EPMA European structural parts group

Club project proposal

ANalysis of DamagE in PM Steel components

(ANDES)

FUNDACION IMDEA MATERIALES

ANalysis of DamagE in PM Steel components
(ANDES)
Consortium Agreement

Issued November 2017

The Project – '**ANDES'** 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 corporate EPMA members funding the Project

The Participants – Paid corporate EPMA Contractors and the Members

The Coordinator and each of the Participants are individually referred to as a '**Party**' and jointly as the '**Parties**'.

UV = unanimous vote of Members and Contractors.

Heads

1. The Members and Contractors agree to cooperate in order to complete the Project according to Annex 1.

2. The Parties undertake for the duration of the Project and for a period of five years after the delivery of the final written report to the Members, to hold in confidence all confidential information (as defined below) disclosed by either Party to the other and to refrain from disclosing confidential information to any third party. Confidential information shall only be disclosed when necessary for the performance of the Project and subject to 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.

Confidential information shall include all technical, financial and business information regarding the Parties and their subsidiaries, as well as their products, processes, production methods and techniques (including metal powder samples), provided that confidential information shall not include:

(i) information which was known by the receiving Party at the time of disclosure as shown by written record to this effect;

(ii) information which at the time of disclosure is in the public domain or which is published after disclosure or otherwise becomes part of the public domain through no fault of the receiving

Party;

(iii) information which the receiving Party can show was received by it from a third party who did not, to the best knowledge of the receiving Party, acquire the information, directly or indirectly, from the other Party under an obligation of confidence

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3. The Contractors agree to refrain from carrying out similar consortium projects on ANalysis of DamagE in PM Steel components with organisations other than the Members until completion of the Project (delivery of the final report). For the avoidance doubt this section shall not in any way restrict the Contractors in their day to day business operations.

4. The Members agree **to share equally the total Project fee** of EUR 60 000. The required minimum number of Members is **four** unless the Members agree to exceed the **maximum Individual Project Fee of EUR 15000 per Member.**

5. 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 other Consortium Members.

6. 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.

7. The Members also undertake to provide the Contractors with the necessary powder materials for the Project. If no agreement on the in-kind contribution can be made between the Participants, each Member is free to withdraw from the Project. If the Consortium agrees to subcontract the in-kind internally or externally at additional costs, the EPMA will coordinate this task and charge equally each Member to cover the cost plus an administrative fee of 15%.

8. **Payment Schedule:**
   - 50% at the start of the “ANDES” Project,
   - 50% after completion of the “ANDES” Project and delivery of the final report of the Part.

9. **IPR** relates to all results in the form of technical information, know-how and intellectual or industrial property rights, including but not limited to patents, models, designs, copyright, trade secrets and rights in unpatented know-how. “Foreground IPR” means any IPR arising or resulting from the Project. Foreground IPR shall be the property of the Party performing the work generating the Foreground IPR. Should several Parties have contributed to the results – then the IPR shall be the property of the Party who has predominantly contributed to such result. Each Member is granted a global, perpetual, royalty free license to freely use any and all Foreground IPR (including the right to change, alter, amend and sub- license such Foreground IPR). Background IPR means any IPR owned or controlled by

a Party at the date of signature of this agreement or developed and/or acquired independently of this agreement. Background IPR shall remain the exclusive property of the Party providing such information. For the avoidance of doubt, no license rights are granted regarding Background IPR through this agreement.

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 for negligence. The Contractor's liability covers the proven damage. Each Member is liable for negligence. Each Members' liability shall be limited to an amount equal to such Member's Individual Project Fee.

All the terms of this agreement may be changed by UV, except for 2, 4, 10 & 11.
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:

DATE:

SIGNATURE:

Annex 1

ANalysis of DamagE in PM Steel components (ANDES)

1. OBJECTIVES

The aim of this project is to carry out a systematic analysis of the evolution of damage in a component manufactured using a powder metallurgy (PM) route. This project can be developed for conventional parts utilized in the steel industry or for a component made by additive manufacturing.

The material under investigation will be a PM Distaloy AB with 0.6% Carbon content. Samples with different density and heat treatment will be considered. Damage will be investigated under both tensile and compressive stresses at room temperature. The damage will be evaluated as a function of the plastic strain, estimated by digital image correlation (DIC), and these data will serve as inputs for the development of a continuum numerical modelling (UMAT), which could later be utilized as a predictive tool.

