journal of materials processing technology 202 (2008) 521–527

journal homepage: www.elsevier.com/locate/jmatprotec

Development of powder metallurgy T42 high speed steel for structural applications

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ARTICLE INFO

Article history:
Received 21 May 2007
Received in revised form
11 September 2007
Accepted 18 September 2007

Keywords:
Heat treatment
Wear
Valve seat insert
Mechanical properties
High speed steel

ABSTRACT

Water atomized T42 high speed steel powders have been processed by a powder metallurgy (PM) route in order to obtain a fully dense material suitable for valve seat inserts (VSI) in diesel engines. Two different heat treatments (isothermal annealing and multitempering) were designed leading to the targeted hardness value (50 HRC). Microstructural characterisation of the heat-treated material was carried out using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Fracture strength and fracture toughness have also been investigated. The wear behaviour was evaluated through pin-on-disc tests at service temperature (360 °C). The obtained results demonstrated the excellent wear resistance of the VSI material without severe wear of the countermaterial (valve).

1. Introduction

High speed steel (HSS) valve seat inserts (VSI) have been developed for heavy-duty applications where the performance of powder metallurgy (PM) products designed for gasoline engines is not acceptable and conventional cast seat inserts based on cobalt, nickel or iron alloys show poor fracture toughness, poor machinability and low compatibility with valve materials (Brico, 1996).

Inspired in previous studies at CEIT (Urrutibeaskoa et al., 1993; Talacchia et al., 1996), the processing route for VSI based on M42 powders was presented by Federal Mogul in a PM World Congress (Whitaker et al., 1998) and is patented by Brico Engineering Ltd. (Brico, 1996). Simultaneously, Hitachi and Nissan introduced a development for high performance exhaust VSI based on HSS (Kawata et al., 1998). More recently, a new cobalt-free material has been presented, consisting of a Fe–3.5Mo matrix (wt%) with a dispersion of two types of hard particles (Fe–Cr–C and Fe–Mo–Si) (Fujiki et al., 2005). In line with these developments, there are now several commercial solutions trying to encompass a good wear resistance at service temperature with microstructural stability, good machinability, low cost and a robust processing (Kawata and Maki, 2006).

One of the last developments related to HSSs for valve seat inserts involve the use of M3/2 tool steel mixed with iron powder and infiltrated with copper in order to optimise the compressibility, thermal conductivity, final density and manufacturing costs (Salgado et al., 2001). Furthermore, the addition of NbC particles leads to an increase of the radial crushing strength, which attains values similar to those for the most expensive Fe–Co alloy (Salgado et al., 2003). On the other hand, the “Mn content iron powder + MoS_2” method has proved to be very efficient to enhance the machinability without decreasing the radial crushing strength (Kawata and Hayashi, 2002).

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0924-0136/$ – see front matter
doi:10.1016/j.jmatprotec.2007.09.062

Table 1 – Chemical composition of the T42 powder (wt%, *ppm)

Material	T42
C	1.32
Co	10.58
Cr	4.20
Mo	3.82
O*	603
Si	0.31
V	3.32
W	9.98

In previous studies (Trabadelo et al., 2002, 2003), the PM T42 HSS was proposed as a suitable material for manufacturing structural components. This powder grade has been selected instead of the more popular M42 due to its higher vanadium content, responsible for a uniform distribution of vanadium carbides. The combination of M_6C (Mo, W-rich carbides) and MC (V-rich carbides) in the microstructure should provide a higher wear-resistant material (compared to M42) for a similar hardness. The hardness values of commercial VSI typically vary between 35 and 55 HRC. Therefore, 50 HRC has been targeted to confer enough wear resistance to the VSI without severe wear of the valve material. The basic approach to obtain this hardness value through annealing or multitempering heat treatments was established in references (Trabadelo et al., 2002, 2003). In order to complement these studies, the present manuscript focuses on the microstructure, thermal stability, mechanical properties and wear resistance of the PM HSS T42 grade.

Table 2 – Fracture strength (σ_f) and fracture toughness ($K_{I\nu}$) for T42 + C after annealing or multitempering to 50 HRC

Heat treatment	σ_f (MPa)	$K_{I\nu}$ (MPa $\sqrt{m}$)
Cycle 1	1350 ± 40	18.7 ± 0.5
Cycle 4	1420 ± 40	19 ± 0.5

2. Experimental procedure

Hydrogen annealed water atomized T42 HSS powder was supplied by Höganäs Great Britain Ltd. (Aylesbury, United Kingdom). The composition of the powder is given in Table 1. The mean particle size calculated from the particle size distribution provided by the manufacturer is 69 µm.

