Analysis of Microstructure and Mechanical Properties of Cryogenically Treated Al7075 Metal Matrix Composite by Stir Casting

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Abstract : The basic Cryogenic treatment (CT) consists in a gradual cooling of the component until the defined temperature, holding it for a given time (freezing time) and then progressively leading it back to the room temperature. The aim is to obtain an improvement of Mechanical properties, typically hardness and wear resistance, but in recent tests fatigue limit too, and to achieve an optimal ratio between conflicting properties, like hardness and toughness. The research about CT has been validated by the first results on machinery tools, which have shown remarkably enhancement in hardness and durability.

***Index Terms*—Metal, Aluminium, Quartz, Internal combustion, alloy, Cryogenic treatment (CT).**

I. Introduction

The use of Cryogenic treatment (CT) to improve Mechanical properties of materials has been developed from the end of the Sixties. The use of thermal treatments to improve Mechanical Properties of metal components is an ancient art expanded down the ages until today. Many of the developed processes apply treatments in a range of temperature higher than room temperature. The first attempts to perform subzero treatments were investigated at the beginning of the 20th century, but the actual interest on Cryogenic treatment (cryotreatment, CT) was developed during the last years of the century.

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From the Nineties, the interest in CT effects has also been applied to many different components: i.e. motor racing parts, in particular gears and bearings, oil drills, gun barrels, knives, surgical and dental instruments and even brass musical instruments, piano and guitar strings, baseball bats and golf clubs too. Nowadays, many companies offer CT services, especially in the USA and in Canada, and in some cases if no improvement in component life has been obtained they promise a refund. Even though the mechanism behind improvement has not been totally clarified, different hypotheses coherently with micro structural observations have been suggested in literature. The aim of the present review is to summarize the most significant works of the last thirty years, focusing on it methods, parameters, results and assumed micro structural mechanisms.

II. Treatment Parameters

A fundamental distinction among different CT is given by the parameters of the cooling-warming cycle. In two families depending on the minimum temperature reached during the cycle are categorized. Shallow Cryogenic Treatment (SCT) or Subzero Treatment: The samples are placed in a freezer at 193K and then they are exposed to room temperature.

Deep Cryogenic Treatment (DCT): The samples are slowly cooled to 77 K, held-down for many hours and gradually warmed to room temperature. The typical process parameters are minimum temperature (T min), hold time, cooling and warming rate. In different values of these parameters used by authors during SCT and DCT on different materials can be found, but anyway it is possible to infer some general indications indication in the selection of a specific temperature by means of micro structural changes investigation (i.e. calorimetric or acoustic emission).Hold time over 36 hours does not bring significant improvements and in most cases 24 hours are enough to obtain results.

Cooling rate values range is restricted in order to prevent thermal-shock cracking. Commonly, the applied values vary from 0.3 K/min to 1.2 K/min.

In many cryogenic systems warming rate is not closely controllable and little importance to this parameter is given in literature despite of some suggested hypothesis about carbides precipitation during the warming phase.

III. Cryogenic Systems

A cryogenic system is equipment which allows controlling temperature in the cryogenic range into a chamber, using liquid nitrogen or helium. Until the end of the Sixties, any attempt to perform CT had been done by direct immersion into liquid nitrogen, with the catastrophic result of cracking the components. The cryogenic treatment system developed by Ed Busch (Cryo-Tech, Detroit, MI) in the late 1960s and later improved by Peter Paulin (300 Below Inc., Decatur, IL) with a temperature feedback control on cooling and heating rate, allows to perform effective and crack less CT.

As a result, many companies have developed systems to perform CT, mainly in the USA and in Canada, but also in China, India and Japan. The three most important cooling systems are described in Heat Exchanger: the liquid nitrogen flows through a heat exchanger and the output cooled gas is diffused inside the chamber by a fan. There is no contact between nitrogen and samples Direct Nebulization: the liquid nitrogen is nebulized directly in the chamber or in a cavity around the chamber. A fan allows obtaining a homogeneous temperature distribution the liquid nitrogen is dispersed around the samples.

Gradual Immersion: the samples are immersed into the liquid nitrogen for a specific time, and then they are extracted and gradually led back to the room temperature by means of a flow of temperature controlled air. Another type of cooling system is the so-called “Hybrid System”, which combines direct nebulization and gradual immersion during different phases of the cooling process, in order to reduce liquid nitrogen consumption (i.e. Vary-Cold from Cryotron, Canada).Cryogenic treatment companies are involved in a combination of processing and after-market treatment, with the former becoming increasingly more significant. Although initially cryotreatment services were applied almost exclusively to products in their finished forms, it has increasingly become part of larger manufacturing chains. However, products such as brake discs, sports equipment and audio cabling are often still treated in their finished forms or after partial disassembly.

Aerospace material such as Aluminum and magnesium alloys represent a developing area for cryogenic treatment. In a study it was determined that DCT at - 196°C (77K) caused a significant (12%) increase in the impact energy of 7075- T651 aluminium alloy, without any significant change in strength or hardness. It is interesting to note that specimens held at their soak temperature for 2hrs showed no significant improvement, whilst those treated for 48hrs did, indicating a time dependent microstructural change is likely responsible. In a study on the effects of cryogenic treatment on AZ91 magnesium alloy (which is typically used in castings), observed improved wear resistance and creep behavior after DCT at - 196°C (77K). The improved creep behavior was attributed to morphological changes which prevented grain boundary grain boundary sliding at high temperature.

