The Market Development of PM Aluminum

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Abstract

The Application of powder metallurgy (PM) aluminum structural parts is at its early growing stage, despite of some automotive applications. The market potential for PM aluminum, however, is large. Growth is expected from the market expansion of the existing applications and new applications, including the replacements of aluminum and zinc based castings and some ferrous PM automotive parts by PM aluminum. Compared to castings, PM is an efficient mass production technology. The PM aluminum is more competitive than die casting for some automotive applications. Besides weight saving leading to performance improvement, the total cost increase for aluminum PM parts is less than 15% compared to ferrous PM automotive parts. The future is promising for PM aluminum.

Keywords: Powder Metallurgy, Aluminum, Castings

1. Introduction

Compared to iron based materials, lighter weight aluminum materials are attractive options for structural and mechanical designs, in particular for the automotive industry. The amount of aluminum materials used for automotive applications has steadily increased as a means to reduce weight and increase fuel economy. For instance, the usage of aluminum die casting components in automotive is forecast to increase from an average of 220 lb per vehicle in 2004 to about 300 lb per vehicle by end of 2006. Aluminum and zinc die casting industries contribute over $7 billion to the US's economy. Nearly 50% of the die castings are used for automotive power-trains[1].

In contrast, applications of components made by pressed and sintered powder metallurgy (PM) aluminum are limited. The PM aluminum industry is much smaller and the total annual production of PM aluminum parts in North America is estimated to be less than $US 20 million. The industry is still at its early growing stage, despite some automotive applications. The market potential for the PM aluminum, however, is large. Growth is expected from the market expansion of the existing applications and new applications, including the replacements of aluminum and zinc based castings and some ferrous automotive PM parts by PM aluminum. It has been shown that PM aluminum is more competitive than die castings for some automotive applications. Compared to castings, PM is an efficient mass production technology, which enables excellent surface finishes, close dimensional tolerance reducing or eliminating the need for machining and other costly secondary operations. The technology not only allows small and intricate features to be produced but also a large number of alloy combinations so as to allow variations in properties such as modulus, toughness and hardness.

2. Result and Discussion

Apart from power tools, business machines and appliances, existing applications of PM aluminum components are predominantly concentrated on automotive camshaft bearing caps. The parts were formerly made by die casting and required extensive machining. Currently, Metal Powder Products Company (MPP) is the largest producer of pressed and sintered PM aluminum structural components in the world. The company started making aluminum components in 1973 and launched automotive components production in 1991. The company is making over a dozen types of cam caps which are used by a number of auto-makers in the world. More than 50 million cam caps have been shipped without any functional failures. In recognition of the significant technological achievement, MPIF awarded the Grand Prize to MPP for a PM aluminum camshaft bearing cap in the automotive engine category of the 2006 Powder Metallurgy Design Excellence Awards Competition. The part is a double hump cam cap and the largest pressed and sintered aluminum structural part in production, Fig. 1. The part is about 17cm long and weighs 220 g. It is made net shape to print without any machining. Compared to die casting, the PM technology enables the part to be designed with an integrated and more complex oil tunnels for cam lubrication and hydraulic control of the VCT system. Over a million of the cam caps have been shipped to the auto-makers in the US, Australia and Japan.

A significant part of future growth for PM aluminum depends on successful replacement of the aluminum and zinc based castings. In this case, the critical factor is cost,

Fig. 1 MPIF 2006 Grande Prize winner, PM aluminum cam cap made by MPP (bottom) and a Toyota die casting cam cap (top).

not performance. In general, commercial PM aluminum materials offer mechanical properties that are better or equivalent to that of the cast aluminum materials. Lowering cost is one of the main reasons for substituting PM aluminum components for aluminum or zinc castings. One major advantage of PM aluminum over castings is the net shape capability, which significantly reduces the cost. For instance, cost of the PM double hump cam cap is more than 20% lower than that made by the casting, despite having lower raw material cost for castings. In addition, the PM technology allows small and intricate features to be produced, leading to the integrated and more complex oil tunnels in the PM cam cap than that of the die casting cam cap. Also, the PM technology produces a more uniform microstructure than the cast components.

The 6-14% silicon in cast aluminum materials increases hardness and wear resistance. The distribution and size of the silicon particles in the microstructure determines the wear and fatigue behavior of the materials. Powder metallurgy Al-Si alloy exhibits a more uniform microstructure, and the size and amount of silicon particles are better controlled, with prevention of silicon segregation that produces undesirable wear and fatigue performance[2]. Similar to the silicon, addition of ceramic particulates to the PM aluminum materials enhances the wear and high temperature properties of the materials[3]. As many potential applications in automotive components are subjected to cyclic load, the fatigue strength of the aluminum materials is of great importance. Incorporation of ceramic reinforcement into the PM aluminum materials significantly improves stiffness and fatigue strength of the materials. Therefore, the PM Al-Si alloy and the ceramic reinforced PM aluminum materials are excellent candidates for replacing cast aluminum materials in applications where wear and fatigue are critical. Advances in compacting and sintering technology for PM aluminum have reached a stage enabling cost of PM components to be lower than that of conventionally forged and cast components.

With regard to the replacement of ferrous PM automotive components, such as pulleys and camshaft sprockets, the critical factor is performance, not cost. In addition to corrosion resistance, the advantage of aluminum over ferrous materials is the light weight that is critical to the automotive industry. For moving parts in automotive engines, the lighter material not only reduces weight leading to lower fuel consumption, but also reduces inertia of the moving parts leading to performance improvement. General impressions have been that aluminum is much more expensive than ferrous materials. In fact, PM aluminum is much less expensive than the perception would suggest. The cost for PM aluminum by weight is three to four times more expensive than the ferrous materials. However, cost by volume for the aluminum is only about 30% more expensive. As material cost is about 25-40% of the total cost for most of the PM parts, compared to the ferrous PM parts the total cost increase for the aluminum PM parts is less than 15%. As the PM aluminum technology is getting matured, the energy saving for the aluminum may also become significant. It is highly possible that the cost increase for replacing the ferrous materials by the aluminum can be controlled to 10% of the ferrous part cost. The future is promising for PM aluminum.

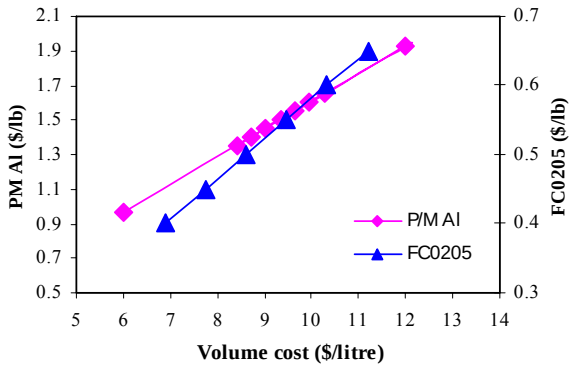

Fig. 2 Cost comparison of P/M aluminum and the ferrous PF grade FC0205 materials.

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