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Low Temperature Properties of Hardmetals

Summary:

Hardmetals retain a good combination of properties at temperatures as low as that of liquid nitrogen. Hardness increases by about 20-30%. Toughness decreases by about the same amount in coarse grained tough hardmetals but is hardly changed in hard fine grained hardmetals.

Background:

Equipment operating in cryogenic environments is often required to be strong and hard wearing, for example bearings and mechanical seals in pumps and freezers which can be subjected to temperatures as low as -200°C. Many drilling operations that use hardmetal tools operate in sub-zero temperatures. There is thus a requirement for knowledge of the properties of hardmetals at low temperatures. There are no standards for measurements in this regime and data is difficult to obtain. This Measurement Note summarises hardness and Palmqvist toughness measurements (obtained from indentation tests) made on a range of WC/Co hardmetals with hardness values from 1000 to 1800 HV30 and previously published in a conference paper [1] in 1981 on the wider use of indentation tests.

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Introduction

For materials with low ductility such as hardmetals, hardness is frequently the only mechanical property measured by industry.

Toughness can be estimated from measurements of Palmqvist cracks. Even though it is not standardised the Palmqvist toughness method is widely used for measuring the fracture toughness of hardmetals because of its perceived apparent simplicity. It is a toughness value, W, obtained by measuring the crack lengths at the corners of a Vickers hardness indentation, either at a single load or from the inverse of the slope of a plot of crack length against load. Palmqvist cracking in hardmetals cannot be explained satisfactorily either in terms of crack geometry or crack length, by theories for growth of median vents in brittle materials or by other models. Nor can Palmqvist parameters be related intrinsically to the plane strain fracture toughness of the as-sintered materials, since the radial cracks grow during loading through material that has been strained by about 8% during the indentation process. Additionally, the cracks grow by about 50% when the indentation load is removed. However, a reasonable one-to-one empirical correlation between Palmqvist toughness and plane strain fracture toughness has been found for materials with toughnesses in the range 10-15 MN $m^{-3/2}$.

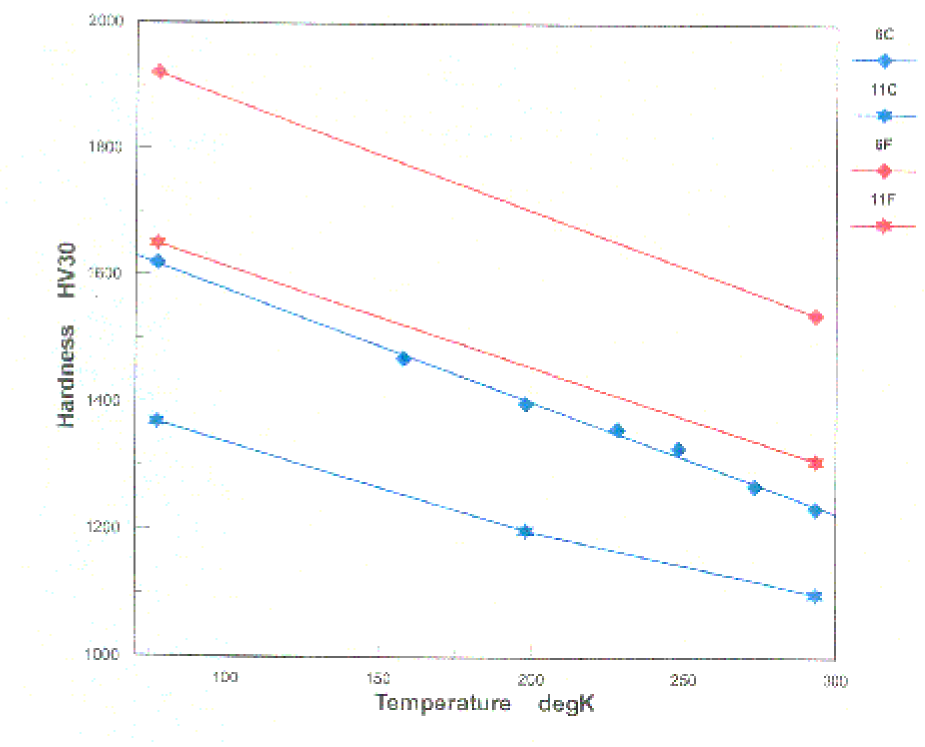

Figure 1: Variation of hardness with temperature for tests on 6F, 11F, 6C and 11C with Vickers indenter.

