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Wettability Study of Aluminum on Advanced Cutting Tools

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Abstract: Wetting test is widely used to find out the chemical affinity of aluminum with different substrates before proceeding for any expensive tests. In this present work, Wettabilty tests were carried out in a high vacuum brazing chamber to find out the spreadability of aluminum on various carbide substrates. The wetting angles were measured by SEM pictures. Geometrical configuration of the wetting specimen clearly indicates that Al_2O_3 has a better wettability than TiN with liquid Al. Hence the tests revealed TiN coated carbide insert showed best result compared to others.

Key words: Ceramics; Interfaces; Diffusion; Surface properties;

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I. INTRODUCTION

Metal-ceramic interface plays a vital role in different industrial applications such as light bulbs, micro-electronic components and medical implants. The studies on mechanism of bond formation at the interface of metal and ceramic were carried out by various research groups. This is reflected by increasing number of experimental and theoretical studies by them. The progress in this area has been particularly rapid in recent years[1-5]. This is due to more refined experimental techniques that are available for exploring the interface atomic and electronic structures. In depth work has been carried out on wetting using various parameters. The contact angle and rigorous derivation of Young, Cassie-Baxter and Wenzel equations which are used for measurement of contact angle at different wetting regimes. Different theories in surface contact mechanics were compared on various substrates [5-9] The wetting characteristics were affected by surface roughness, chemical heterogeneity, gaseous environment, interaction with different substrates and application of current at the interface etc

II. EXPERIMENTAL PROCEDURE AND CONDITIONS:

All the experiments were conducted under the pressure 1×10^{-5} Torr at temperature of 800^0C ($\cong 40^0$C per minute) and kept for five minutes. The nominal dimensions of the solid block were 12.7×12.7×3.76 mm. Cylindrical pure rolled aluminum specimen (Ø3×3 mm) used in wettability test and was produced by machining. The aluminum cylinder was first placed on the solid specimen block with it's axis vertical. The pair was then placed on the horizontal graphite block of the vacuum furnace. The graphite plate acted as a resistive heater in the vacuum furnace. The thermocouple tip was placed on the graphite block. The wetting angles were measured by SEM pictures.

III. RESULTS AND DISCUSSION

Formation of bond between liquid and solid interface depends on both physical and chemical interactions between two materials. The work of adhesion and chemical reactions between species has been presented [3-10]. The high degree of wettability is observed in presence of substantial interaction of a chemical compound, solid solution intermetallic compound and mutual solubility. Such chemical compound formation leads to negative free energy of reaction, which results in a reduction of interfacial tension at liquid Al and substrate interface.

The surface cobalt content was found to be 6% and wetting angle (θ) measured to be 90^o. It can be noted that received surface is composite in nature consisting WC particles dispersed in Co matrix. The chemical interaction of Al-Co interface is more pronounced than at Al-WC interface.

SEM pictures indicate better wetting (wetting angle=80^o) of TiC surface than WC rich surface by liquid Al at 800^oC. Such reduction in wetting angle can be explained by reduction in the interfacial tension through dissolution of TiC in Al at 800^oC. This is due to formation of strong chemical interactions such as covalent bond of Al-Co. The interface is composed of Al_4C_3 compound. The spreadability of aluminum towards TiC is also vigorous on both ends.

Relatively poor wetting of TiN surface by liquid Al at 800°C in comparison to TiC is observed. In this case the wetting angle is found to be as high as 145°. The wetting of a metal on carbide, boride or nitride of transitional element (titanium) depends on their chemical stability. Since the chemical stability of TiN is higher than that of TiC, the larger wetting angle is expected in case of TiN. The interface is composed of intermediate brittle phase like TiO and/or TiO_2.

The wetting angle was observed to be 135° between aluminum and Al_2O_3 coating. The tendency of liquid Al to wet Al_2O_3 is promoted by chemical reaction between Al and Al_2O_3 with formation of the compound Al_2O. The thermal mismatch for these coexisting material combinations is a very important factor which decreases the shear strength during cooling and residual stress develops in both metal and ceramic. Geometrical configuration of the wetting specimen clearly indicates that Al_2O_3 has a better wettability than TiN with liquid Al. Thus TiN is the best tool for machining Al compared to other tools.

Sl.No	Solid Surface	Remarks	Wetting Angle (In Degrees)
Tool Geometry: 0^0, 6^0, 5^0, 5^0, 15^0, 75^0, 0.8 mm (ISO)			
Tool 1	Sandvik SPGN 120308 K10 carbide insert	As received WC=94% and Co=6%	90
Tool 2	CVD TiC coated carbide insert	Interlayer	80
Tool 3	CVD TiN coated carbide insert	Interlayer	145
Tool 4	CVD Al_2O_3 coated carbide insert	Interlayer	135

