EPMA European Structural Parts Group

Correlation study of mechanical properties/microstructure/fracture behaviour of industrial parts and standardized tensile specimens.

"MicroTest"

Consortium Agreement

Issued October 2014

The Project – "MicroTest" as defined in Annex 1
The Contractors –

- Instituto IMDEA Materiales, C/ Eric Kandel, 2, Tecnogetafe, 28906, Getafe, Madrid (España): **IMDEA**

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 – The 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.
2. All information generated under the Project will remain confidential to the Members during the Project and for 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.

   For IMDEA: the contractor is obliged to publish in the usual scientific form the results of studies undertaken during performance of the project. The client gives their fundamental consent to such publication. The contractor will inform the client beforehand of any planned publication and will give them the opportunity of commenting on it within a reasonable period, at latest four (4) weeks after submission of the text intended for publication. A Member is entitled to refuse their consent to a publication if it is intended to publish company related data or, in connection with the granting of patent rights, if it is intended to publish any anticipatory information likely to constitute a bar to novelty. In such cases, the contracting parties will, without delay, seek to reach a special agreement governing the form and timing of rapid publication and taking due account of the legitimate interests of both parties.

3. The Contractors agree to not carry out a similar project on Correlation study of mechanical properties/microstructure/fracture behaviour of industrial parts and standardized tensile specimens with organisations other than the Members until completion of the project (delivery of the final report). The aforementioned obligation shall not apply to other entities of IMDEA other than its performing entity (Mechanical design and Metallurgy group) research group.

4. The Members agree **to share equally the cost of the Project** (EUR 40,000). The required minimum number of Members is **four** unless the Members agree to exceed the maximum Project Fee.
5. **VAT**: The Project Fee is excluding 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.
6. The Members also undertake to provide the Contractors with the necessary materials (powders, specimen etc...) for the project. If no agreement on in-kind contribution between the industrial partners can be found or if the Consortium agrees to subcontract it internally or externally at additional costs, the EPMA will coordinate this task "Work Package 0" and charge equally each Member to cover the cost plus an administrative fee of 13%.
7. **Payment Schedule:**
   For Work Package 0: Full payment within one month of invoice if necessary.
   For "MicroTest" project:
   - **50% at the start**,
   - **50% after completion** of the "MicroTest" Project and delivery of the final report.
8. New paying members may be admitted during the Project by UV on payment of an additional reasonable premium (10%). The premium will be used to decrease the Project Fee for the Consortium Members.
9. Except for the deliverables of Annex 1, each Participant will retain the Intellectual Property for any other outcomes of the Project.
10. **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.
11. **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.

All the terms of this agreement may be changed by UV, except for 4, 9 & 10.

Coordination will be undertaken 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 arbitrate any unresolved disputes.

Signatures: signed individually by all Members and Contractors

ORGANISATION:

VAT NUMBER:

NAME:

DATE:

SIGNATURE:

Annex 1

1. Overview of the proposal

The objective is to study the mechanical properties and the fracture behaviour (hardness and tensile features) in correlation with the microstructure using real parts produced in industrial conditions and standard specimens obtained in the same industrial conditions. **This project can be developed for conventional PM parts obtained in the Steel industry, as well as for parts made of different materials obtained by other PM technologies, such as Additive Manufacturing.**

The proposal can be focused in different components made of different raw materials. In case of steels, it could be different steels. In case of additive manufacturing, it could be interesting to analyse the size effect and for this purpose parts of different sizes could be proposed, and for different materials. Produced parts must be large enough to machine microspecimens.

All the existing data regarding the mechanical behaviour of sintered materials are based in test made on standard specimens, being the results extrapolated to the parts obtained with the same materials. To extract tensile samples from real parts is not an easy task, but today with the new machining techniques is feasible to get microtensile samples to be tested in micromachines and get a real tensile value from the real part.

2. Experimental proposal.

For the study, up to four different components can be proposed. In principle, four microtensile samples (see Figure 1) for each component will be manufactured by the industrial partners. Standard tensile test samples will also be manufactured in the same conditions by the industrial partners unless it is decided otherwise. Alternatively the microtensile samples could be produced by IMDEA at additional costs (ca. EUR 300 + VAT for 12 microtensile samples, see Item 6, “Work Package 0”).

A full study of mechanical properties will be done at two levels: microscale and standard scale. Microstructure and fracture surface will be also studied.

The study will have four different levels to approach:

1) In **situ tensile test** (inside the scanning electron microscope), where the initiation of the crack and it propagation can be monitored (and where can be seen the crack path during the test);

2) **The Digital Image Correlation** (DIC) technique, that allows to identify which individual microconstituent is contributing in the plastic deformation process when the material is loaded under a continuous axial stress, and to measure this value,

3) **Fracture surface** of the broken samples after the tensile test

4) **Tensile features** in standard samples.

