

Ultrasonic Fatigue Testing of Hardmetals in the gigacycle regime Project

UFTH Stage 3:

Extension of Stage 2a and Brazed Hardmetal-Steel Test Specimens

Consortium Agreement

Issued 25 April 2016

The Project – “UFTH Stage 3” as defined in Annex 1 and Annex 2

The Contractors –

- Institute of Chemical Technologies and Analytics, TU Wien, Getreidemarkt 9/164, A 1060 Vienna, Austria: **TUW**,
- CEIT Centro de Estudios e Investigaciones Técnicas de Gipuzkoa, Materials Department, Manuel Lardizabal Ibilbidea, 15 20008 Donostia-San Sebastián, Guipúzcoa, Spain: **CEIT**

The Coordinator –

- The European Powder Metallurgy Association, Talbot House, 2nd Floor , Market St., Shrewsbury SY1 1LG, England: **EPMA**

The Members - **paid up corporate EPMA members*** funding the Project

The Participants – **Paid up corporate EPMA Contractors*** and the Members

UV = unanimous vote of Members and Contractors; MV = majority vote of 2/3 members or higher

Heads

1. The Members and Contractors agree to cooperate in order to complete the Project according to Annex 1 and Annex 2.
2. All information generated under the Project will remain confidential to the Members during the Project and for FIVE (5) years 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 Contractors agree 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). The aforementioned obligation shall not apply to other entities of TUW other than to its performing entity Institute of Chemical Technologies and Analytics.

The Member is aware of the Contractors status as scientific research establishment, and, consequently, a generous attitude to publication shall be maintained. In order to ensure that no risk to potential patents is taken, however, no publication of any result from the

Project shall be made without the Members written consent, which will not be unreasonably withheld. A Contractor shall supply the Members with the manuscript of the intended publication, and, within four (4) weeks, the Members will respond with permission, or otherwise, to publish the manuscript either as is, or after suggested changes in content have been made. Failure of a Member to respond as specified will be considered as consent by default.

4. The Members agree **to share equally the cost of the Project** (EUR 25,800) through a Project Fee of maximum **EUR 8,600** per Member according to the Payment Schedule detailed in 8. The required minimum number of Members is **three** unless the Members agree to exceed the maximum Project Fee.
5. **VAT**: VAT will be added to the Project Fee as appropriate but may be reclaimed according to local arrangements (e.g. "Reverse Charge" mechanism). All VAT numbers are to be provided to the EPMA.
6. **UTFH results access premium**. New Members, who did not participate in all the UTFH Stage 1, UTFH Stage 1 Extension and UTFH Stage 2 and Stage 2a projects, may participate in the UTFH Stage 3 project by settling a "UTFH results access premium" of **EUR 30,000** at the start of the UTFH Stage 2a Project in addition to the UTFH Stage 3 project fee. The premium will be used to decrease the Project Fee for the UTFH Stage 3 Consortium Members.
7. The Members also undertake to provide the Contractors with the necessary test specimens and their appropriate surface preparations (Work Package 0 "WP 0"). 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%.
8. **Payment Schedule**:
For the Work Package 0 "WP 0": Full payment within one month after invoice if necessary.
For each other Work Package:
 - **50% at the start,**
 - **50% after completion** of the Work Package and delivery of the Work Package report.
9. New paying members may be admitted during the Project by UV on payment of full Project Fee plus the "UTFH results access premium" and an additional reasonable premium (10%). The premium will be used to decrease the Project Fee for the UTFH Stage 3 Consortium Members.
10. Except for the deliverables of the Annex 1 and Annex 2, each Participant will retain the Intellectual Property for any other outcomes of the project.
11. **Warranty**. The contractor's warranty extends solely to the use of due scientific diligence and to compliance with accepted engineering practice. The contractor does not guarantee that the desired objectives of the research and development project will be achieved.
12. **Liability**. The contractor is liable solely for wilful actions and gross negligence. Liability for proven damage is limited to the amount of the contractual sum.
13. Except for the term 4, all the terms of this agreement may be changed by UV.

