Stiffness Moduli of Hardmetals

EHMG Collaborative Research Proposal – June 2010

50% Co funded by NPL

Presentation of the Project

Proposal

The Proposal has two objectives:

1) To conduct research using the standard impact excitation method on a wide range of hardmetal grades to quantify the effects of WC grain size and Co composition (carbon content) on the Young's Modulus (YM), Shear Modulus (SM) and Poisson's Ratio (PR) of hardmetals with Co contents between 5-30 wt% and grain sizes of 0.2-20 μm.
Deliverable 1: NPL report describing the results of testing and the levels of discrimination that impact excitation can achieve between hardmetal grades

2) To develop a table-top simple method using similar excitation principles, which can be delivered to project members for subsequent use with in-house measurements for future material development and quality control.
Deliverable 2: Supply to each project partner the complete table top equipment, (hardware and software), necessary for each project partner to carry out their own stiffness moduli measurements for production or development purposes. The data from deliverable 1 will provide calibration curves for microstructure-modulus relationships.

Introduction

Increasingly the performance of hardmetal components is being modelled using finite element packages that require mechanical data for their implementation. A fundamental requirement of these routines is knowledge of the stiffness properties, (Youngs Modulus, Shear Modulus, Poissons Ratio), of the relevant hardmetal grades. Also, in the recent EHMG Gigacycle fatigue project it was clear in the experimental design stage that accurate values of stiffness moduli would be needed to ensure the resonant testing system was correctly balanced. Some information exists [1-5] and Fig 1, but there is considerable scatter in the data, particularly at high Co contents. It is likely that a major contributory factor to this scatter is variability due to differences in Co binder phase composition (the amount of W in solution in particular will affect the stiffness of the binder phase) and WC grain size.

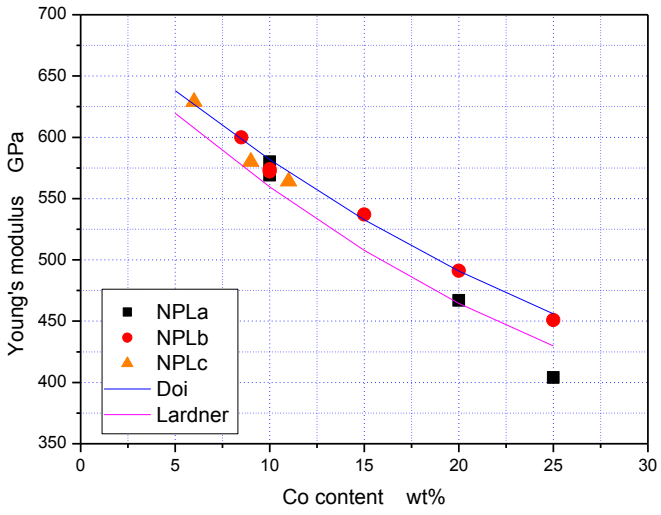

Figure 1 Basic data on Young's Modulus from references 2, 4, 5.

Therefore a systematic study of the effects of these variables would yield understanding that could be directly applicable to more accurate modelling of the mechanical behaviour of hardmetal components. Furthermore, the measurement of these properties will provide an additional tool to quantify the quality of production batches of material since the stiffness will also be sensitive to changes in chemistry and impurity content.

Dynamic methods of measurement, such as that based on impact excitation [1,4], are the most relevant techniques for material characterisation in this study and typical test pieces need to have one of two preferred shapes.

Disc	-	35 mm diameter, 2 mm thick
Rectangular Bar	-	80 mm long, 10 mm wide, 2 mm thick

It is essential that the dimensions are accurate to ± 0.01 mm and that surfaces are parallel to ± 0.02 mm. The disc should also be round to ± 0.02 mm. *Note however the aim below for use with non-standard geometries*. Test pieces must also be fully dense (e.g. sinterhipped).

There are also good prospects for developing a table-top modification to this method (the standard technique uses commercial equipment) that could be developed with simple hardware and software for use with a laboratory PC. As well as developing this method as a deliverable to participating project partners, additional studies would determine the accuracy and repeatability that could be achieved when **this table-top equipment is used for non-standard test piece shapes that might be more typical of industrial production**. There would also be scope for using materials from the microstructural study as reference materials for use with the table-top method.

Proposed Work plan

Participating industrial partners would provide suitable test pieces of a range of hardmetals with varying Co content (5-30 wt%), WC grain size (0.2-20 μm) and carbon content (across the two phase WC-Co region). This would be a significant in-kind contribution to the project (**WP0**).

