Performance of TiC base cermets sintered by different techniques

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The performance and structure of some advanced TiC base cermets with Ni steel binder, sintered by different techniques (sintering atmosphere, vacuum level, etc.), prospective for metal forming, were investigated. It is shown that the influence of sintering technology on the performance characteristics of TiC cermets (strength, wear resistance) depends on the composition and structure of their binder. Regarding the performance characteristics (transverse rupture strength and adhesive wear resistance) TiC base cermets with martensitic–bainitic steel binder sintered by optimum techniques demonstrated a marked superiority over those with austenitic binder and particularly over those with Ni alloy.

Keywords: Cermets, Wear resistance, Strength, Sintering technology (techniques), Structure

Introduction

Tungsten carbide base hard metals are the most widely used carbide composites in different wear conditions because of their excellent combination of high wear resistance and good strength toughness. 1 TiC base cermets (so called ‘tungsten free hard metals’) may be successful in some applications as a result of their low friction coefficient, high specific strength and favourable physical properties. 2–5 TiC base cermets have proved their performance in metal cutting and some special applications. 4, 6 Advanced TiC cermets have demonstrated their superiority over ordinary WC hard metals in blanking of sheet metals. 7, 8

The sintering technology widely used for ordinary cermets (cermets with a TiC fraction less than 30 wt.% and Ni alloy or low alloyed steel binder) consists of two steps (i) pre-sintering in hydrogen and (ii) finish sintering in vacuum. 9, 10 Results presented in Refs 10 and 11 refer to the possibility of substituting hydrogen by argon or nitrogen. In Refs 4 and 12 and 13 a vacuum was used for sintering of cermets.

This paper focuses on the mechanical and wear behaviour of some advanced TiC base cermets containing 60–70 wt.% TiC with Ni steel binder, prospective for metal forming. 11 The influence of sintering techniques (sintering atmospheres, vacuum level) on the properties of these alloys was analysed.

Experimental

Materials and technology

The study covers TiC base cermets with 60 and 70 wt.% TiC cemented with Ni steels with martensitic bainitic (8 wt.% Ni) and austenitic (14 wt.% Ni) structure of the binder, grades T608 and T7014, respectively. For comparison, an ordinary TiC base cermet with Ni Mo alloy binder (with equal carbide fraction 70 wt.%) TN30 was investigated. The sintering technologies (modes) used for manufacturing of TiC cermets are presented in Table 1.

Testing procedures

Transverse rupture strength RTF was tested in accordance with the standard ISO3522 using specimen B. Vickers hardness was determined according to the standard EN-ISO 6507-1.

The wear behaviour of alloys was studied in adhesive wear conditions. The adhesive wear is featured as a surface failure of very high structure sensitivity. 14 It dominates in the surface failure of cemented carbides used as tools for blanking (metal forming) operations. 8 The adhesive wear conditions were realised by turning mild steel (HV 30 < 170) at low speed (v < 18 m min−1). The wear resistance was determined as the length of cutting path (distance) Lc, when the wear track (height h) at the tool (specimen) nose achieves the critical value h = 1 mm (see Fig. 1). Fair correlation between the adhesive wear resistance characteristic Lc of cemented carbides and their wear in blanking (blanking performance ADW) was demonstrated. 7, 8

The tests were complemented by scanning electron microscopy (SEM) studies, conducted on the electron microscope JEOL JSM 840A.

Results

Wear behaviour

The results of experiments, the adhesive wear kinetics (wear curves) of three TiC cermets of approximately equal carbide volume fraction and hardness, differing in their binder composition and structure and sintered by two different techniques, are shown in Fig. 2. It can be seen that in terms of wear performance, TiC cermets

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with Ni steel binder T60/8 and 70/14 are clearly superior over the ordinary cermet with Ni alloy binder TN30.

The global presentation plotted in Fig. 3 refers to an obvious influence of sintering techniques on wear performance of TiC cermets. The influence appears to depend on the binder composition and of cermet structure. It is strong for cermets with martensitic– Bainitic binder structure (grade T60/8) and uncertain for those with austenitic (T70/14) or Ni alloy ones (TN30).

In respect to adhesive wear performance, cermets sintered by one step techniques in vacuum (Fig. 3, mode 1) demonstrated an obvious superiority over alloys sintered by two step techniques with presintering in hydrogen or vacuum (Fig. 3, modes 2-1, 2-2, 2-3). Hydrogen of high purity (low dewpoint <−50°C) used during presintering and high vacuum (pressure $p < 5 \times 10^{-2}$ mbar) during finish sintering, improves the wear performance of TiC cermets substantially. Decrease in the vacuum level during one step sintering up to $3 \times 10^{-1}$ mbar does not induce a remarkable reduction of the adhesive wear resistance of TiC base cermets.