Coordination will be by the EPMA, who will have responsibility for invoicing, 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:

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 Ultrasonic Fatigue Testing of Hardmetals in the gigacycle regime Project

Stage 3a-Extension of Stage 2a

In UFTH Stage 2a, a testing rig and procedure for ultrasonic fatigue testing by 3-point bending have been developed and built. However, it showed that the test specimens HM grade E10 delivered by the industrial partner had widely varying surface and edge quality, which was regarded as a probable reason for poorly reproducible results. In stage 3, the remaining samples from the UFTH 2a stage are to be repolished by the industrial partner, and defined edge geometry and quality will be established. After surface preparation, the specimens will be annealed for stress relieving following the standard procedure (at 800°C in vacuum).

The specimens thus produced will be characterized by SEM regarding surface and edge quality and, in case of sufficient quality, fatigue tested in 3PB at TUW. The data obtained will be compared to those measured for the same HM grade in push-pull.

WP 0 Selection and Surface Preparation of Test Specimens

Solutions will have to be found regarding the polishing steps and the annealing steps according to Item 7 of the Consortium Agreement.

Distribution of tasks: Industrial Partners

- Polishing of about 15 samples (to be defined): Industrial Partner
- Annealing of about 15 samples: Industrial Partner

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 WP 0 plus an administrative fee of 10% according to Item 7 of the Consortium Agreement.

Estimated duration: ca. 2-3 Months for WP0.

Deliverables: Polished and annealed test specimens

WP 3a: Extension of the UFTH Stage 2a-3PB (fatigue testing in 3-point bending)

Program:

Measurement of S-N curves – E10. Surface preparation: Ground Annealed and Polished, check of surface quality by SEM:

Distribution of tasks:

- Supply of material data: **Industrial Partners**
- Surface preparation: **See WP0**

- Measurement of residual stresses of 2 (E10 grade) samples after the polishing step:
CEIT
- Measurement of residual stresses of 2 (E10 grade) samples after the annealing step:
CEIT
- Gigacycle fatigue testing -> simplified S-N curve with 3 levels of Stress Amplitudes (High, Medium and Low) and reduced sample numbers: **TUW**
- Fractographic evaluation: **TUW**

Estimated duration of WP 3a:

ca. 6-7 Months in total

ca. 4 Months from samples delivery

Deliverables (TUW; CEIT):

- Final report
- Measurement data points (xls file)
- SEM images

Annex 2:

Work Packages in the Ultrasonic Fatigue Testing of Hardmetals in the gigacycle regime Project

Stage 3b-Brazed Hardmetal-Steel Test Specimens

In UFTH Stage 1-2, ultrasonic fatigue tests were carried out in push-pull mode using hourglass-shaped hardmetal test specimens. These tests were successful; however, specimen manufacturing proved to be tricky and very expensive since the hourglass shape could not be introduced through machining of presintered specimens to final shape but extensive grinding was necessary. Furthermore, introducing the M10x1 thread at one end also was not easy, although compensating for shrinkage during liquid phase sintering proved to be possible.

Since the fatigue loading is applied in the center section of the specimens and the ends, with a much larger diameter, are required only for amplifying the load, it is regarded feasible to use test specimens that contain a cylindrical hardmetal bar at the center and steel endpieces joined to the hardmetal bar, at best by brazing, hardmetal-steel brazing being state of the art.

In the proposed project, hardmetal bars (suggested: Sandvik grade SHM-C) are to be brazed to steel endpieces, and one of the endpieces shall have a thread M10x1 (external or internal) for coupling it to the resonance tester. For the endpieces, structural low alloy steel is to be used (42CrMo4 or similar). An FEM simulation of the specimen is shown in Fig.1 and sketches of the endpieces in Fig.2. This is one possible proposal for the shape; another one, with simpler endpiece geometry, is shown in Fig.3. The final endpiece geometry (or, if applicable, geometries) will be defined in discussion with the project partners.

