

Figure 1: Spectrometer

The billets having a bar stock unit size of 150 mm diameter and 215 mm length, each carrying net weight of 17.5 kg were heated in electrical furnace for 700°c and soaked for an hour. After the initial soaking at 700°c, the billets were heated to a temperature of 930°c at a rate of 50°c per hour and soak it for 120 minutes. Heating temperature for the operations should be controlled within narrow limits. Titanium and titanium alloys must be protected from contamination by oxygen, nitrogen, hydrogen and carbon during heating for the forging operations Although heating in vacuum or in a suitably inert atmosphere is feasible, this is most effectively done by coating the forging slugs in a liquid glaze which is allowed to dry before heating for forging. Prolonged heating should be avoided for all titanium alloys.

For forging operations the preferred temperature lies between 850°c and 950°c. After proper heating the billets were transferred in to the hammer for the further processing. The hammer having a capacity of 10 tonne is applied along the alloy surface for creating different shapes.

While the forging operations the temperature of the alloy may be reduced to below the working temperature range. Due to the reduction of the temperature the alloys should be reheated in the electrical furnace, under precisely setting the temperature gradient under controlled environment.

The forging temperature of titanium alloys is absolutely critical to the process and die heating is essential, as excessive heat losses through the tooling will produce defective forgings. Despite the protection offered by the glass coating, a small amount of contamination does occur and must be removed by grinding or chemical etching. When forging titanium, care should be taken to prevent contact with steel scale. A thermal type reaction can occur and seriously damage a forging die. Apparently the titanium reduces iron oxide in an exothermic reaction set off by pressure and high temperature.

If an unscheduled delay such as a press breakdown occurs, the stocks should be removed from the furnace, and then it should be reheated when forging is resumed. Particular attention need to be paid throughout the processing cycle to avoid contamination by oxygen, nitrogen, carbon, and/or hydrogen, which can severely impair ductility and toughness properties and overall quality of a forged part.

JOB NO	TEMPERATURE AFTER 10 BLOWS	JOB NO	TEMPERATURE AFTER 10 BLOWS
1	927	12	863
2	920	13	845
3	915	14	918
4	920	15	915
5	908	16	912
6	903	17	909
7	898	18	904
8	901	19	897
9	890	20	894
10	880	21	887
11	885		

Table 1: Temperature of the jobs after 10 blows

The temperature of each of stocks during the forging operations were noted (Table 1). Optical pyrometer which intercepts the thermal radiation from the alloy were used to measure the temperature of the billets while the operation.

The temperature of the alloys may be increased due to the plastic deformation of the stock or the temperature decreases during the transferring of the stock from furnace to the hammer. [1] The various reasons for the variation of the temperature and the reheating of the titanium alloys at the electrical furnace during the operations were identified and their effects were explored in this work. Statistical process control charts are used to determine temperature variation and fishbone diagram is used to identify the causes and effects of the increases or decrease in temperature.

III. RESULTS AND DISCUSSIONS

The forging operations of the Ti6Al4V, titanium alloy having a batch size of 21 was taken in to the study. During the operations one of the alloy temperature decreases below the minimum range. The average temperature of each alloy in the batch is calculated after 10 blows and it is represented in a control charts, having an upper control limit of 930°c, lower control limit of 850°C. and mean temperature of 899.57°C and it is represented in figure 2.

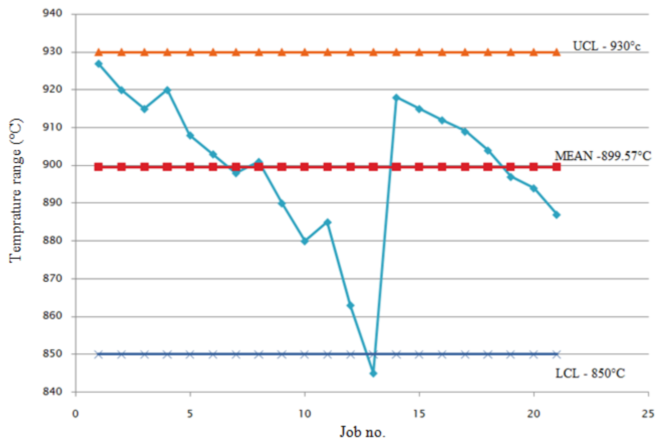

Figure 2: Control chart for the forging temperature

From the figure 2 it is evident that, the temperature of one job (job no 13) is decreased, which results in the reheating of that particular job in the electrical furnace. The reheating of the titanium alloy in the electrical furnace results in increase power consumption, fuels, working hour etc. and if the forging temperature of the alloy becomes below 850^0c,changes will happens in the microstructure of alloy, and also in the formation and filling of the material.

The different causes for the reheating of the titanium alloy in the electrical furnace includes unskilled workers, short circuiting of electrical systems, improper die packing, conventional material handling systems, environmental factors such as presence of salvage, surrounding temperature. These main causes are supported by some other causes also, which is represented in figure 3.

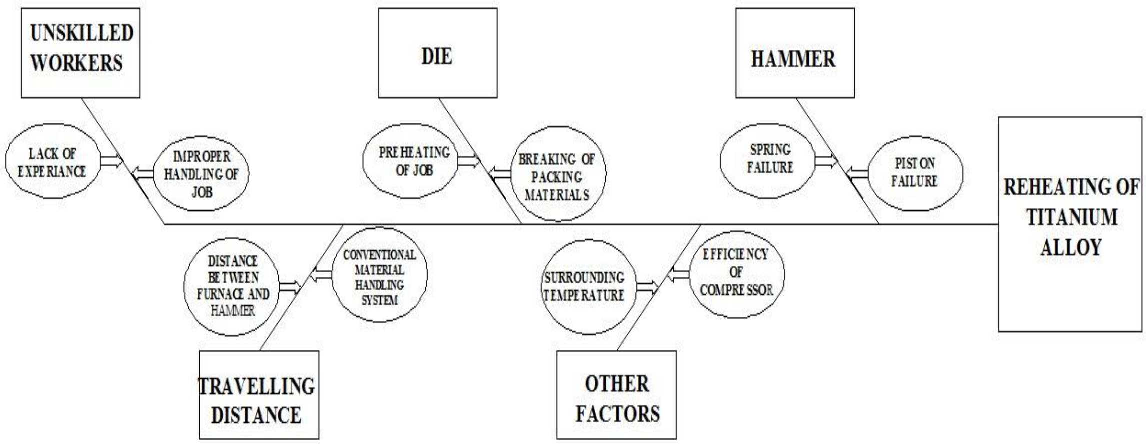

Figure 3: Cause and effect diagram

IV. CONCLUSION

The different causes for the reheating of the titanium alloy during the forging operations were determined with the help of fishbone diagram.

- ✓ Proper training should be given to the workers in order to reduce the no. of blows during the operations and handling of the job.
- ✓ The efficiency of the compressor should be calibrated periodically.

- ✓ Periodically the maintenance operations should be carried out in the hammer. The forging operations should be done below the maximum capacity of the hammer.
- ✓ Conventional material handling systems should be replaced by conveyors and AGV's to reduce the travelling time between the hammer and the furnace.
- ✓ The efficiency of the Plant layout should be tested using Arena software. Inventory and scraps should be removed after each operations.
- ✓ Application of Kaizen in industry wills results im good performance.
- ✓ Operation of the electrical furnace should be done at controlled environment

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