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Progress in the use of Additive Powder Layer Manufacture

for Compact Heat Exchangers.

Drummond Hislop,

Technology Director

HiETA Technologies Ltd.

Introduction

- Additive Manufacturing (AM) is a new manufacturing technology that "grows" products by adding and processing material layer by layer. AM allows previously unattainable design complexity, compactness and functionality.

- HiETA uses Selective Laser Melting (SLM), a form of AM that processes high performance metal alloys in the design, development and manufacture of thermal management products, particularly compact heat exchangers.

- Main markets: aerospace, defence, automotive and clean energy, where there is an increasing need for more compact, lighter and efficient components

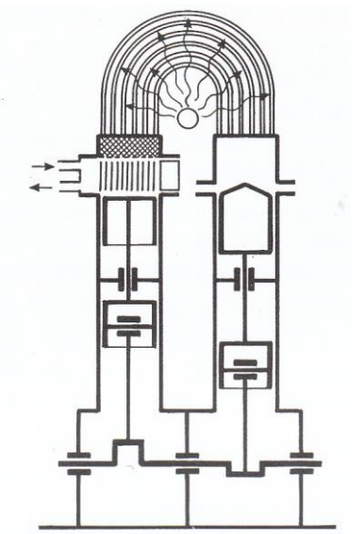
- SLM products have the potential to meet these requirements.

SLM – The Process

- A thin layer of the powder is spread on a metal platen.
- A CAD-driven laser scans and melts each layer where it is to be solid.
- The molten powder cools quickly to a fine-grained solid structure
- Each layer is a very thin horizontal slice of the part being built.
- A new layer of powder is spread over the previous layer.
- Each new layer is melted into the previous layer.
- The component is “grown” layer by layer until it is complete
- The finished part is cut away from its platen and excess powder removed

The Advantages of SLM

- Very high degree of 3-D design freedom.
- Elimination of welded, brazed and other joints.
- Can build very complex parts with internal voids.
- Parts can be packaged with much greater design flexibility.
- Different functions can be combined in single builds (eg heat exchange/structural/fluid flow control).



Why SLM for Compact Heat Exchangers?

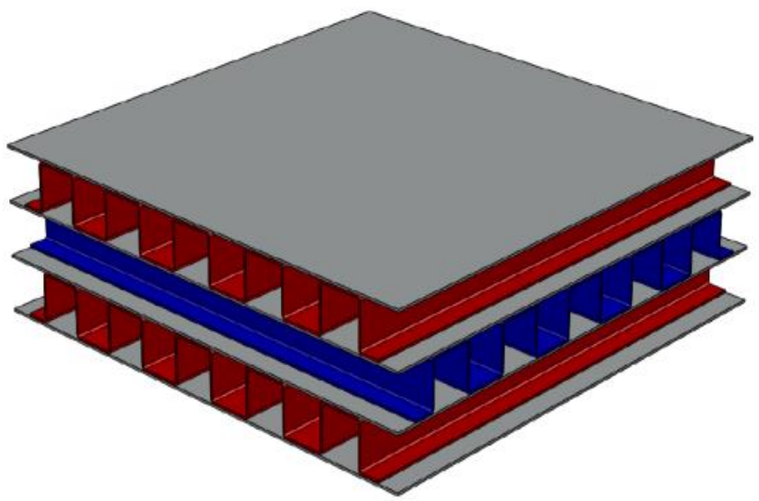
•Stirling engines: need for new solutions to heat transfer problems in combustor, air pre-heater, heater; also cooler.

•Micro-turbine recuperators: existing components too large, heavy, expensive and unreliable for new demands in automotive and aerospace applications.

•Thermal management in defence and aerospace – increasing demands for heat removal, particularly in UAVs, but weight limitations getting stricter.