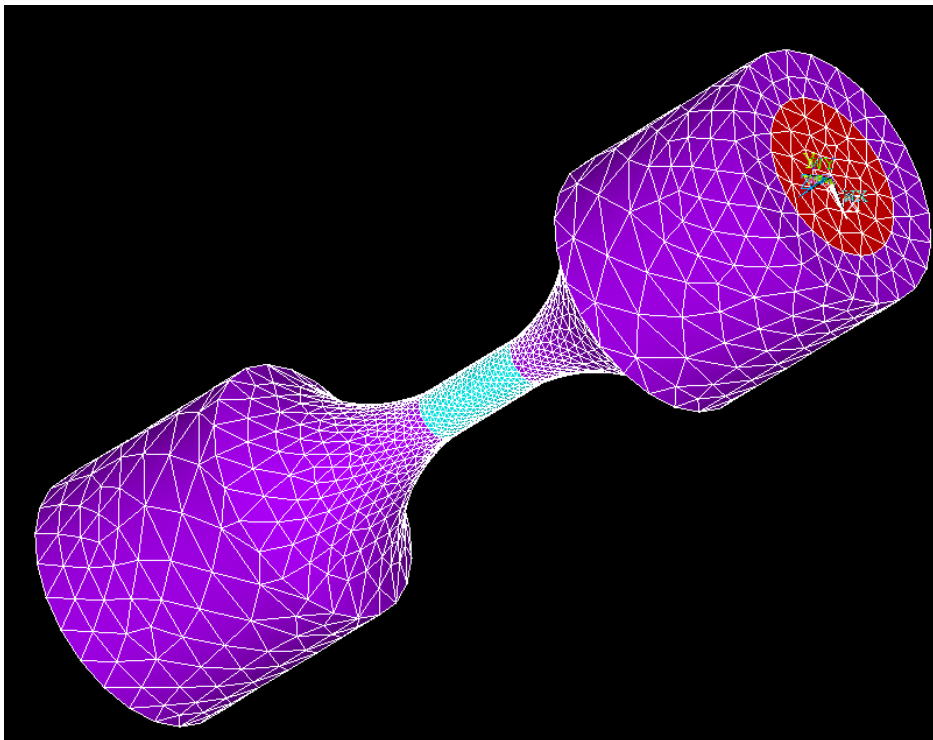


Fig.1: FE simulation of the hardmetal-steel resonance test specimen

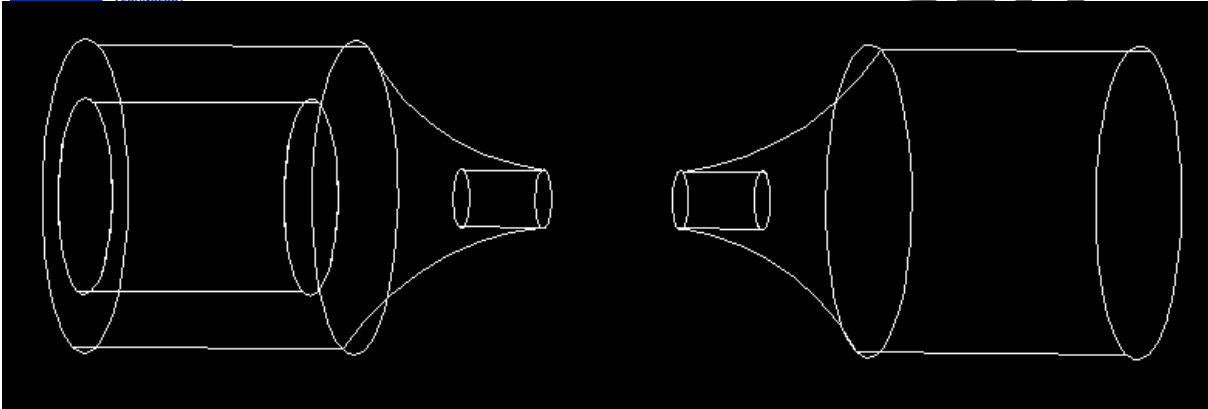


Fig.2: Sketches of the steel endpieces to be brazed to the cylindrical hardmetal bar (proposal)