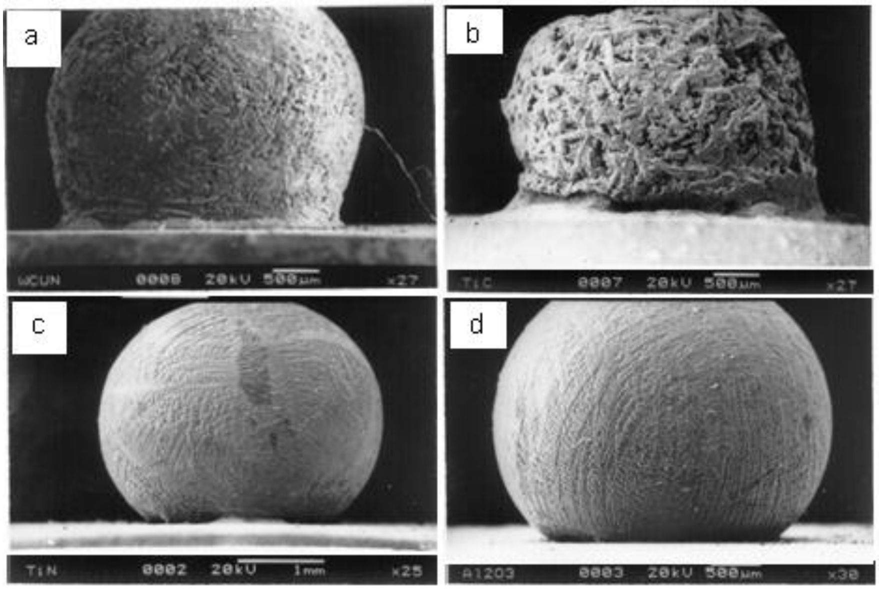
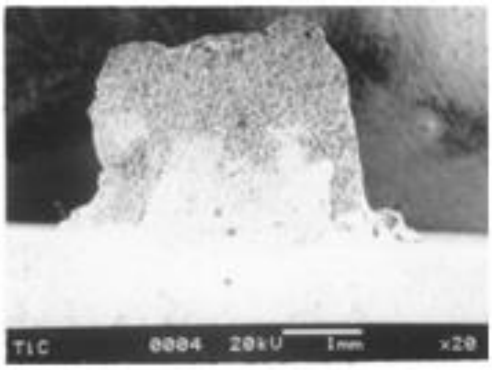
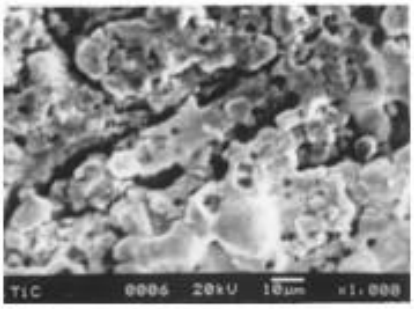


Figure 1: Variation in wetting angles of aluminum on different solid surfaces. They are (a) Tool 1 (b) Tool 2 (c) Tool 3 (d) Tool 4.



(a)



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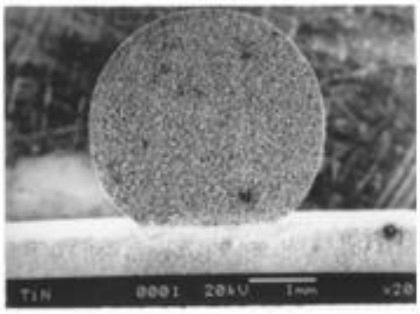

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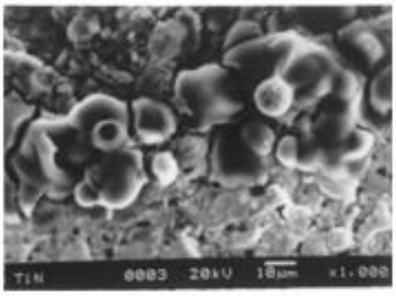

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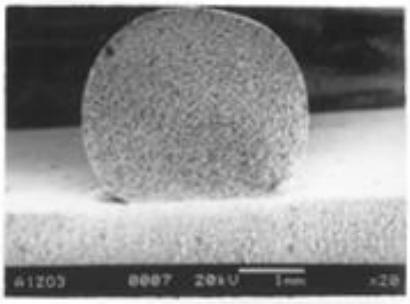

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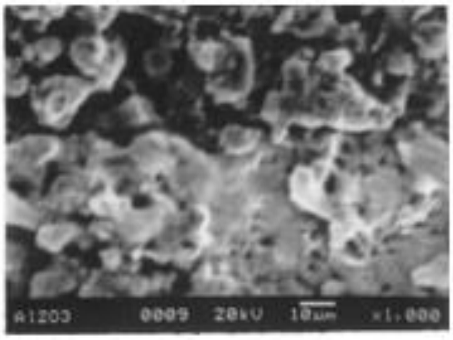

(f)

Figure 2: Wetting cross-sectional and interface variation of aluminium on different solid surfaces. They are (a) & (b) Tool 2 (c) &(d) Tool 3 (e) &(f) Tool 4.

IV. CONCLUSION

- Wettability test is an effective means for evaluating the compatibility of a cutting tool material towards a work piece material.
- Among coated inserts, the TiC coated tool has shown the highest affinity towards aluminum.
- TiN coated carbide insert is highly inert to aluminium.
- Wetting of Al_2O_3 by aluminum is promoted by their chemical interaction during the test.

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