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Synthesis of Functionally Graded Material by Powder Metallurgy

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Abstract—*Automobile industry and medical industry are one of the perspective areas of application for lightweight advanced materials, including titanium alloys. However, despite the excellent mechanical properties and corrosion resistance of titanium alloys, other industries cannot afford titanium unless its cost is significantly reduced. Near net shape processing's, amongst which are powder metallurgy techniques, look the most appealing ways of cost reduction.*

In this paper the blended elemental technology by a simple pressing and sintering method has been investigated using Titanium Diboride and Aluminium A7075. Main part of work was done on Al A7075-TiB_2 (wt. %) composition. Chemical characteristics of initial powders, temperature and time of sintering were main variables of the study.

Experimental results shows the self lubricating properties of produced FGM as porosity obtained is nearly 20% in FGM plate. With increase in the amount of TiB_2 by weight percentage in Al A7075, after sintering the hardness increases. In addition, it is found that with increase in sintering time the hardness is increased. Micro structural investigation showed a phase and structural homogeneity of the synthesized material. This can give rise to the mechanical properties to be comparable with those of cast and wrought iron.

Keywords: AA7075, TiB_2, Powder Metallurgy and Microstructure

1. INTRODUCTION

1.1 Introduction of FGM

Functionally Graded Material (FGM), a revolutionary material, belongs to a class of advanced materials with varying properties over a changing dimension. Functionally graded materials occur in nature as bones, teeth etc. Nature designed these materials to meet their expected service requirements. This idea is emulated from nature to solve engineering problem the same way artificial neural network is used to emulate human brain. Functionally graded material, eliminates the sharp interfaces existing in composite material which is where failure is initiated. It replaces this sharp interface with a gradient interface which produces smooth transition from one material to the next. One unique characteristics of FGM is the ability to tailor a material for specific application.

Functionally Graded Materials (FGMs) has drawn considerable attention. A typical FGM, with a high bending–stretching coupling effect, is an inhomogeneous composite made from different phases of material constituents (usually ceramic and metal). Within FGMs the different micro-structural phases have different functions, and the overall FGMs attain the multi-structural status from their property gradation. By gradually varying the volume fraction of constituent materials, their material properties exhibit a smooth and continuous change from one surface to another, thus eliminating interface problems and mitigating thermal stress concentrations. This is due to the fact that the ceramic constituents of FGMs are able to withstand high-temperature environments due to their better thermal resistance characteristics, while the metal constituents provide stronger mechanical performance and reduce the possibility of catastrophic fracture.

1.2 AA7075

Aluminum alloy 7075 is an aluminum alloy, with zinc as the primary alloying element. It is strong, with strength comparable to many steels, and has good fatigue strength and average machinability. It has lower resistance to corrosion than many other Al alloys, but has significantly better corrosion resistance than the 2000 alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable. Aluminum alloy 7075 is an Aluminum Alloy, with Zinc as the primary alloying element includes. Zinc 6%, Magnesium 2.3%, Copper 1.4 %. A Japanese company, Sumitomo Metal, developed the first 7075 secretly in 1943. 7075 was eventually used for airframe production in the Imperial Japanese Navy.

Density: 2.810 g/cm³

Tensile Strength: 280 M Pa

Melting Point: 477 - 635 °C

Elongation: 9-10%

Fig. 1 Aluminium alloy7075

1.3 TiB2

Titanium di boride (TiB_2) is an extremely hard ceramic, which has excellent heat conductivity, oxidation stability and resistance to mechanical erosion. TiB_2 is also a reasonable electrical conductor,so it can be used as a cathode material in aluminium smelting and can be shaped by electrical discharge machining. TiB_2 is the most stable of several titanium-boron compounds. The material does not occur in nature but may be synthesized by carbothermal reduction of TiO_2 and B_2O_3. TiB_2 is very similar to titanium carbide, an important base material for cermets, and many of its properties(e.g. hardness, thermal conductivity, electrical conductivity and oxidation resistance) are superior to those of TiC.TiB_2 does not occur naturally in the earth. Titanium diboride powder can be prepared by a variety of high-temperature methods, such as the direct reactions of titanium or its oxides/hydrides, with elemental boron over 1000 °C, carbothermal reduction by thermite reaction of titanium oxide and boron oxide, or hydrogen reduction of boron halides in the presence of the metal or its halides. An example of solid-state reaction is the borothermic reduction, which can be illustrated by the following reaction

$2\ TiO_2 + B_4C + 3C \rightarrow 2\ TiB_2 + 4\ CO$

Density ($g.cm^{-3}$): 4.52

Melting Point (°C): 2970

Hardness (Knoop): 1800

Elastic modulus (GPa): 510 -575

Fig. 2 Titanium Diboride Powder

2. METHODOLOGY

In methodology the work initiated with the acquiring of aluminium alloy7075 and titanium diboride powder. The base metal taken is AA7075 and TiB_2 was mixed by weight percentage. Three samples were made i.e. mixture having 2%, 3% & 4% of TiB_2 powder. Acrawax was also added to the powder mixture in order to bond the powder particles properly in compacting process. After powder mixing, the powder was then compacted to form green compact under a pressure of 1500 lbs/sq. inch.

Fig. 3 Compacted FGM plates

After compacting, the compacted plates were then sintered at a temperature of 560°C three times in Degussa furnace under the atmosphere of dissociated ammonia gas. After second sintering, the plates were sized under a pressure of 1000 lbs/sq. inch to increase its density and then sintered for the third time as at this temperature the plates were not sintered properly when first sintering was carried out.

Fig. 4 Sintered FGM plates

3. RESULT AND ANALYSIS

3.1 Hardness Test

The material hardness is increasing with increase in the composition of TiB2.

Hardness of 2% TiB_2 sintered three times at 560 ° C at bottom is 55 HRB, Hardness of 3% TiB_2 is 62 HRB and Hardness of 4% TiB_2 is 70 HRB.

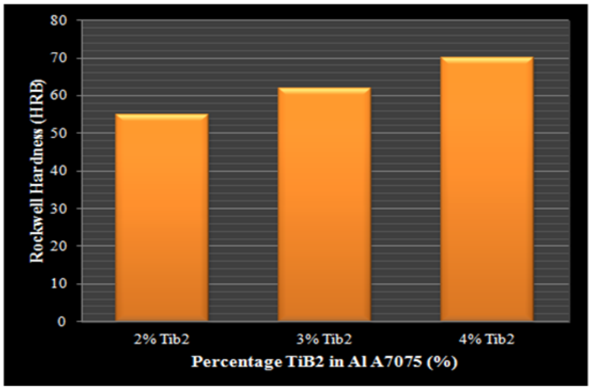

Fig. 5 Graph showing Rockwell Hardness in HRB

4. CONCLUSION

Brittleness of FGM plate increases with the % of TiB_2 increases. The Melting point of FGM is higher than base metal. Hardness of the FGM increases.

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