Proposition for a Club Project on Environmental Health and Safety Issues in Laser-based Powder Bed Fusion (LB-PBF)  
“PBF-EHS”

Overview of the proposal

Laser-based Powder Bed Fusion is the most common and industrially successful additive manufacturing technology for metals. The metal powders used in the process pose hazards that are already known: dust exposure, explosion risk, fire hazard and the risk of suffocation (Table 1).

<table>
<thead>
<tr>
<th>Dust exposure</th>
<th>Explosion risk</th>
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<tbody>
<tr>
<td>Risk of contamination with powder particles through:</td>
<td>Possible ignition of airborne metal powders or welding fumes/condensate</td>
</tr>
<tr>
<td>▪ Contact with skin and eyes</td>
<td>▪ Critical for alloys containing large amounts of Mg, Al, and Ti</td>
</tr>
<tr>
<td>▪ Aspiration</td>
<td>▪ Other alloys may still be critical</td>
</tr>
<tr>
<td>▪ Substances which are carcinogenic, mutagenic and toxic to reproduction</td>
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<table>
<thead>
<tr>
<th>Fire hazard</th>
<th>Risk of suffocation</th>
</tr>
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<tbody>
<tr>
<td>▪ Metal powders represent a high fire load</td>
<td>▪ Shielding gases can have a choking effect</td>
</tr>
<tr>
<td>▪ Hard to extinguish once at fire</td>
<td>▪ Especially critical when machines are placed in small rooms</td>
</tr>
<tr>
<td>▪ Regulations and laws on fire protection are regionally very different</td>
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</table>

Table 1: Important hazards connected to AM/PBF

Nevertheless, the actual contaminations and resulting EHS risks are not publicly known. Moreover, regulations and standards, especially on safety values, are not available on European level. For this reason, companies and research institutions have no possibility to follow general recommendations on the handling of EHS-equipment, hazardous substances and processes.

Therefore, this project aims to aggregate available information on EHS-procedures and regulations in order to derive recommendations on EHS-equipment and procedures. For this purpose, standards from the fields of welding and other powder technologies such as MIM or PIM are also examined. In this way, the question of whether the regulations and standards applicable for LPBF in companies need to be extended, supplemented or changed will be investigated.

Laser-based Powder Bed Fusion of metals will be in focus, but other processes (e.g. powder-DED or E-PBF of metals) may be considered if explicitly requested by the consortium.
With the results of the study, the partners of the consortium have an overview of various challenges along the process chain. Here, examples of daily challenges for industry and research in the LB-PBF process chain are described:

- In the pre-process, for example, dusts can be whirled up during powder preparation. Therefore, powder could be inhaled or an explosive dust atmosphere can be created.
- During the in-process consisting of production process, the removal of the components and the recycling of the powder, welding fume is often an issue is an important topic.
- In the post-process the removal of the remaining powder in complex components with support is a central point to avoid contaminations outside the AM-workshop.

For this reason, the necessary checklists, limit values and associated safety solutions for project partners are drawn up. Eventually, objectives and deliverables of the project are:

- Project report including recommendations on safety procedures and safety equipment concerning dust exposure, gas monitoring, fume exhaust, material handling and static electricity (exclusively for partners)
- Aggregated list of relevant safety standards (available to the public)
- Description of different requirements necessary for practical and industrial use of LB-PBF

Work packages:

1. **Analysis of standards and regulations on EHS available in German and English language** – 2 months

Fraunhofer IGCV analyzes the standards and regulatory aspects that are available in English (e.g. ISO/ASTM WD 52932) and German language (e.g. TRGS 402, DGUV, VDI 3405) as well as other, non-binding sources (e.g. BAD). If the consortium is interested, regulations in other languages and from other countries like France, Italy or Sweden (e.g. AFS 2011:18) can be included. The selection of the additionally examined countries depends on the committee. If more than one additional country is selected, the budget must be adjusted.

Especially standards and regulations are used which also apply to welding or other powder technologies such as MIM or PIM. The members of the consortium can provide Fraunhofer IGCV with regulations they use, which will be included in the project.

2. **Survey on the state of the art in EHS at AM-facilities** – 3 months

After the analysis of standards and regulation, the state of the art in EHS at facilities that use metal powder based additive manufacturing technology is initiated. Therefore, Fraunhofer IGCV visits approximately five additive manufacturing sites and documents the implemented security standards. Furthermore, an (online) survey on used EHS standards starts across different users of the technology. This is also promoted by EPMA to their members.

In this way, an anonymized documentation of the implemented security standards according to the visits and the survey is evaluated and summarized.
3. **Comparison of standards and regulations to the state of the art** – 2 months

Research results of work packages 1 and 2 allow the standards and regulations of different countries to be compared, as well as compliance with them. For this, extraction of relevant information for AM-facilities are made.

With this information, Fraunhofer IGCV drafts a checklist on necessary and mandatory safety concepts for AM-facilities. Moreover, an action plan for better EHS concepts is proposed.

4. **Market research on relevant players and contacts for safety solutions defining the future state of the art** – 3 months

After checking standards and state of the art, Fraunhofer IGCV conducts a market research in which necessary or recommended protection and security solutions are summarized. As a result, a list of safety equipment, suppliers and measurement providers (dependent on the included countries) are provided.

This allows the consortium to directly compare the results of the previous work packages with the offers on the market and to adapt its own equipment to the standards and recommendations.

5. **Project management and report** – 8 months

The management enables the planning, control and monitoring of the project over the entire project period. Eventually, the aggregation of the results leads to:

- Brochure on EHS-guidelines available to the **public** (5 pages, results from work package 1)
- Project report on EHS in powder bed fusion including the aggregated lists, a proposed course of actions and a list of possible equipment suppliers including suggestions on relevant equipment exclusively for partners (max. 30 pages).

The contractor IGCV should provide the consortium with short progress reports every three months, minutes and presentations after each meeting or teleconference and a final report at the end of the project. Two or Three meetings with all contractors would be held, a kick-off meeting, a possible mid-term meeting (physical or teleconference) 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.
Timeline for work packages (months):

<table>
<thead>
<tr>
<th>WP</th>
<th>Title</th>
<th>Project months</th>
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<tbody>
<tr>
<td>1</td>
<td>Analysis of standards and regulatory aspects available in English or German language</td>
<td>12345678</td>
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<tr>
<td>2</td>
<td>Survey on the state of the art in EHS at AM-facilities</td>
<td>12333344</td>
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<tr>
<td>3</td>
<td>Comparison of standards and regulations to the state of the art</td>
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<tr>
<td>4</td>
<td>Market research on relevant players and contracts for safety solutions defining the future state of the art</td>
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</tr>
<tr>
<td>5</td>
<td>Project management and report</td>
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Milestones:

M1 (2 months): Aggregated list of relevant standards and regulatory aspects

M2 (6 months): Guidelines on how to meet standards and regulations

M3 (8 months): Project report finished

Duration: 8 months, 3 meetings (kick-off, mid-term, final)

Budget: 60.000 € (+ VAT if applicable)
including Fraunhofer IGCV: 50.000 €
and EPMA (Management fee): 10.000 €

Minimum expected partners: 6

Maximum expected partners: 15

Contact:

Dr.-Ing. Georg Schlick  
Fraunhofer IGCV  
Beim Glaspalast 5 | 86153 Augsburg  
georg.schlick@igcv.fraunhofer.de  
Tel: +49 821 90678-179  
Fax: +49 821 90678-199  
www.igcv.fraunhofer.de

Kenan Boz, EPMA, kboz@epma.com