WP1 NPL would measure the stiffness properties of these materials and characterise the microstructure. Stiffness would be measured using the impact excitation method [1]. WC grain size would be measured using EBSD. Co composition would be ascertained using magnetic moment values. Regression analysis would be used to calculate the dependency of stiffness on microstructural parameters. Probably at least 30 grades of material would need to be supplied by participating organisations to cover the range of microstructures required to ensure a good correlation of properties with structure. Measurement uncertainties would be established through accurate changes in test piece dimensions. A final NPL report for partners would be prepared.

WP2 NPL would develop the hardware (test piece support and transducer to detect test piece modes of vibration) and PC software to enable participating companies to subsequently make measurements of stiffness on their own materials. The materials from the principal study of the effects of microstructural variables will be used to validate this potential in-house method and quantify the dependency of the magnitude of uncertainties on test piece dimensions. A fully operating system will be provided to participating companies, for no additional cost. NPL would retain the IP for this system.

Proposed Project Timetable

It is anticipated that practical work in the project would commence after the Florence PM2010 meeting and be completed within one year. Both parts (microstructural study and measurement solution) will proceed in parallel. Two meetings with participants would be held, one approximately half way through to report on progress and one wind-up meeting at project completion. Work at partner organisations to prepare materials should start as soon as the project has sufficient members to meet the financial requirements.

Proposed Project Management

EHMG will oversee the project and ensure that NPL and partners meet their commitments. EHMG/EPMA will use various methods (web, etc) to ensure satisfactory dissemination of the project outcomes.

Proposed Project Costs

The final cost structure will clearly depend on how many participants can be persuaded of the benefits, but the overall cost of the work, including some final test piece shaping at NPL, will be £53k (ca. €64k), comprising:

- £29k (ca. €35k) for the microstructure/modulus study (WP1)

and

- £24k (ca. €29k) for completion of the development of the new software/hardware measurement option (some preliminary work has already been conducted on this method for metallic materials). (WP2)

The cost to each participating partner would be dependent on numbers taking part but the research will be **co-funded by NPL at about the 50% level** so the **overall cost of the project to the project partners would be halved to £26.5k (ca. €32k)** + £2.5k (ca. €3k) EPMA management fee = **£29k** (ca. **€35k**)** (plus VAT if applicable*).

** Non UK participants do not pay VAT provided they give their VAT number to the EPMA. UK participants have to pay VAT regardless and then reclaim it.*
*** Non UK Participants will be charged at the Euro rate relevant on the date of the invoice.*

The industrial participants will be responsible for the Selection and Manufacture of Test Specimens (WP0).

The participants would share equally the cost of the project. Thus, for example, eight partners would be required to contribute around ca. €4.4k each. The measurement option in the second part of the project would be provided as a benefit as a stand-alone facility to participating members. NPL would retain the IP and rights to sell the detector/software/PC package to non-participating organisations outside the EHMG community at a suitable price.

If you are interested in the project please sign and return to the EPMA the following Consortium Agreement.
If you are not an EPMA member or would like more information please contact Dr Olivier Coube, EPMA Technical Director, oc@epma.com

References:

1 ASTM C1259-01 Standard test method for dynamic Young's modulus, shear modulus and Poisson's ratio for advanced ceramics by impulse excitation of vibration: Annex A: Disc shaped specimens.
2 Doi, H., Fujiwara, Y., Miyake, K., Oosawa, Y., A systematic investigation of elastic moduli of WC-Co Alloys, *Met. Trans. A*, 1970, **1**(5), 1417-25.
3 Brookes, K.J.A., *World Directory and Handbook of Hardmetals and Hard Materials*, Int. Carbide Data, East Barnet, Herts, UK, 6th edition, 1996.
4 Morrell, R, Determining elastic moduli of hardmetals NPL Measurement Note, MATC (MN) 33, 2004.
5 Lardner, E and McGregor N B, Determination of elastic contants and stress/strain relationship to fracture of sintered tungsten carbide-cobalt alloys, *J Inst Met*, 80, 1951-2, 369-374

EPMA European Hard Materials Group
Stiffness Moduli of Hardmetals Project: Consortium Agreement
Issued June 2010

The Project - Stage 1 as defined in Annex 1
The Contractor – Materials Division NPL
The Members - **paid up corporate EPMA members*** funding the Project

