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Microstructure and abrasion properties of tool steels reinforced by dispersed oxides and carbides phases

Abstract

Two ferrous matrix, a high speed steel and a maraging steel were reinforced with alumina, titanium and vanadium carbides. The composite was realized by powder metallurgy. The particles were mechanically mixed with the prealloyed powder before compaction. To optimize the composite properties, the processing parameters (i.e. prealloyed powders, size, mixing conditions, temperature of sintering,...) and the effect of reinforcement (size and composition of particles, volume, fraction,...) were studied. It is necessary to obtain full density with minimum porosity and to control the size, distribution and dispersion of the reinforced particles. The optimal sintering temperature depends on the reinforcement particles used and is of great importance for the properties. Processing parameters (mixing of particles) can greatly affect the final properties. The use of Al_2O_3 was shown to increases wear resistance in the two matrix.

Introduction

For long applications and for many others, a material with properties between hard metal and high speed steel is necessary. An attractive solution consists in combining in a composite the properties of a tough ferrous matrix with those of hard reinforced particles. In varying the nature and the proportions of reinforcement and matrix, the properties of the composite can cover many applications. The fabrication route chosen was PM metallurgy. In fact, PM high speed steels have been a commercial reality for nearly 20 years ; thus PM metallurgy is an easy way to produce composites.

Choice of matrix and reinforcement - Fabrication method

Two standard matrix were studied :

- a high speed steel : 1,5 % C, 4,5 % Cr, 12,5 % W, 5 % V, 5 % Co, Fe,
- a maraging steel : 18 % Ni, 8 % Co, 5 % Mo, 0,4 % Ti, Fe.

The high speed steel powder is obtained by water or gas atomization. The maraging steel is obtained only by gas atomization due to the presence of Ti and Al.

The fabrication route involves consolidation to full density by cold pressing and sintering. The particles are mechanically mixed with the prealloyed powder before compaction. This operation can be done directly on water atomized powder. But, due to the state of the gas atomized powder, a specific preparation has to be made to obtain a powder that could be mechanically mixed.

The reinforced particles must present the following important characteristics :

- high hardness (min 1700 HV),
- good interaction with the matrix,
- low solubility in the steel.

Some carbides such as TiC or NbC as well as TiN on Al_2O_3, could be used. The interest of VC is less, as the eutectic Fe-VC appears at a temperature near the sintering temperature.

Experimental results

Most of the experimental work was done with the high speed steel matrix to determine the best compacting and sintering conditions with the different particles.

These results were used for the maraging steel.

a. High speed steel matrix + alumina

Different types of alumina were used. In fact particles vary due to the different powder - manufacturing methods used. Particles characteristics such as shape, density and purity have a significant influence.

Two types of alumina were studied in particular : calcinated alumina and electro-furnace alumina.

The high speed steel powder used is obtained by water atomization and its granulometry is less than 150 µm.

The ferrous powder was mechanically mixed with the particles (10 % in volume) during 24 hours. The powder was mechanically compacted without lubricant. These samples were sintered under vacuum at temperature from 1000 to 1400°C to determine optimum conditions. The best sintering conditions seems to be 1270°C during one hour. For these conditions, hardness is maximum (660 HV) and residual porosity rather low (< 0.04 %) ; moreover the grain size is not too high (25 µm). If the sintering temperature is increased, the grain size as well as the particles size increase.

The obtained microstructure is made of the ferrous matrix together with round carbides (V, W) C and alumina particles. As alumina has no reaction with the matrix, the carbides distribution is the same as in the matrix alone.

b. High speed steel matrix + carbides

Particles of VC (10 % in volume) were mixed to the high speed steel powder under the same conditions. The best sintering temperature is again about 1270°C. At this temperature, hardness is high (680 HV) and porosity low (0.43 %). An increase in the sintering temperature leads to bigger carbides and grain size.

The obtained microstructure is made of (V, W) C carbides dispersed in the ferrous matrix.

Particles of TiC (10 % in volume) were mixed to the high speed steel powder under the same conditions. The best sintering temperature is higher (1320°C). Hardness is high (657 HV) and porosity low (0,60 %). The microstructure is made of an acicular TiC particles with the (V, W) C carbides. Because of the high temperature, the size and dispersion of (V, W) C carbides is rather heterogeneous.

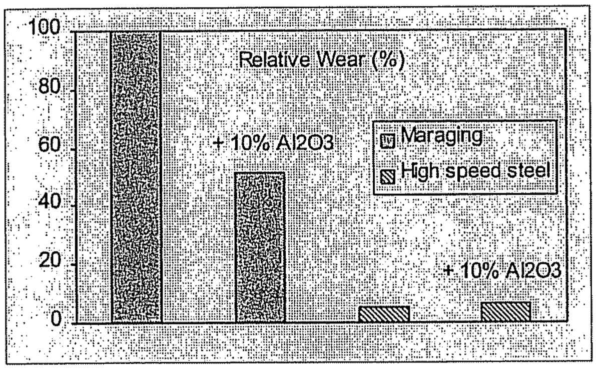

Figure 1 - Results of abrasion test

c. Properties

Mechanical properties were determined on the best composite obtained after compaction with alumina particles. The properties used to classify the composite are hardness and porosity level. For alumina particles, the electro-furnace alumina with low titanium content gives the best results. The size of the particles must not be too small.

The composites studied were evaluated in tension and wear tests.

The results of the tensile tests are illustrated in Table I. Figure 1 gives the results of the abrasion tests.

Alloy	Rupture strength
High Speed Steel	1270 MPa
High Speed Steel + 10 % Al_2O_3	825 MPa
Maraging Steel	2250 MPa
Maraging Steel + 10 % Al_2O_3	1715 MPa

Table I - Tensile Tests at room temperature

Conclusions

The use of ceramic reinforcement in these matrix lowers the rupture strength of the composite in comparison with the results obtained in the matrix alone but the tensile resistance of the obtained composite remains high (825 MPa - 1715 MPa).

On the other hand, the use of alumina particles increases the wear strength of the composite. In rubber wheel abrasion tests (V = 3 m/s, abrasif = quartz) (1), the composite maraging steel + alumina possesses a good behaviour : relative wear is nearly twice better, compared to the maraging steel. The high speed steel is characterized by a better wear resistance compared to the maraging steel. The carbides present in the high speed steel matrix are really very hard and the use of alumina does not change wear resistance, which is similar in matrix with and without Al_2O_3.

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