Cryogenic systems Applications

For space application, alloys of titanium and magnesium have been tested at cryogenic temperatures, usually by direct immersion in liquid nitrogen. Mechanical test on Ti-2.5Cu alloy at temperature of 77K obtain by this method, finding that both the ductility and low-cycle fatigue life of the alloy was improved. They conclude that Nano-scale precipitates hinder the movement of dislocation, thereby preventing crack formation. Similar tests were performed to determine the tensile properties of an extruded alloy at cryogenic temperature. Their result showed a significant increase in tensile strength, yield strength and elongation before fracture, which they attribute to the precipitation of a large number of “rod-like and chrysanthemum-like” feature within the microstructure.

While direct immersion in liquid nitrogen, or Cryo quenching may lead to thermal shock and brittleness of material, these investigation seem to show that the microstructural changes due to DCT may have a more significant effect on the performance of a material. Cryogenic processing has also been shown to have beneficial effects on non- metallic composite materials, typically used as bearing liner material due to their tribological properties, PTFE and Kevlar exhibit poor adhesion to the resin binder due to their chemically inert nature. Cryogenic treatment was shown to improve the wear resistance of the hybrid material, with the improvement suggested to be as a result of increased mechanical interlocking of the phenolic resin used, as a result of the fabric roughening at cryogenic temperatures.

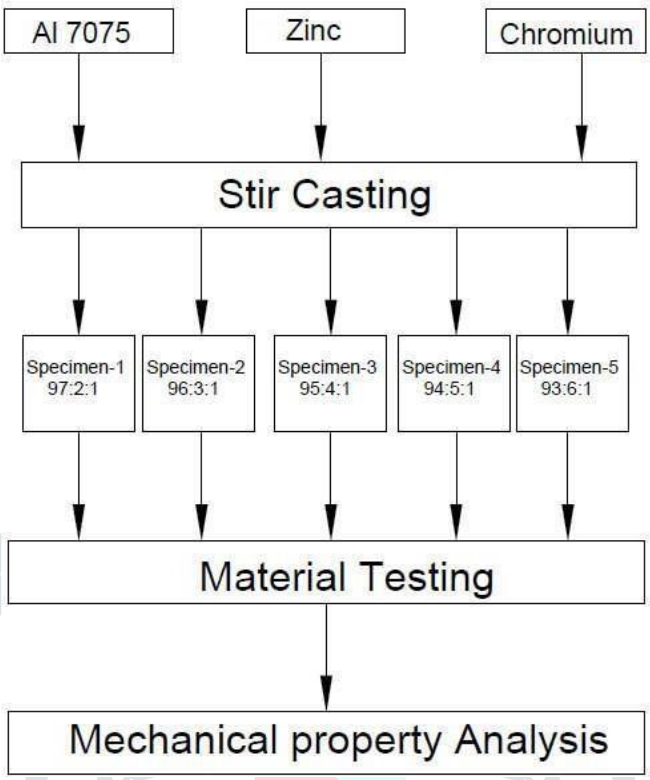
IV. STIR CASTING PROCESS

Stir casting method is one of the outstanding and economical routes for improvement and processing of metal matrix composites materials most of the researchers are using 7075Aluminum matrix reinforced with Zinc and Chromium particles for high corrosive properties. Aluminum alloys A7075 were chosen as the matrix and Zinc and Chromium as Nano-particles, with an average diameter of 50nm, as reinforcements.

The stir casting technique was used to fabricate the composite specimen as it ensures a more uniform distribution of the reinforcing particles. This method is most economical to fabricate composites with discontinuous fibers or particulates. In this process, matrix alloy (Al 7075) was first superheated above its melting temperature. Then keep the matrix alloy in the Semisolid state. At this temperature, the preheated Cr particles of 2 % (by weight) and Zinc particle of 1 %(by weight) were dropped into the slurry and mixed using a graphite stirrer.

The Cr particles help in distributing the particles uniformly throughout the matrix alloy. The melt was then superheated above liquids temperature and finally poured into the cast iron permanent mold for testing specimen. The size of the fabricated billet composite is 100 mm length and 100 mm width and 10 mm thickness. Fig. 1 shows Process flow chart for Al 7075 preparation.

Figure 1 Process flow chart for Al 7075 preparation



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REFERENCES

[1] S.K. Rajendra, and C.M.Ramesha. (2013), "A Survey of Al7075 Aluminium Metal Matrix Composites", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue. 5, pp. 1-9.

[2] Qiang Shen, Chuandong Wu, Guoqiang Luo , Pan Fang, Chenzhang Li, Yiyu Wang, Lianmeng Zhang. (2013), "Microstructure and mechanical properties of Al- 7075/B4C composites fabricated by plasma activated sintering", International Journal of Modern Engineering Research, Vol. 3, Issue. 5, pp. 2713-2716.

[3] M.Dinesh, and R.Ravindran. (2014), "Tensile And Hardness Behavior Of Aluminum 7075 And Zinc And Chromium Metal Matrix Composite By Stir Casting Route ", International Journal of Recent advances in Mechanical Engineering, Vol. 3, No. 1, pp. 53-62.