TITANIUM P/M PREFORMS, PARTS AND COMPOSITES

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Introduction

In the past twenty years the titanium industry has grown from a start-up condition in 1951 to a major industry in 1971. In this time period a variety of titanium alloys have been developed and programmed into an increasing number of applications. Most of the typical product forms (billet, sheet, forgings, castings, etc.) are readily available. A number of the commonly used ferrous and non-ferrous metals, in addition to being available in a wide variety of mill and formed products, are also readily available in powder forms. It is only recently that technical advances have made available titanium powders suitable for consolidation into P/M products.

The most significant characteristic of titanium metal, and especially titanium powder, is its affinity for compound forming elements; specifically nitrogen, oxygen, carbon and hydrogen. These elements readily react with titanium, and very small quantities have a drastic effect on mechanical properties. Strength increases rapidly with a corresponding rapid decrease in ductility (1). The ductility of P/M parts is generally a sensitive area, and this added problem of titanium's reactivity has been the characteristic which up to now has precluded the commercial exploitation of P/M titanium.

Titanium powders of satisfactory purity are being produced by several processes. These include: hydride-dehydride, mechanically attritioned, rotating electrode and chemical reduction. The basic elements of these processes will be described briefly.
Titanium Powders

The hydride-dehydride process takes advantage of the reactivity of titanium. Feed material is reacted with high purity hydrogen at elevated temperature forming an extremely brittle hydride. This is crushed and fed to an attrition mill to produce powder of the desired size distribution. An argon atmosphere is used during the powder production steps to prevent contamination. The milled powder is then dehydrided by heating in vacuum. The loosely sintered powder is again passed through the attrition mill and screened to yield the finished product.

The mechanical attriting process starts with pieces of titanium which can be milled to chips. De-ionized cold water is used as a coolant. The finely milled chips are then dried and fed through a series of jaw-crushers housed in an inert gas chamber. The crushers are cooled with liquid nitrogen which chills the chips. This facilitates the crushing operation and reduces oxidation. The final operations consist of screening and magnetic separation.

The rotating electrode process (2) starts with bar stock. This is spun at high speed in a protective atmosphere chamber while the end is melted by a tungsten arc. Small droplets fly off the end of the bar and are quenched in flight as spherical powder particles. There is essentially no contamination resulting from this process, but the high strength spherical powders are extremely difficult to cold compact into complex shapes with adequate green strength and density. The three processes described are generally used to produce pre-alloyed powders. In addition to being more difficult to process than the elemental powders, the pre-alloyed powders are significantly more expensive. They range in price from $10 to $30 per pound.

The fourth process, chemical reduction, produces elemental titanium powder almost directly from the reaction. The resulting product is then sized and purified yielding an inexpensive powder approaching the price of sponge, $1.50 - $3 per pound. Alloys are then produced by the diffusion of "so-called" elemental powder additions. It is this inexpensive high purity powder that has opened the door to many practical applications.

Pressing & Sintering

The most practical advantage of utilizing elemental powders as opposed to pre-alloyed powders is demonstrated in Figure 1. The plot shows green density as a function of die pressing pressure. The elemental powder blend achieves a green density, 84% of theoretical, at a pressing pressure of 30 TSI. This pressure is slightly in excess of the yield strength of C.P. titanium. To achieve an equivalent green density, it is necessary to press the pre-alloyed