A 0.6 wt% compaction lubricant was added. Additionally, a 0.4 wt% carbon in the form of graphite powder (particle size <5 µm) was added to improve the sinterability of the alloy (Giménez and Iturriza, 2003). The powders were blended with a Turbula® (Glen Mills Inc., Clifton, New Jersey) device during 2 h at a constant speed (30 rpm). Cylinders with 16 mm

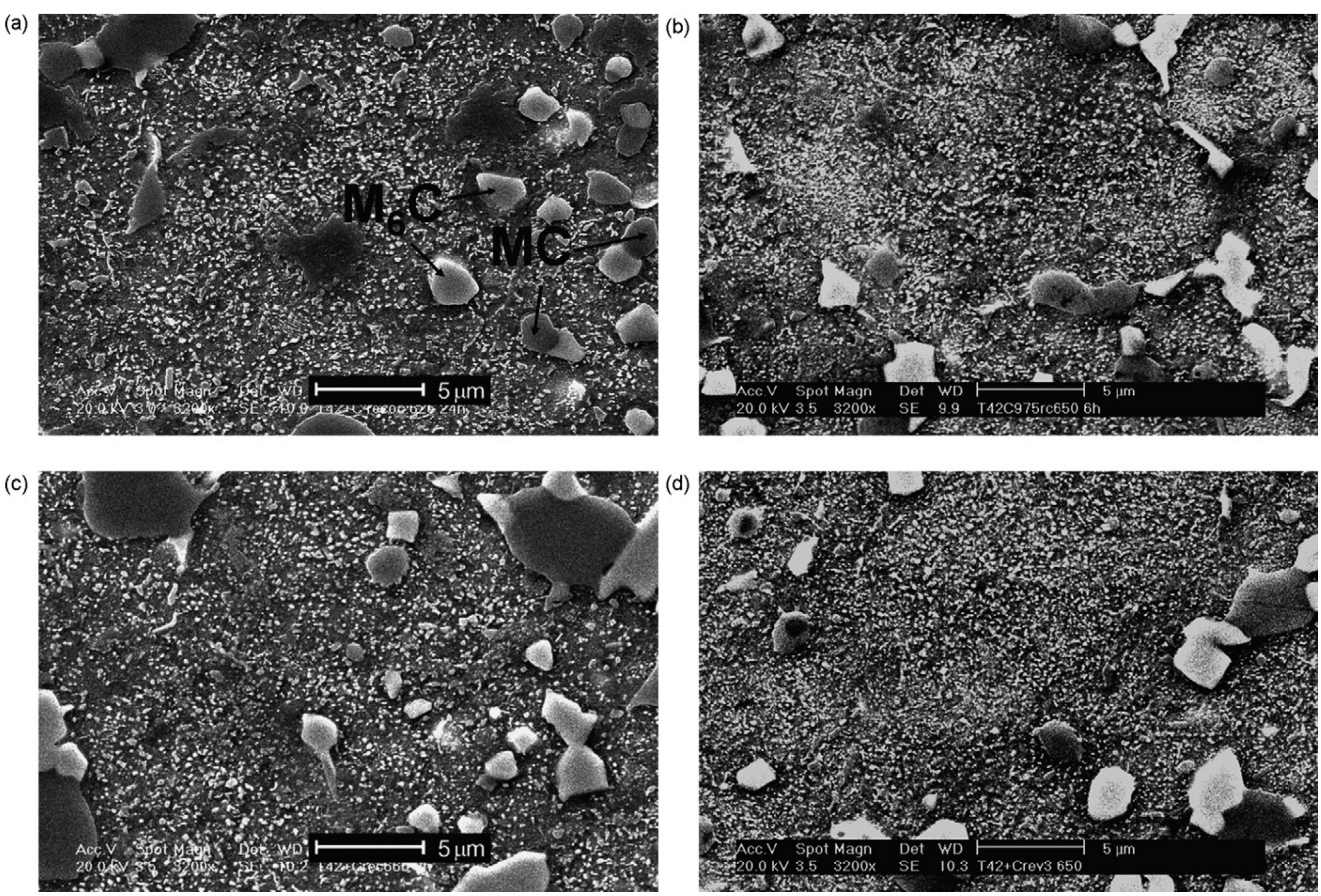

Fig. 1 – SEM micrographs of T42 + C annealed or multitempered to a hardness value of ≈50 HRC: (a) cycle 1; (b) cycle 2; (c) cycle 3; and (d) cycle 4 (all the micrographs were taken at the same magnification).