

The improvements in technology engineering essay

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Introduction

The improvement in technology has favored mankind in the study of materials. Materials now have many applications both for commercial (buildings, transportation and medical care) and military purposes (armor and defense systems). Metallurgical science has evolved during these present years. In the engineering field, materials are studied on their physical metallurgy, extraction metallurgy and process metallurgy. This has brought a wide range of alloys used today in the field. Metallic materials show a reduction in strength based on the diffusion, grain boundary sliding and re-crystallization process, this can be controlled by single crystal components or coarse and elongated grain structures [1]. It is also known that the strength of metals at high temperatures could be increased by the deliberate addition of fine dispersion of insoluble refractory oxides [7]. Alloying of metals comes with its limitations when using the conventional methods. It was found that different metals were reluctant to form alloys based on their differences in melting point temperatures with the conventional methods [13]. For example, alloying a metal with a high melting point and another with a lower melting point can form in solution in the liquid state but during the course of cooling and solidification the metal with the lower melting point tends to separate out of the solution. Over the past years a new method of alloying metals has been introduced that could bypass many of the limitations that occurred with the conventional way of alloying metals. This new technique is known as mechanical alloying (MA). MA is the milling of two or more elemental powders in their solid state [3]. It was found that when solid articles were made from different blends of

metal powders, the degree of homogeneity attained in the final product was limited by the particle size in the powders [13]. If the particles are coarse, the different elemental powders will not inter-diffuse during heating or solidification. This problem can be resolved by starting with finer powders. One way to produce a finer metal powder is to grind a coarse powder in a ball mill. Although, there are other techniques used in producing finer powders like atomization and reduction which will be mentioned briefly in this report but to accelerate the formation of metal composites and eliminate the dependency of the final powder homogeneity. I will be using ball milling. Alloy materials can be in the form of ferrous alloys (high or low alloy steels) or non-ferrous alloys (light alloys, Cu alloys, super alloys and refractory metals) [2]. Low alloy steels are relatively low strength and low hardenability while super-alloys such as, nickel-based have the highest strength among super alloys due to gamma-prime (γ') strengthening $\text{Ni}_3(\text{Al/Ti})$ and at high temperatures they show ceramic content of about 2.9% [1]. Ceramic metal matrix composite (CMMC) is made from metals and ceramic as the name implies, a metallic substrate material is reinforced with ceramic hardened particles. The differences in the physical metallurgy, extraction metallurgy and process metallurgy properties of CMMCs prevent the use of conventional manufacturing processes commonly employed in monolithic metals. Therefore, alternative techniques need to be used and powder metallurgy is a fabrication process that produces near net shape, high productivity as well as dimensional accuracy of CMMC. The sintering of the ceramic and metal are done by mechanical alloying (MA) which is the starting process. MA has been used for over 20 years as a method of producing materials for different

application both commercially and for research purposes. In this report, we will be taking a look at the mechanical alloying of aluminum with stainless steel by using the experiments carried out to analyze the process.

Literature Review

Powder metallurgy

Powder metallurgy (PM) is a manufacturing method used to produce components by bringing a powder of the starting material into desired end shape. Material used may be ceramic or metal. The important feature is that the bonds between particles are produced without total melting. PM process offers chances for the manufacture of materials that cannot be obtained by classical metallurgical techniques, such as very high alloy tool steels with an isotropic microstructure or cemented carbides [4]. PM method is very helpful in the manufacture of structural parts, by eliminating most of the machining techniques required for wrought semi-products and casting. The basic step in PM method to arrive at a finished or semi-finished object from alloyed powders is the powder production, compaction, sintering and secondary operations. The advantages of PM process is that it gives good dimensional control and surface finishing, capable of manufacturing bimetallic products that are difficult to produce by using other alloying methods, production of parts with controlled porosity and suitable for making parts of high melting points [5]. Figure 2. 1 shows a schematic diagram of the powder metallurgy process. Figure 2. 1. Basic steps of the powder metallurgy process

Powder Production

Metallic powder performances during processing and the powder metallurgy are dependent on the characteristics of the metal powders used. The characteristics of the metal powders are the particle size, purity, compressibility, apparent density and particle shape [6]. All these characteristics influence the production of powders. There are various methods used for the production of powders, depending on the nature of the metal. The methods can be classified as chemical methods (reduction, condensation), physical methods (atomization, electrolytic deposition) and mechanical methods (shotting, ball milling (crushing and milling) and machining) [6]. The main purpose for powder production is to make powder particles with a high yield of fines ($<20\mu\text{m}$) and powder particles with shapes that are nearly spherical. Ball Milling (crushing and milling) Atomization Atomization is the change of a substance liquid into spray of liquid droplets in a closed vacuum or gas [8]. Atomization process of elemental powders can be done in two different ways, either by water atomization or gas atomization. The major difference between them is substantial oxidation taking place. When the metal comes in contact with water it reacts in accordance with: $x\text{Me} + y\text{H}_2\text{O} \rightarrow \text{Me}_x\text{O}_y + y\text{H}_2$ The metal is partly oxidized, even though the atomizing tank has been purged with an inert gas to minimize oxidation of the powder [9]. Water atomization method is used to achieve a narrow size distribution of powder particles but this technique is not suitable for the production of clean and spherical powders. Gas atomization method does produce powder particles which are spherical in shape but the extra cost does not make this method commercially

acceptably. Here are some previous works done on with this technique. In 1999, Takeda and Nakabaya used water atomization with a water pressure ranging from 60MPa to 150MPa that produced a stainless steel powder with particle size as fine as 5 μ m [10]. Sawayana and Seki in 1996 used a water atomization system that allowed them with a water pressure of 50MPa to produce stainless steel powders with a mean particle size between 12 μ m to 15 μ m [11]. In 2000 Matsunaga, Kikukawa and Iwatsu used a swirl jet that rendered the particle shape to be more spherical with high pressures of 83MPa [12]. Reduction

Powder compaction

Compaction is a necessary step in powder processing as it allows the forming of loose metal powders into required shapes with enough strength to endure till sintering is finished. Compaction performs the following functions on metal powders [14]: To fuse the metal powder into desired shape To impart, to as high a degree as possible, the desired dimensions with due consideration to any dimensional changes resulting from sintering. To impart the preferred level and form of porosity. To impart satisfactory strength for later handling. PM employs many methods for compacting and shaping metal powders such as injection molding, hot isostatic pressing, slip casting and rigid die pressing etc. Phenomenology of powder compaction can be explained in stages using a die press. When pressure is applied to the powder particle at the initial stage, densification progresses as the powder particles re-arrange to fill up large voids and breakup particle bridges. The applied pressure needs to be sufficient enough to withstand the internal friction in the powder mass [9]. The addition of lubricants and the

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smoothness of powder particles aid in the densification. In the next stage, as the applied pressure is increased, plastic deformation happens at the inter-particle contact points which lead to the interlocking of protruding asperities on the particle surface. Finally in this stage, significant change occurs on the shape of the powder particles which cause a reduction in porosity because plastic deformation becomes widespread. Leading to strain hardening, the generation of new oxide-free surfaces and cold welding of contacting surfaces [9]. In figure

Sintering

Mechanical Alloying