Industrialization and Current Field Experience of Additively Manufactured Gas Turbine components
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What is additive manufacturing and how is it different from conventional production?

**Product transformation**
- Shift from conventional design to innovative DFAM

**Conventional production**
- Multiple components/part
- Long lead times for design & prototyping
- Design limited by mfg process, e.g. casting

**Reimagine products**
- Reduce weight, material
- Scan-to-product
- Expand performance
- Accelerate innovation cycles
- Freedom of design is no longer restricted by design rules of conventional manufacturing

**Rethink business**
- Individualization, personalization
- Zero inventory – on demand printing
- Design anywhere. Print anywhere.
- Accelerate innovation

**Reinvent manufacturing**
- Eliminate molding/castings/tooling
- Eliminate/simplify assembly process
- Reduce supply chains
- Affordable low volume production

**Manufacturing transformation**
- Shift from prototyping / experimentation to mainstream industrial production
Siemens was an early adopter of SLM AM technology and have successfully scaled its production.
Siemens is pursuing 2 major business objectives with driving AM into our core products and building an external service business.

1. Leading User of AM Technology to strengthen competitiveness

2. Leading AM Service Provider to leverage internal capabilities

Digital Factory

- Only Supplier of seamlessly integrated AM solution
- Software
- Control & Automation
- Part Manufacturing Platform (PMP)
Manufacturing Footprint expansion signed for FSP and MSL
Global footprint growth into North America

- Finspong
- Worcester
- Montreal
- Charlotte
- Berlin

- Various EOS units
- 1 x M290
- 1 x M400
- 1 x Trumpf

Production and development
Prototype and development
Planned prototype
Three main pillars when applying AM

Rapid Prototyping
Significant reduction of time to market

Rapid Manufacturing / Spare Parts on Demand
Completely new design only possible via SLM

Rapid Repair
10 times faster and easy upgrades
WE achieved a major BREAKTHROUGH … … first turbine blade is printed and tested in the engine

**Approach**
- Use SLM for rapid prototyping of blades
- Rainbow test in gas turbine for selection of best design
- Calibration of calculation tools and design methods
- Full scale engine test performed

**Benefits**
- Excellent tool for optimization of blade cooling designs
- Substantial lead time reduction for engine upgrades - 1st blade manufactured already 2 weeks after receipt of 3D model
- Minimized risk by verification of blade temperature prior to casting
Burner manufacturing by means of SLM for flexibility, shorter lead time and improved life time

**Approach**

- Manufacturing of SGT-700/SGT-800 burners by means of SLM
- Redesign of existing burners for SGT700/800 to utilize the design freedom offered by SLM
- Full scale engine test performed
- Commercial operation in 2018

**Benefits**

- Reduced lead time by 23 w
- Enabling customization for fuel flexibility
- Removal of TBC

**Conventional**

- 13 parts / 18 welds
- TBC on front
- 26w lead time

**SLM burner**

- 1 integrated part
- No TBC due
- 3w lead time
3D printing parts are already in use at Nuclear Power Plant Krško, Slovenia

First 3D printed water pump impeller is on successful commercial operation at nuclear power plant

Customers benefits:
• Obsolete parts can be re-produced
• Significant lead time reduction
• Parts on demand
AM technologies overview
Laser Cladding - Smart Repair

Rotor Repair
- Fully operational since 2016
- > 40 rotor repairs successfully performed
- Covering extended range of rotors (steam turbines, compressors, generators) & filler materials
- Repair time reduced by approx. 50%

Valve Repair
- Fast track repair for valve spindles & valve cages (lead time down to several days)
- Stellite & Hard surfacing of valve components (for new manufacturing)

Stator Repair
- Substitute repair method of sealing faces of guide blade carriers (earlier: weld in forged ring and final machining)
- For both cast iron & cast steel
- Repair time reduced by approx. 30%
Current field experience of AM manufactured & repaired components > 100 000 hours

Successful in commercial operation

**Rapid Repair**
- **Product**: SGT-700/800
- **Component**: Burner tip
- **Benefit**: 90% lead time reduction
- **Status**: In commercial application since 2013
  > 30 000 EOH

**Rapid Manufacturing**
- **Product**: SGT-700
- **Component**: Burner
- **Benefit**: Longer life
- **Status**: In commercial application since 2017
  > 8 000 EOH

**Rapid Manufacturing**
- **Product**: SGT-750
  - **Component**: Swirler
  - **Benefit**: Swirler can only be made via SLM
- **Status**: In commercial application since 2013
  > 30 000 EOH

**Rapid Manufacturing**
- **Product**: SGT-800
  - **Component**: Burner
  - **Benefit**: Longer life
  - **Status**: In commercial application since 2017
    > 8 000 EOH

**Spare parts on demand**
- **Product**: SGT-1000F
  - **Component**: Burner head
  - **Benefit**: Reduced lead time by up to 6 months
- **Status**: In commercial application since 2016
  > 10 000 EOH
AM Vision: "Autonomous", Closed Loop & Self Healing Processes, Gas Turbines Order Spare Parts by Themselves
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