Institut für Anwendungstechnik Pulvermetallurgie und Keramik an der RWTH Aachen e.V.

EPMA european powder metallurgy association

EPMA EuroHIP - EuroAM

Combination of Additive Manufacturing and HIP
Project NAME: "AM&HIP 18"

Consortium Agreement

Issued October 2017

Please note this document is a draft and the included points will be raised and discussed at the Kick-Off meeting to ensure all participants agree.

The Project – "**AM&HIP 18**" as defined in Annex 1

The Contractors –

„Institut für Anwendungstechnik Pulvermetallurgie und Keramik an der RWTH Aachen e. V. Augustinerbach 4, 52062 Aachen": IAPK

The Coordinator – The European Powder Metallurgy Association 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;

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 Participants and Coordinator 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.

3. For **IAPK**: Under the relevant provisions of the Universities Act NRW (Hochschulgesetz NRW), the contractor is obliged to publish in the usual scientific form the results of studies undertaken during performance of the project. The contractor will inform the Members beforehand of any planned publication and will give him the opportunity of commenting upon it within a reasonable period, at latest ten (10) weeks after submission of the text intended for publication. A Member is entitled to refuse his consent to a publication if it is intended to publish company related data or 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.

4. The Contractor agree to not carry out a "AM&HIP 18" project 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 RWTH other than its performing entity IWM.

5. The Members agree to share equally the cost of the whole "AM&HIP 18" Project (EUR 63.716), excluding a possible Work Package 0 as detailed in 7, through a Project Fee of maximum EUR 21.238 per Member according to the Payment Schedule detailed in 8. The required minimum number of Members is 3 unless the Members agree to exceed the maximum Project Fee.

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 materials (powders, specimen etc...) for the project. If no agreement on in-kind contribution between the members can be found, the EPMA will coordinate this task “Work Package 0” and equally charge each Member to cover the cost plus an administrative fee of 15%. The Work Package 0 total amount should not exceed EUR 5.000 per Member.

8. **Payment Schedule**:
   For the Work Package 0: Full payment within one month after invoice if necessary.
   For the “***AM&HIP 18***” project:
   - **50% at the start**,
   - **50% after completion** of the “***AM&HIP 18***” project and delivery of the final report.

9. New paying members may be admitted during the Project by UV and by payment of an additional reasonable premium (10%) regardless Head 5. The premium will be used to decrease the Project Fee for the Consortium Members.

10. Except for the deliverables of the Annex 1, each Participant will retain the Intellectual Property for any other outcomes of the project. The Contractors should get the right to use the Intellectual Property for internal research only.

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 direct damage is limited to the amount of the contractual sum received by Contractor under this Agreement. For the avoidance of doubt the Contractor shall not be liable for any indirect or consequential loss. The Member is not liable for this project.

13. Coordination will be carried out 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 by the Members. Should the Parties fail to resolve a dispute, then such dispute shall be subject to the exclusive jurisdiction of the English Courts. The laws of England and Wales govern all matters arising out of or relating to this agreement, and all transactions contemplated hereby, including, without limitation, its validity, interpretation, construction, performance and enforcement.

14. Except for the terms 11 all the terms of this agreement may be changed by UV.

Signatures: **signed individually by all Members and Contractors**

ORGANISATION:

VAT Number:

NAME:

(Date signed)

***If you are not an EPMA member please contact Dr Lionel Aboussouan, EPMA’s Executive Director, la@epma.com**

Annex 1

EPMA EuroHIP - EuroAM

Project NAME:

"AM&HIP 18"

Project Description

In the last decade, the interests concerning Additive Manufacturing (AM) processes have increased. One of the most common procedures for metals is Selective Laser Melting (SLM). Based on CAD data, a laser melts the desired structure layer-wise in a powder bed [1]. In this operation, one essential part is the setting of the laser. Parameters like laser power, laser focus, and scan speed have a direct influence on the properties [2]. Numerous investigations concerning the influence of the process settings on the final properties are published [3–6]. Also, the initial properties of the powder are an important factor in SLM. Especially, the powder size distribution and the shape of the powder influence the setting of the process [7].

For stainless steels, optimized laser-scanning strategies enable the production of components with high densities between 98 % and 100 % [8].

Regarding the mechanical properties, both yield strength and tensile strength are comparable to conventional produced samples, only the ductility is significantly lower [9]. Depending on the material and stress mode, even a low remaining porosity can have a major influence on the resistance against cyclic loads [10, 11]. A post-processing, like Hot Isostatic Pressing (HIP), could close the remaining porosity and could increase the reliability and predictability of the mechanical behavior of SLM components.

Objectives

- Identification of a set of HIP parameters to obtain full density and optimal mechanical properties in components produced by SLM
- Determination of the increase in fatigue strength that can be obtained by adding a HIP cycle to the SLM-process
- Optimization of the entire process chain: SLM + HIP in order to get a solution with minimum process costs and maximum performance regarding mechanical properties

Benefits for the industrial partners

The costs for SLM scale with the scanning speed of the laser beam. The speed can be increased when no full density is required. On the other side post densification by HIP gives full density. Combination of SLM + HIP gives a potential for an optimum in terms of production costs.

