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Influence of processing parameters and particle size on the properties of hot work and high speed tool steels by Spark Plasma Sintering

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ABSTRACT

Spark Plasma Sintering (SPS) is a newly developed rapid technique for powder sintering. In this study, consolidation by SPS of high speed steel (AISI M2) and hot work tool steel (AISI H13) commercial powders is investigated. The influence of sintering temperature (900 to 1150 °C) and time (0 to 30 min) as well as the particle size and distribution is evaluated with respect to final density, hardness and fracture toughness. Properties have been compared with those of samples produced by Hot Isostatic Pressing (HIP).

Density increases with increasing temperature up to 1050 and 1100 °C for H13 and M2, respectively, a minor influence of time being observed for times longer than 5 min. Near fully dense samples (>99.5%) are obtained after sintering at 1100 °C for 5 min only under uniaxial pressure of 60 MPa. Fine powders with a narrow size distribution or, alternatively, powders with a wider particle distribution and sufficiently high fraction of small particles show higher propension towards the achievement of full dense samples. The maximum densification rate occurs at lower temperature for H13 than M2, being negatively affected by the ferrite–austenite transformation during heating and the corresponding resistivity variation. Hardness and fracture toughness are found to increase with increasing density. Comparatively good values are obtained with respect to samples produced by Hot Isostatic Pressing confirming the possibility to produce tools by SPS.

1. Introduction

The need to improve sintering processes has led to develop new techniques. One of the most promising is Spark Plasma Sintering (SPS), involving the use of electrical current to activate the sinter-bonding [1–5]. In the SPS process, which is a pressure sintering method, a pulse on–off direct current is applied to the material. It was claimed that the pulsed current momentarily generates localized high temperature sparks of plasmas into the gaps or at the contact points between conductive powder particles, as well as spark impact pressure, Joule heating and an electrical field diffusion effect [1]. More recent investigations advocated the absence of plasma during SPS [6]. All the cited phenomena are believed to be responsible of the purification and activation of the particles surface and of the promotion of material transfers at both the micro and macro levels. Hence SPS allows the production of high-quality, fully dense sintered compacts at lower temperature and in a shorter time than conventional sintering processes. These benefits make SPS suitable for the development of many innovative materials difficult to be produced by traditional methods, like functionally graded materials, fibre reinforced ceramics, metal matrix composites, nanocrystalline materials [1–4,7].

To the authors best knowledge, while a discrete number of papers has been published on the fabrication of iron [8] and iron-base alloys [9–11], few ones only deal with the production of harder tool and high speed steels by SPS [12,13]. Tool steels are characterized by high hardness and good wear resistance due to a microstructure constituted by a tempered martensitic matrix strengthened by a fine dispersion of secondary carbides. High speed steels are much harder in view of a high fraction of primary and eutectic carbides, but comparatively less tough. Powder metallurgy (PM) allows the production of steels with a finer and more homogeneous microstructure compared to conventional casting [14], bringing a more favourable combination of toughness and hardness. Around 10% of the world tool steels production is nowadays based on PM technology [14]. Conventional PM tools are currently produced via Hot Isostatic Pressing (HIP). For economical reasons rough products (bars) are fabricated using high pressured argon (100 MPa) at temperatures comprised between 1000 and 1200 °C for several (4) hours. Tools are then obtained by mechanical and/or electrodischarge machining. The opportunity of producing a new tool by SPS having near net shape, in a shorter time and with a finer microstructure represents an interesting challenge for researchers. The further possibility to combine different powders

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