2. DURATION OF THE RESEARCH PROJECT

The duration of the project will be **18 months.**

3. WORK PLAN

The research activities will be divided in 3 Work Packages (WPs).

WP1 Characterization of the starting material (Distaloy AB with 0.6% C content) (M1-3)

Three as-received materials, with different density and pore distributions will be considered in this research project. In addition, one of these as-received materials (to be determined) will be subjected to two different heat treatments. The microstructure and properties of the as-received

materials will be characterized exhaustively at selected locations using several complementary techniques. In particular, the following properties and features will be measured.

- *Density.* The Archimedes method will be utilized to measure this property. It will be measured in the cross section (without gripping heads) since the density distribution is not homogeneous.
- *Hardness.* A Shimadzu microhardness indenter will be utilized to measure hardness at selected locations. An average value will be estimated from at least 10 measurements at each location.
- *Microstructure.* The size and shape of grains, as well as the distribution of different phases will be examined by optical and scanning electron microscopy, in samples etched using the appropriate chemical solution.
- *Residual stress.* A Panalytical X-ray diffractometer, furnished with an open Eulerian cradle, will be utilized to measure residual stresses at the locations of interest.

WP2 Analysis of the evolution of damage at room temperature (M4-12)

The evolution of damage at room temperature will be evaluated by the Chaboche-Lemaitre damage concept. This method consists on repeated loading and unloading steps in order to determine the degradation of the elastic modulus with strain. The damage is then estimated based on the variation of the elastic modulus. The strain will be precisely measured considering the digital image correlation (DIC) procedure. Some additional strain measurement using strain gauges for comparison will be also performed. In order to analyze the reproducibility of the mechanical tests and the evolution of damage, five tests will be carried out in tension and compression at room temperature and strain rate of 10^{-3} s^{-1}.

Tensile and compressive tests will be performed in a Kammrath-Weiss micromachine and an electromechanical testing machine (INSTRON 3384) respectively, both available at IMDEA Materials.

The evolution of damage will be measured both in standard samples provided by Höganas as well as in tensile samples machined from selected locations of the PM components under investigation. Tensile specimens will be machined with the following geometry:

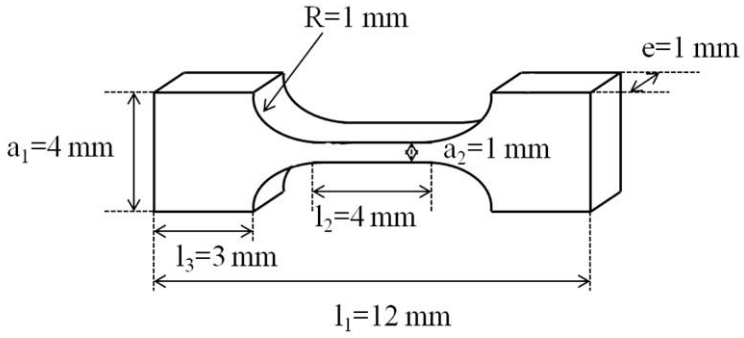

Fig. 1 Dimensions (in mm) of the tensile specimens.

Cylindrical compression samples will be machined with the following geometry:

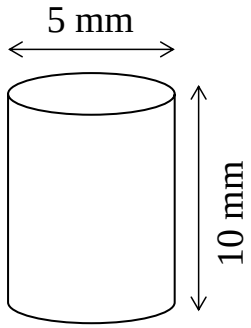

Fig. 2 Dimensions (in mm) of the compression specimens.

In order to minimize friction stresses, additional compression tests considering the Rastagaev specimen with a lubricant reservoir will be also performed for comparison. The best geometry will be selected for the next compression tests.

Prior to testing, the density of all coupons will be measured by the Archimedes method.

WP3 Finite element modeling of damage evolution (M12-18)

After carrying all the experimental campaign, the damage evolution study will be extended to a simulation study by finite element modeling. An existing constitutive model of the ABAQUS material library will be used. The model will be based on the J2 plasticity with damage. The model will

be adjusted based on the experimental results. An effort will be made so that the results may be easily transferrable to other FE products such as Ansys or Nastran.