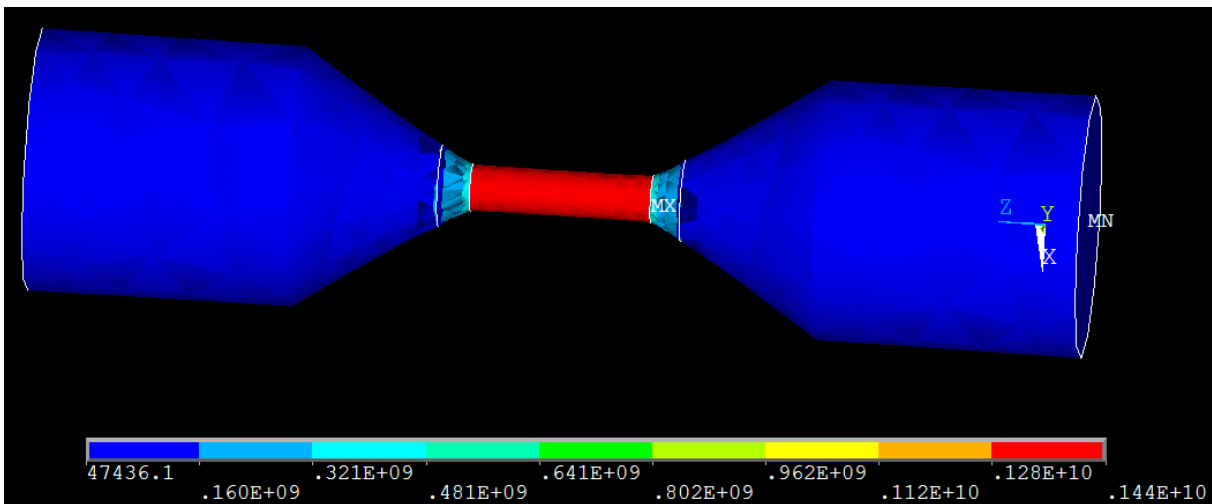


Fig.3: FE simulation of the hardmetal-steel resonance test specimen with simpler endpiece geometry

As evident esp. from Fig.3, the stress within the hardmetal rod is the same for the entire exposed length, right to the brazed joints. Therefore there might be some risk that the specimens will fail at the joint. In this case, the solution might be to introduce a slightly thinner section in the central part of the hardmetal rod (see Fig.4), which of course implies the questions of surface quality and residual stresses; in any case this grinding operation should be done before brazing.