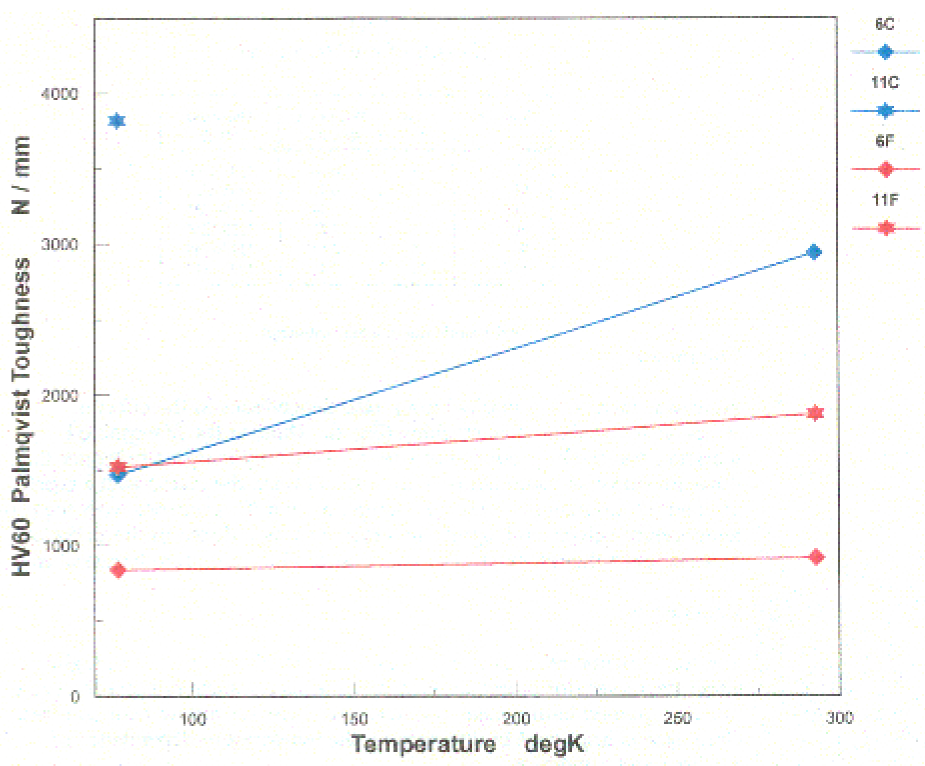

Figure 2: Variation of Palmqvist toughness with temperature.

Materials and Tests

The specimens were supplied as 5 x 6 x 20 mm rectangular blocks in the as-sintered condition (Table 1). They were diamond ground and lapped to a 1 μm finish. No graphite or eta-phase was present; the materials were of relatively high carbon content.

The tests were performed in a Vickers hardness testing machine with a loading cycle of 12 s using a diamond pyramid indenter. Indentation diagonals and crack lengths were measured optically at x500.

Hardness

Although hot hardness measurements have been used to assess high temperature properties of tool materials there is little information on the properties of hardmetals at temperatures below 0°C. In most metallic materials the resistance to plastic deformation increases and toughness decreases as the testing temperature is lowered. This was also found to be true for hardmetals, as can be seen in Fig. 1 for tests on the 6% and 11% Co/WC materials. The temperature dependence of hardness for the four hardmetals shown in Fig. 1 is in good agreement with that observed on a 10% Co/WC material [2]. It appears that the variation with temperature was not dependent on grain size or Co content.

Table 1: Details of the Hardmetals

Material	**Co wt %**	**WC grain-size, μm ***	**Hardness HV30**
6F	6	0.96	1535-1560
9F	9	0.93	1385-1420
11F	11	0.84	1305-1355
6C	6	3.21	1225-1245
9C	9	3.13	1120-1140
11C	11	3.47	1090-1115

* Arithmetic mean linear intercept

Toughness

However, there was a marked grain size dependence in the effect of temperature on Palmqvist cracking (Fig 2). Thus, in the fine-grained materials the cracks produced at -196 °C were only marginally longer than those produced at room temperature. In contrast, the cracks in the coarse-grained 6% Co material were 50% longer at -196°C compared with the room temperature values, and significant cracking was induced in the 11% Co material even though cracks could not be produced at room temperature.

Conclusion

The fundamental relevance of the results is that they show that toughness either decreases (for coarse grained hardmetals) or stays roughly the same (for fine grained hardmetals) and hardness increases at low temperatures. Grain size is important in determining the temperature dependence of cracking and toughness.

Acknowledgements

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References

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2. H Suzuki, T Tanase, F Nakayama and Y Hayashi. Low temperature transverse rupture strength of WC/Co cemented carbide. J. Jap. Soc. Powder Metall. 25, 1978, p 32ff.

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