The wear performance of TiC cermet with martensitic– Bainitic binder structure T60/8 sintered by optimum techniques demonstrated a clear superiority over cermets with austenitic binder (grade T70/14).

**Mechanical properties**

The influence of sintering techniques on the strength of TiC base cermets is demonstrated in Fig. 4. In general, the relationship 'strength–sintering mode (techniques)' is similar to that of 'adhesive wear resistance–sintering techniques' (Fig. 3). The influence is remarkable for cermets with martensitic– Bainitic steel binder (T60/8) and uncertain for those with austenitic (T70/14) or Ni alloy (TN30) ones.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Sintering modes</th>
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<td>Pos</td>
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*DP: dewpoint of hydrogen used*
In the case of using two step sintering instead of one step, hydrogen of high purity (low dewpoint) during presintering and high vacuum during finish sintering improve TiC cermets with steel binder strength properties.

It should be noted that the influence of sintering techniques on the strength of TiC cermets is not as sharp as that on its adhesive wear resistance: the wear resistance alters, depending on the sintering technique by as much as 10 times, while transverse rupture strength \( R_{\text{TR}} \) alters ‘only’ three times. This is attributed to the higher structure sensitivity of the adhesive wear of cemented carbides in relation to their strength.\(^{14}\) In contrast to transverse rupture strength, the hardness HV30 of TiC cermets demonstrates a low sensitivity to changes in sintering technology.

**Discussion**

The results obtained refer to an obvious influence of sintering techniques on the microstructure of TiC base cermets with martensitic Ni steel binder. Cermets sintered by one step techniques in vacuum that have a considerably higher performance characteristics (strength, wear resistance) in relation to those sintered by the two step technology are featured by a microstructure of high homogeneity. The high homogeneity is expressed by low porosity, higher uniformity in binder distribution, lower contiguity of carbide selection (Fig. 5A).

The degradation of the microstructure of a cermet during sintering (Fig. 5B and C) may be related to the oxidation decarburisation processes taking place during presintering and storing in air-atmosphere after pre-sintering.\(^{12,15,16}\)

Oxides in cemented carbide structure act as contaminants, inducing first enhanced residual porosity and second, deterioration in wettability (between metallic binder and carbide phase).\(^{16,18}\) The latter results in an increase of the contiguity of the carbide skeleton and failure in the uniformity of the binder distribution, which is the origin of the ‘lakes’ in the structure.\(^{17,19}\)

The increase in porosity and contiguity induces the degradation of the resistance of carbide composites to brittle fracture to a failure initiated by tension stresses (decrease in transverse rupture strength \( R_{\text{TR}} \) and fracture toughness \( K_{\text{IC}} \)).\(^{20,27}\)

While strength \( R_{\text{TR}} \) of a cermet is affected by porosity and contiguity, the adhesive wear resistance is, to a great extent, influenced by the binder distribution in the structure too.

As stated, roots of the adhesive failure of the surface of cemented carbides are in the binder phase, and takes place by extraction (by prevalence of tension stresses). It is preceded by the processes of interaction: local plastic strain of asperities, origin of juvenile surfaces and adhesive bonds between wearing contacting surfaces.\(^{14,21}\) Therefore the adhesive wear resistance of
6 Relationship between transverse rupture strength and adhesive wear resistance of TiC cermets sintered by different techniques

7 Microstructure of cermet TN30

A one step vacuum sintering, B two step sintering

-1. The performance characteristics of TiC base cermets with Ni steel binder exceed substantially those of ordinary TiC cermets with Ni alloy binder (at an equal hardness level and carbide fraction).

-2. The influence of sintering techniques (sintering atmosphere, sintering mode) on the performance of TiC cermets depends on their composition and binder structure. It is considerable for cermets with martensitic-bainitic steel binder and negligible for those with Ni alloy (Ni-Mo).

-3. In respect to performance characteristics TiC cermets with martensitic-bainitic steel binder sintered by the optimum technique (one step vacuum sintering at \( p < 3 \times 10^{-2} \) mbar) have a substantial advantage over those with austenitic binder.

-4. The improved performance of TiC cermets with steel binder (sintered by optimum techniques) is related to the high homogeneity of their microstructure.

-5. The fair correlation between adhesive wear resistance of cermets and their transverse rupture strength refers to the existence of similarity between both failure processes (bending fracture and adhesive surface failure).

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References


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