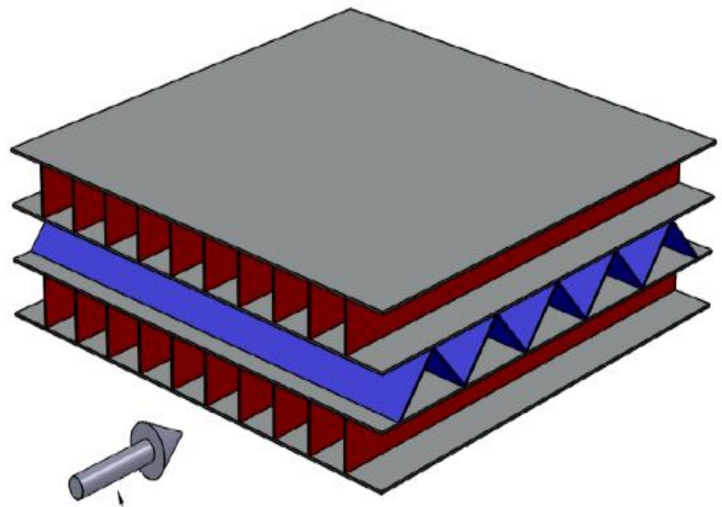
•Motorsport: new regulations encourage more effective thermal management and lead to a need for more heat exchangers.

Initial Advantages of SLM for Compact Heat Exchangers



Total mass: 149.34 gm

Plate fin HX



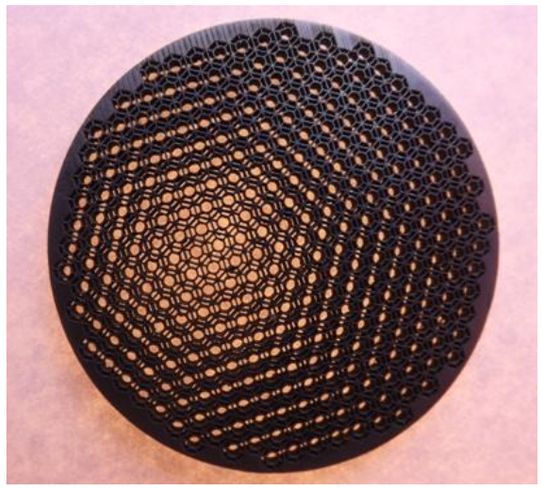
Total mass: 115.62 gm

SLM version of plate-fin HX: 25% lighter by eliminating surplus metal/joins

Potential Advantages of SLM for CHX

- Low hydraulic diameters and high surface/volume ratios.
- Variable surface finish.
- Tube-in-tube, primary surface counter-flow heat exchange.
- New geometries – eg tubes with varying cross-section.
- Optimised design to reduce stress raisers, minimise thermal fatigue.
- Optimised secondary heat transfer surfaces/surface enhancement.
- Provision of tertiary heat transfer surfaces.
- Manifolds that exchange heat and reduce the core size.
- Any shape for optimised packaging.
- Quicker manufacture of test pieces for new surfaces and layouts.
- Integration of 2 or more components in single SLM build

Initial Examples of Complex SLM Builds for CHX



Recuperator cross section

Aerospace cooler

CHX Requirements

- Thin walls of ~0.1 mm, zero connected and very low unconnected porosity.
- Control of surface finish, as most surfaces of narrow ducts are inaccessible.

State of the SLM art

- Most SLM parts have thick walls.
- They can tolerate small amounts of porosity, even if connected.
- Initially, minimum 0.5 mm thick walls needed for zero leakage
- Surface finish typically 7-12 RA – much rougher than plate.
- Increase heat transfer in laminar flow, but also increases pressure drop.
- Post-process control of surface finish possible, as most surfaces accessible.

Potential Solutions

Materials

•Optimise alloy constituents for SLM process – equivalent to welding/brazing.

•Optimise particle size and size distribution – reduce particle size?

Machines and Processes

•Optimise machines: laser – pulsed/continuous; powder recoater – hard/soft/roller.