Micro tensile bars will be used to analyse the fracture behaviour. The unusual gauge length forces to calculate the strain from the crosshead displacement. Tensile load will be applied with a rate of 10^{-3} s^{-1}. With these samples tensile tests will be made outside and inside a scanning electron microscope (SEM) (in situ tests). In all the tests will be measured the Yield Strength (YS), the Ultimate Tensile Strength (UTS) and the elongation (ε).

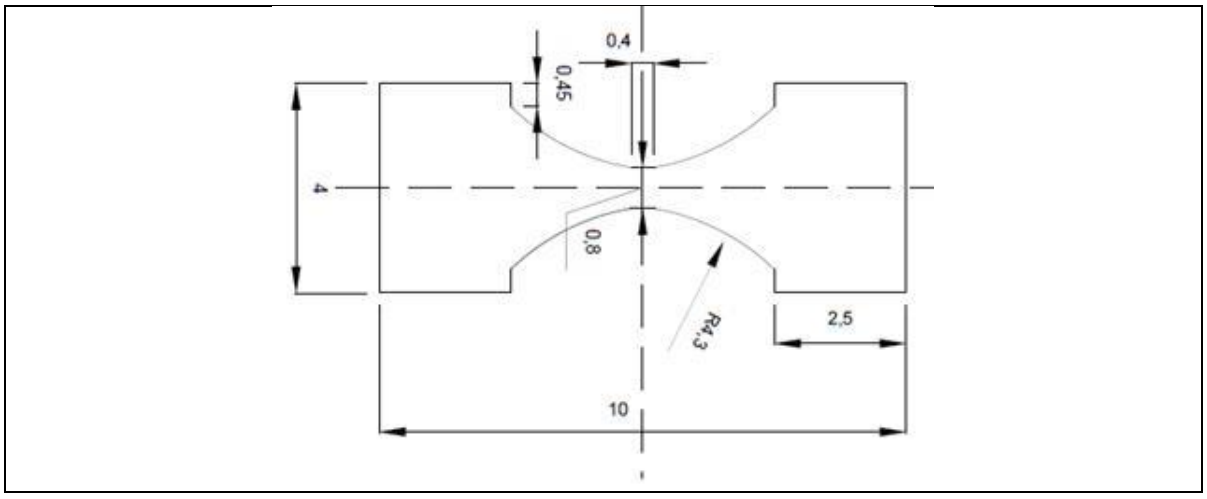

Figure 1. Sketch of the tensile specimen geometry (dimensions are in mm). Thickness: 1mm

To analyse the origin and the crack propagation in the in situ tests, the application of the load will be stopped at different levels of strain to have different images. In the case of

the DIC analysis (explained bellow), all the images for the analysis will be taken after releasing the load for the selected specific strains.

In DIC we can obtain deformation maps associated with the different phases or microconstituents that are present in the microstructure. From the starting microstructure and taking as reference different points in the surface of the specimen, the displacement correlation in DIC is based in the movement of those key points, tracked and compared with the initial position. When the sample is submitted to a tensile stress, after certain level of strain, we can track, by comparison, the plastic deformation level once the stress is relaxed and by comparison with the microstructure with the original one (through the displacement of the key points). The accuracy of the method will be related with two different parameters: from one side, the size of the key-point (than can be of some µm in size till some hundreds of µm) and on the other size, the distance of the measured images to the place where fracture takes places at the end of the test (that also can be of a few µm or much more). In [i] it is explained the technical principles where DIC is based. The study is completed with a fractographic analysis on the fresh fracture produced after a tensile test in each material, using SEM.

3. Description of Work

Tasks (for 3 different components made of 3 different raw materials):

Task 1: Definition of experimental plan

Distribution of tasks: All partners**.**
Estimated duration: 1 month

Task 2: Delivery of components. Production of microtensile and standard samples (including machining).

Distribution of tasks: All partners + possible subcontracting (“Work Package 0”)
Estimated duration: 2-4 months

Task 3: Mechanical test on microsamples and standart samples.

Distribution of tasks: IMDEA Materials Institute
Estimated duration: 3-4 months

Task 4: Microstructural study and fractography study.

Distribution of tasks: IMDEA Materials Institute

Estimated duration: 2 months .

Task 5: In situ tests and plastic deformation maps.

Distribution of tasks: IMDEA Materials Institute
Estimated duration: 3 months

Task 6: Project Management.

Distribution of tasks: IMDEA Materials Institute + EPMA

Two or three meetings with all contractors will be held, a kick-off meeting, one approximately half way through to report on progress (if necessary) and one wind-up meeting at project completion.

Project Management: EPMA
Final Report: EPMA + Institute IMDEA Materials

Estimated duration: Task 1-5 + 1 Month for Report

Total project duration: 12 Months (overlapping tasks)

4. Costs

Total Costs: €40,000 (including €4000 EPMA Management Fee) + possible "Work Package 0" costs (Subcontracting of microtensile samples manufacture)
Estimated total duration: ca. 12 Months

[i] R. Cintrón and V. Saouma."Strain Measurements with the Digital Image Correlation System Vic-2D" in: CU-NEES-08-06, Center for Fast Hybrid Testing, University of Colorado, 2008.