Work Packages descriptions

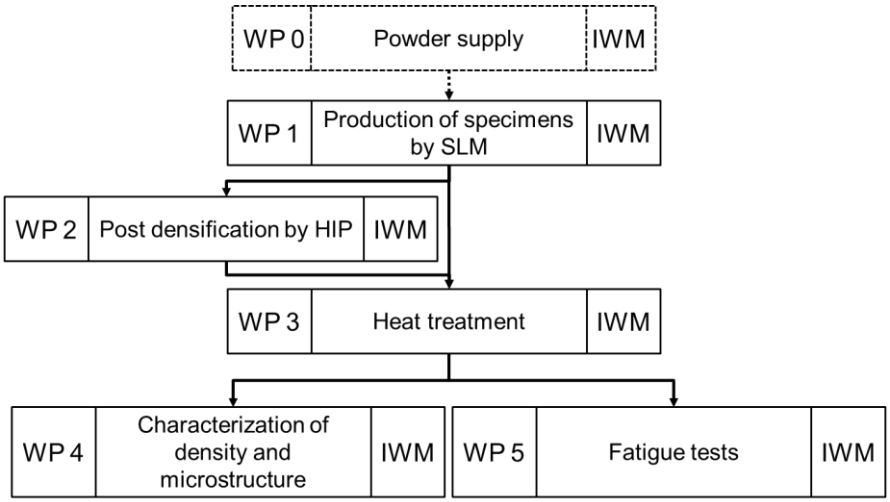

Figure 1. Work packages of AM&HIP18

WP0. Powder supply

In Work package 0, two different metal grades are defined for the testing procedure. Materials produced under industrial condition should be tested. The specification of the material is done by the industrial consortium, e.g. 17-4PH, IN718 and ASTM F75.

Thus, the companies involved in the project consortium should produce and deliver powder of the specific material. The involved companies should also deliver reference material in the as-cast or as-forged state. If that is not possible, the necessary powder and reference material will be purchased.

WP1. Production of specimens by SLM

In Work package 1, an iterative identification of optimal SLM-parameters (like laser power, laser focus, scanning speed, and hatch strategy) is performed by the production of cube shaped specimens. The scanning parameters are defined for the support structure, outer boundaries, and inner areas.

- Production of cube shaped specimens with different density due to variation of SLM-parameters
- Production of specimens for fatigue tests (rotating-bending-tests). The building axis is parallel to the sample axis. The SLM specimens are machined to the final sample geometry, assuring equal surface quality for all samples.

WP2. Post densification by HIP

In Work Package 2, twelve different HIP cycles (six HIP cycles per material grade) are conducted with variations of pressure, temperature and dwell time, in order to identify a set of HIP parameters to obtain full density and optimal mechanical properties combined with minimum process costs.

WP3. Heat treatment

In Work package 3, all samples are heat-treated. The thermal cycles are planned and conducted at IAPK or facilities of the involved companies. Regarding comparability, the samples of chemical identical materials should be heat treated at the same facility.

WP4. Characterization of density and microstructure

Work package 4 focuses on characterization of density and microstructure. The characterization is carried out after “SLM”, after “SLM + thermal treatment” and after “SLM + HIP + thermal treatment”. The density is measured by He-pycnometry and Archimedes’ principle. Additionally, the porosity is characterized by image analysis of cross section. The microstructure is determined by etching and light microscopic images.

WP5. Fatigue tests

In Work package 5, the fatigue behavior of different conditions is determined. Rotating bending tests are conducted with stress ration of R = -1. For each conditions “SLM + heat treatment” and “SLM + HIP + heat treatment” one S-N-diagram is calculated, as well one for the reference state (as-cast or as-forged). In addition, the identification of crack origins in the fatigue fracture surface is done by SEM analysis. In total, 6 S-N-diagrams (Wöhler-curve) will be determined, with 30 specimen each.

Work package time planning

Duration of the project: **10 months**

		month									
		1	2	3	4	5	6	7	8	9	10
WP0	Powder supply										
WP1	Production of specimens by SLM										
WP2	Post densification by HIP										
WP3	Heat treatment										
WP4	Characterization of density and microstructure										
WP5	Fatigue tests										
Reporting		KM					IM				FM

KM: Kick-off meeting, **IM**: Interim Meeting, **FM**: Final Meeting

References:

[1] Yap CY, Chua CK, Dong ZL, Liu ZH, Zhang DQ, Loh LE et al. Review of selective laser melting: Materials and applications. Appl. Phys. Rev. 2015;2(4):41101.
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[3] J.-P. Kruth, M. Badrossamay, E.Yasa, J. Deckers, L. Thijs, J. Van Humbeeck. Part and material properties in selective laser melting of metals.
[4] Antony K, Arivazhagan N, Senthilkumaran K. Numerical and experimental investigations on laser melting of stainless steel 316L metal powders. Journal of Manufacturing Processes 2014;16(3):345–55.
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