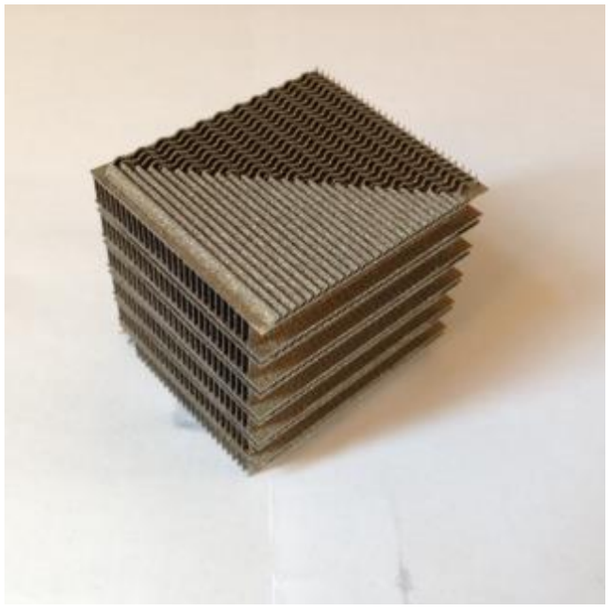
•Optimise process: layer thickness, laser spot size/power, scan speed and pattern.

•Assess/develop suitable post-process surface treatments.