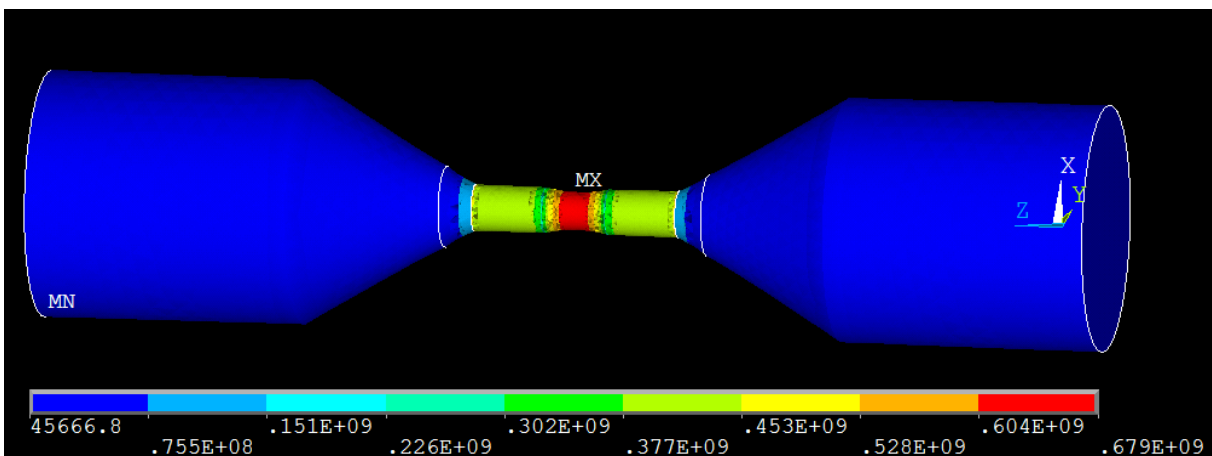


Fig.4: FE simulation of hardmetal-steel resonance test specimen with slightly thinner central gage section.

Here the expertise of the industrial partners is required to assess if any weakening effect of the brazing process on the hardmetal rod is to be expected; the geometry will be selected accordingly.

The machined endpieces will be brazed to the hardmetal rod, suitable brazing techniques being available at the partners. One important item is to avoid excessive wetting of the hardmetal rod by the liquid filler since this would necessitate expensive grinding and polishing of the surface (and possibly another annealing step).

The specimens thus produced will first be characterized regarding their resonance behaviour and, if necessary, machined to length for optimum resonating behaviour. Then they will be fatigue tested using the ultrasonic resonance tester and testing procedure employed in previous stages of UFTH, and the S-N curves obtained will be compared to those obtained with the full hardmetal SHM-C specimens. The fracture surfaces will be investigated by SEM.

WP 0 Preparation of Test Specimens

The cylindrical test bars (diameter 3 mm, length 28 mm) will be supplied by Sandvik (grade SHM-C) or another Industrial Participant. Solutions will have to be found regarding the manufacturing of the steel endpieces and the brazing according to Item 7 of the Consortium Agreement.

Distribution of tasks: Industrial Partners

- Manufacturing of endpieces for 30 specimens (final shape to be defined): Industrial Partner
- Brazing of endpieces to hardmetal rods: Industrial Partner

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 WP 0 plus an administrative fee of 10% according to Item 7 of the Consortium Agreement.

Estimated duration: ca. 2-3 months for WP0.

Deliverables: Brazed hardmetal-steel test specimens

WP 3b: Fatigue testing of the brazed specimens (fatigue testing in push-pull, R = -1)

Program:

Testing of the resonance behaviour of the test specimens; if necessary, final machining to optimum length.

Measurement of S-N curves – SHM-C. Surface preparation: as brazed, check of surface quality by SEM.

Distribution of tasks:

- Supply of material data: **Industrial Partners**
- Specimen preparation: **See WP0**
- Measurement of residual stresses of 4 (Sandvik grade SHM-C or equivalent) samples after the polishing step: **CEIT**

- Measurement of residual stresses of 4 (Sandvik grade SHM-C or equivalent) samples after the annealing step: **CEIT**
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- Gigacycle fatigue testing -> S-N curve with 4 levels of Stress Amplitudes: **TUW**
- Fractographic evaluation: **TUW**

Estimated duration of WP 3b:

ca. 6-7 Months in total

ca. 4 Months from samples delivery

Deliverables (TUW; CEIT):

- Final report
- Measurement data points (.xls file)
- SEM images

Overall Costs

Cost of WP3a:

- Contribution by industrial partners: cost not included here (WP 0)
- TUW: 6,500 €
- CEIT: 1,200 €
- EPMA Mngt fee: 1,400 €

Total Cost of WP 3a =

9,100 €

Cost of WP3b:

- Contribution by industrial partners: cost not included here (WP 0)
- TUW: 12,000 €
- CEIT: 2,400 €
- EPMA Mngt fee: 2,300€

Total Cost of WP 3b =

16,700 €

Total Cost of UFTH Stage 3:

25,800€