UV = unanimous vote; MV = majority vote of 2/3 members or higher
Project Fee = full fee paid at start of Project Stage 1

Heads

1. The Members and Contractor agree to cooperate in order to complete the Project according to Annex 1.
2. All information generated under the Project will remain confidential to the Members during the Project and for one year after delivery of the final written report to Members, and may only be disclosed to third parties (e.g. for dissemination purpose in PM Congress) with UV.
3. The Contractor agrees to not carry out a similar project on hardmetals with organisations other than the Members until the completion of the project (delivery of the final report).
4. The Members agree to share equally the cost of the Project (GBP 29,000 / ca. EUR 35,000) through a Project Fee of maximum **GBP 7,250** / **ca. EUR 8,750** per Member, plus VAT if applicable, excluding the Work Package 0 (Selection and Manufacture of Test Specimens). The Members agree to share equally the cost of the Work Package 0 according to Annex 1, if necessary. The required minimum number of Members is **four** unless the Members agree to exceed the maximum Project Fee.
5. New paying members may be admitted during the Project by UV on payment of full Project Fee plus a reasonable premium (10%).
6. The terms of this agreement may be changed by UV.

Coordination will be by the EPMA, who will have responsibility for day to day liaison with the Contractors and keeping Members informed. The EPMA will operate under the same confidentiality agreement as Members and the EPMA President will be arbitrator for unresolved disputes.

Signatures: signed individually by all Members and Contractors

ORGANISATION:
VAT Number:
NAME:

(Date signed)

***If you are not an EPMA member please contact Dr Olivier Coube, EPMA Technical Director, oc@epma.com**

Annex 1: Work Packages in the Project: Stiffness Moduli of Hardmetals Project

1. WP 0 Selection and Manufacture of Test Specimens

Distribution of tasks:

- Selection of materials (between 24 and 32 grades with each partner to supply specimens from between 4 up to a maximum of 6 grades each)[1]: **all partners**
  It is expected that partners will supply standard grades but to obtain a sufficient spread of properties for validation of the method, the table in appendix needs to be populated evenly so early participants will have a greater choice of grades that can be supplied.
- Supply of material data: **Industrial Partners**
- Surface preparation: industrial partners to supply specimens ground to shape and blanks for common grinding route at NPL. **Industrial Partners**
- Measurement/supply of static properties: **Industrial Partners**
- Pre-test (if necessary) and final test samples shaping: **NPL**

Cost:
- Contribution by Members (industrial partners): cost not included here. If no agreement on in-kind contribution between the industrial partners can be found, the EPMA will coordinate the WP 0 and charge equally each Member to cover the cost of WP0 plus an administrative fee of 10%.

Estimated duration: Months1-4. **Deliverables**: Test samples (see presentation of the project)

2. WP 1 Measurement of the Stiffness Properties and Characterisation of the Microstructure

Distribution of tasks: NPL:

- Measurement of the WC grain size by EBSD
- Assessment of Co composition using magnetic moment values.
- Calculation of the dependency of stiffness on microstructural parameters.

Estimated duration: Months 2-9. **Deliverable**: Report for all grades, Meeting

3. WP 2 Development of Standalone Hardware/Software package to measure the stiffness

Distribution of tasks: NPL:

- Development of Hardware
- Development of Software
- Validation on all grades supplied above

Estimated duration: Months 3-11. **Deliverables**: Report on testing of grades supplied, Meeting. One stand-alone facility including PC, test jig and software per participant.

4. WP 3 Project Management and Reporting

Distribution of tasks:

- Project Management: **EPMA**
- Final Report: **EPMA + WP 0-2 Leaders**

Estimated duration: WP 0-3 + 1 Month for Report

5. Costs:

NPL: € 32,000 (WP 1 and WP 2) ; **EPMA**: ca. 10% Administrative cost of WP 0-2 (WP3 + Travels)
Total Cost: WP1-3 = € 35,000.- (plus VAT if applicable and WP 0)
Estimated total duration: ca. 12 Months

[1] Further grades can be measured at extra cost to be negotiated with NPL

Appendix 1

Approximate size ranges sought, with a range of carbon contents in each category, according to ISO 4499:

		WC grain size (μm mean linear intercept)				
Co Content (wt%)		Submicron (0.5 – 0.8)	Fine (0.8-1.3)	Medium (1.3-2.5)	Coarse (2.5-6.0)	UltraCoarse (>6)
	2-5					
	5-7					
	9-12					
	14-16					
	>20					