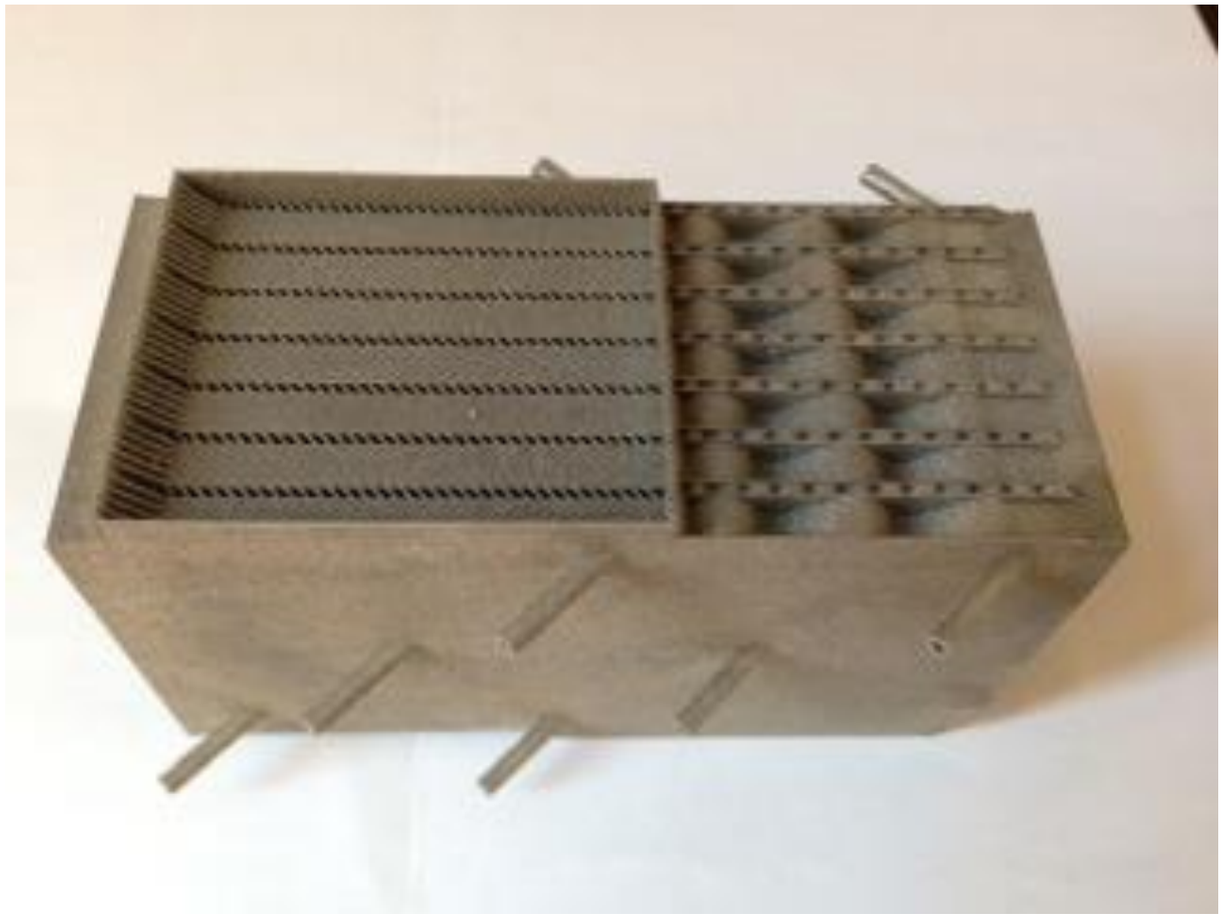
Progress so far

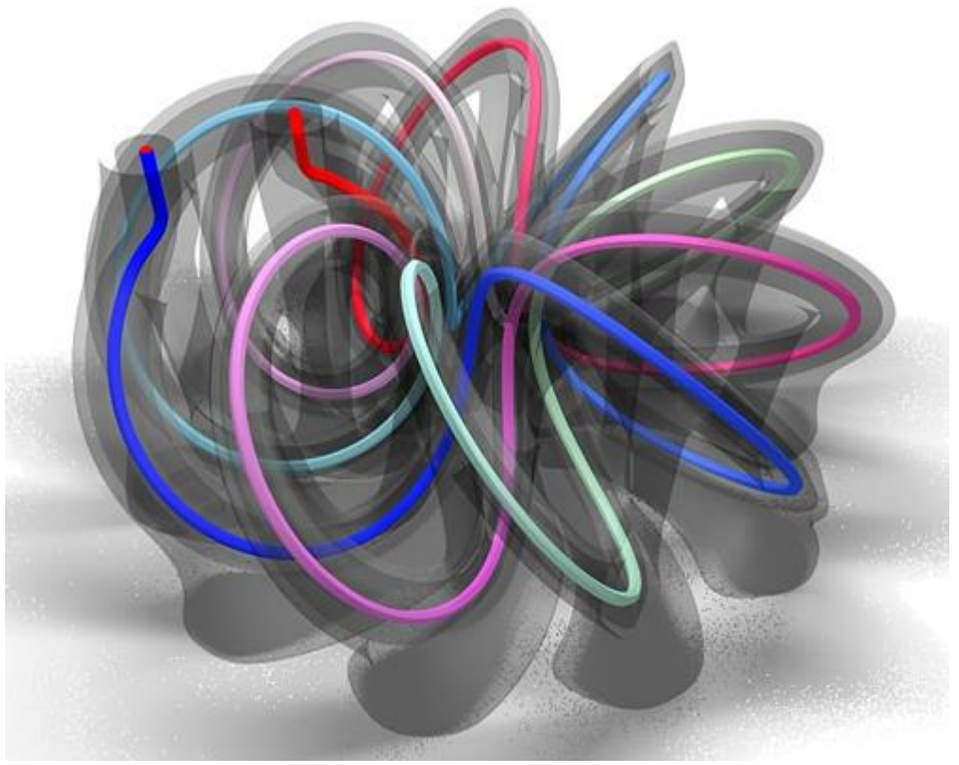
Modification of alloys

- Two alloys – CuSn and CuNi – modified by adding wetting agent.
- Test pieces built, assessed with SEM and LCM, and tested.
- Assessed with Scanning Electron and Laser Confocal Microscopy.
- Addition of wetting agents improves porosity but, so far, not roughness.
- Machine and setup may affect minimum wall thickness as much as alloy constituents.
- Testing recuperators with thinner walls – 0.3 mm down to 0.15 mm



Micro-turbine recuperator test sections





The Future?

Questions