Fives Pillard

A review of R&D into additive manufacturing techniques and their application to combustion components and systems
Fives, a unique brand

and

18 Business lines

Fives, a multisector group, managed by expert teams
Fives, a pioneer Group, innovating the factory of the future

Fives develops proprietary technologies with high added value, superlative energy and environmental performance

€33.6 million spent on R&D in 2019 (outside of orders)

2,016 patents in force

13% of patents applications are related to energy and environmental performance

+8,000 Collaborators, 79 nationalities

Fives’ Plants of the Future Observatory, a think-tank on the industry of tomorrow

Smart Technologies

Additive Manufacturing

2017 key figures
Fives European Combustion Center

- **30 MW** installed test power (test capability up to 40 MW)
- Combustion training courses for customers
- External collaboration / discussions
- **Additive Manufacturing dedicated training coming soon…**
✓ Fives Pillard products line for Energy and Mineral markets
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Products line for Energy markets - Boilers

Pillard LONOxFLAM® G2

Pillard NANOxFLAM®

Pillard LONOxFLAM® AS

Pillard GRFLAM™

Pillard LEANGASFLAM™
Low LCV gas burners (COG, BFG…)

Pillard BIOFLAM™
Burners for biogas
Products line for Energy markets – Oil&Gas / HRSG

Pillard SULFLAM®
Acid gas burners for Claus units

Natural or forced draft burners for petrochemical heaters

Pillard OPTIMAFLAM™
For atmospheric distillation furnace

Pillard INDUCTFLAM® L
Natural or process gas

Pillard INDUCTFLAM® Ci
Liquid and gaseous fuels
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Products line for Mineral markets

Pillard NOVAFLAM®

Pillard PRECAFLAM™

Pillard ROTAFLAM®

Pillard HeatGen™ Systems

Pillard Fuel Systems
(Fuel handling)

Pillard NEUTRINOx™
SNCR system

Pillard STAPILDOS™
dosing system
How to incorporate AM……but first……WHY ?

- Improve performance of the products
- Improve products general design (marketing / communication)
- Increase IP protection level
- Shorten delivery time for complex part - Limit Stock quantities
- Develop more cost-effective solutions
Industrial example:

- Premix technology for ultra low NOx burner

- each mechanical piece has **one** single function

- **Step 1**: improve the design of each single piece **individually** – 1 piece = 1 function

- **Step 2**: improve the **global** design of the burner part – 1 piece = 4 functions
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**Industrial examples:**

- **Premix technology for ultra low NOx burner**

- Improve performance of the products

- Improve products general design (marketing / communication)

- Increase IP protection level

- Develop more cost-effective solutions ???

<table>
<thead>
<tr>
<th>Coefficient of gas variation at outlet:</th>
<th>Standard solution price:</th>
<th>AM solution: (x 6 !!!)</th>
<th>AM optimized solution: (x 3 !!!)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfect Premix</td>
<td>0%</td>
<td>440 €</td>
<td>1500 €</td>
</tr>
<tr>
<td>3D Printed injector</td>
<td>15%</td>
<td>2525 €</td>
<td></td>
</tr>
<tr>
<td>Standard Injector</td>
<td>36,5%</td>
<td>1290 €</td>
<td></td>
</tr>
</tbody>
</table>

£ 380  £ 2170  £ 1290
Industrial examples:

- **Premix technology for ultra low NOx burner**

<table>
<thead>
<tr>
<th>Targets</th>
<th>Standard solution</th>
<th>Additive Manufacturing solution</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products performance</td>
<td>+</td>
<td>++</td>
<td>😐</td>
</tr>
<tr>
<td>Products general design</td>
<td>-</td>
<td>+</td>
<td>😐</td>
</tr>
<tr>
<td>IP protection level</td>
<td>-</td>
<td>+</td>
<td>😐</td>
</tr>
<tr>
<td>Delivery time</td>
<td>=</td>
<td>=</td>
<td>😐</td>
</tr>
<tr>
<td>Cost-effective solution</td>
<td>+</td>
<td>-</td>
<td>😐</td>
</tr>
</tbody>
</table>

- AM relevant to improve product performance, general design and IP protection level

- AM **not** relevant if **only** cost-killing target...so far...!

- Necessity to move forward to Step 2 to reach all-in-one engineering design (burner functions mix) to improve cost and delivery time
Other industrial examples:

- **AM from metal parts to metals parts**
  - NOVAFLAM® AXIAL TIP
  - ZV2™ LIQUID FUEL ATOMISING SET
  - OPASTOP® HEAT SINK

- **AM for metal parts to ceramic parts**
  - NOVAFLAM® CENTRAL STAB
  - CLEANTIP™ SCRACHER
  - AXIAL TIPS PROTECTION SiC TILES

- **AM for metal parts to plastic parts**
  - DARKSCAN™ DIAPHRAGM
  - OPAGAZ™ INTERNAL CHAMBER
**Other industrial examples:**

- **AM parts under engineering study…**
## AM incorporation into Fives Pillard applications

<table>
<thead>
<tr>
<th>Technology used</th>
<th>Material chosen</th>
<th>Applications</th>
<th>Pros/Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&amp;D tests</td>
<td>Production (low volume)</td>
<td>Production (high volume)</td>
</tr>
<tr>
<td>Powder Bed Fusion (PBF)</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Laser Beam Melting (LBM)</td>
<td>CS / SS / Inconel / SiC</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Electron Beam Melting (EBM)</td>
<td>-</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Powder Bed Sintering (PBS)</td>
<td>Selective Laser Sintering (SLS)</td>
<td>Polyamide (PA12/2200) SiC</td>
<td>✓</td>
</tr>
<tr>
<td>Direct Energy Deposition (DED)</td>
<td>Laser Metal Deposition-powder (LMD-p)</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Laser Metal Deposition-wire (LMD-w)</td>
<td>-</td>
<td>✓</td>
<td>X</td>
</tr>
</tbody>
</table>
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**Conclusions**

- **R&D staff**: *Create differently!*
  - Burners functions mix to increase AM relevance
  - Mix design with standard manufacturing for simple parts and AM for complex parts
  - Standardization for simple parts + customized parts for complex parts
  - Different IP strategy

- **Mechanical engineering staff**: *Think differently!*
  - From matter removal approach to matter addition approach!
  - Staff training with additive manufacturing specialists, starting from internal proprietary parts and internal processes
  - Access to new material for specific applications when physical properties are requested, without upgrading function
  - Possibility to reduce total weight of equipments

- **Procurement and purchase staff**: *Buy differently!*
  - Comparison between machine-time costs? (standard milling or drilling vs metal 3D printing)
  - New organization of supply chain to reduce delivery time (less players in the loop!)

- **Sales & Services staff**: *Sell differently!*
  - Increase of products added value with performance improvement
  - Customized main parts and spare parts
Thank you for your attention!