WP4 Project Management and Reporting (M1-18)
The Project Management will be supported by EPMA. The intermediates and final report will be written by IMDEA. Intermediate reports will be send every 4 months to the Consortium by IMDEA.

Three meetings are foreseen for the ANDES project: A kick-off meeting, An intermediate review meeting and a final meeting.

Additional meetings and teleconferences shall be organized if needed.

4. RESEARCH CONDITIONS AT IMDEA MATERIALS

IMDEA Materials Institute (Madrid Institute for Advanced Studies of Materials) is a non-profit research institute, promoted by the regional government of Madrid, to carry out the top research in Materials Science and Engineering in Spain. IMDEA Materials Institute is committed to excellence in research and to foster technology transfer to the industrial sector in a truly international environment. More information about the research and scope of the activities of IMDEA Materials Institute can be found at the institute webpage: http://www.materials.imdea.org

The institute is a multidisciplinary and international research center with expertise in areas such as design of advanced metals, metals processing, metals microstructure and property characterization, etc. All this expertise will be available to the project. The task force for this project will comprise one postdoc researcher, one senior research associate and one senior researcher.

5. PERSONNEL INVOLVED IN THE PROJECT

- **Principal investigator: Dr. Teresa Perez-Prado, (F)** is a Senior Researcher at IMDEA Materials Institute since September 2008, where she leads the research group on Physical Metallurgy. Since 2014 she

additionally heads the institute´s programme on Alloy Design, Processing and Development. Her current research interests involve applied and fundamental work on the processing, characterization and mechanical behavior of advanced metallic materials for transport, energy and biomedical applications. Since 2001 she has worked on the processing and physical metallurgy of novel Mg alloys for light transportation, developing novel routes for grain refinement in Mg alloys by severe plastic deformation techniques and investigating the microscopic deformation mechanisms operative at a wide range of strain rates. Her latest research involved 3D and in-situ characterization of the microstructure and mechanical behavior of metals. She has published 102 papers in peer reviewed international journals, which have been cited more than 3700 times. Her h factor is 31 (Source: Google Scholar). She also published 1 book ("Five power law creep in metals and alloys", Kassner and Pérez-Prado, Elsevier, 2004) and has 3 patents. She is a member of the international advisory board of several top international conferences, such as ICSAM, ICSMA, THERMEC and is regularly requested to give keynote and invited lectures at international conferences in the field. She has led 14 projects and has supervised 5 PhD thesis.

Dr. Pérez-Prado will be principal investigator (PI) of the present project.

- **Senior Research Associate**: **Dr. Carmen Cepeda-Jiménez, (F)** is Research Associate at IMDEA Materials Institute since 2013. She has held post-doctoral positions at the Department of Physical Metallurgy at the National Centre for Metallurgical Research (CENIM-CSIC), and at CELME company (Alicante, Spain) as head of the R+D+I department. She has participated in different research lines, all of them with the aim of optimizing mechanical properties of metallic materials (Al and Mg alloys, Ti6Al4V, steel) by new processing routes and its advanced characterization. She has developed wide experience in the study of deformation mechanisms of metallic materials under different testing conditions. Dr. Cepeda-Jiménez has published 56 papers in peer reviewed international journals on these topics, 25+ publications in the area of processing of high-strength aluminum alloys for aerospace applications, and holds a h-index of 16. She has participated in 14 research projects funded both by national and international agencies. Dr. Cepeda is

supervising 1 PhD thesis and has also supervised 4 undergraduate and master´s theses.

Dr. Cepeda-Jiménez will be co-PI of the present project.

External consultant: **Prof. J.M. Torralba, (M)**, currently General Director of Universities at the Madrid Regional Government, was formerly Deputy Director of IMDEA Materials Institute between 2008 and 2015, and Professor at the Carlos III University for 22 years. He is a world recognized expert in powder metallurgy. He has published more than 500 papers on this area, has advised 22 PhD theses and has acted as principal investigator in 20 research projects. Prof. Torralba will provide guidance to the researchers involved in the project and will participate in the project meetings that take place in Madrid in order to contribute to the discussion and analysis of the obtained results.

6. BUDGET

The total cost of the project will be 60000 euro. The budgets for each WP are, accordingly, €18K (WP1), €20K (WP2), and €15K (WP3) so in total €53K for IMDEA. EPMA Management fees (ca.13%): €7K