Maximising Additive Manufactured Heat Exchanger Efficiency
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Next Generation Computational Fluid Dynamics
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Overview

• Introduction to HiETA Technologies

• CFD Optimisation

• Case study: wavy ducts optimisation

• Case study: condenser ducts optimisation

• Summary
Introduction to HiETA Technologies

Design, engineering and industrialisation solutions for Additive Manufacturing

- SME based in Bristol & Bath Science Park
- 4 years old
- Approximately 20 staff with experience in several sectors, including multi-sector engineering, material science, manufacturing, product development and project management
- Number of past and current Innovate UK and CDE projects for defence, automotive and aerospace applications
Introduction to HiETA Technologies

Products and services

Design Engineering
- Heat Management
- Lightweighting
- Integration
- Novel Functionality

Prototyping & Manufacture
- Metal
  - Aluminium
  - Inconel
  - Titanium
  - Stainless Steel
- Polymers
- Product/Component Design
- Materials & Structures
- System Development

Collaboration Projects
- Industrialisation

AM Consultancy
- Materials
- Product Assessment
- Engineering Analysis
- Process Viability/Implementation
Lightweight Structures & Integrated Components

HiETA Technologies design, manufacture and validate lightweight, space-efficient components & systems to minimise mass and volume whilst maintaining/improving functionality and capability

- Lattice structures utilised for enhanced stiffness, lightweighting and improved impact absorption

- Integration of novel lattice topologies for improved thermal performance

- Topology optimisation (with lattice inclusion in the development)

- Development of a lattice optimisation tool (collaborative project)

- Efficient material utilisation

- Parts no longer constrained by “conventional” manufacturing constraints - mass added for draft angles etc. no longer required
Heat Exchangers

*HiETA Technologies design, manufacture and validate high-efficiency, compact Heat Exchangers to increase thermal performance and to reduce component weight and volume*

- Proprietary primary and secondary surface designs
- Complex internal architectures taking advantage of AM design freedom
- Thin wall sections for enhanced heat transfer and weight reduction
- Novel design solutions for phase-change heat exchange
- Parameters and shape optimisation for improved performance
CFD Optimization

Hypermesh → Morphing (HyperMorph) → Solver → Visualization

Meshing/Preprocessing → Optimization/DOE → HyperStudy

Design variables
- shapes
- parameters

Responses
Case Study: wavy ducts optimization

**Application:** Microturbine recuperator for automotive industry

**Objective:** to determine the best geometric dimensionless parameters ($\alpha$, $\varepsilon$ and $\gamma$) and flow conditions ($Re$) for minimal volume requirement for the HX core.

**Design variables**

- Friction factor ($f_F$)
- Colburn factor ($j$)
- Area goodness factor ($j/f$)
- Volume goodness factor

**Responses**

- $\varepsilon = \frac{S}{2\alpha}$
- $\alpha = \frac{S}{H}$
- $Re$
Case Study: wavy ducts optimization

HyperStudy set up

- DOE → Fit (approximation) → Optimization
- User defined matrix for DOE
  - 4 design variables (3 shape variables and 1 parameter)
    - Re from 200 to 800
    - 27 total shape combinations
    - 108 runs
- Optimization objective: minimize HX core volume

CFD model

- Steady state analysis
- Air properties
- Mesh 3.2m elements
Results

Friction factor ($f_F$)

Colburn factor ($j$)

Area goodness factor ($j/f$)

- Response surfaces plotted versus corrugation ratio and spacing ratio for fixed Re (200) and aspect ratio (0.25)
Optimised geometry presents swirl flow and big recirculation zones which enhance heat transfer with low pressure penalty.

- Friction factor reduced by 20% for cold side and 54% for hot side*
- Colburn factor increased by 46% for cold side 57% for hot side*

*Subjected to experimental validation
Case Study: Condenser ducts optimisation

Application: Heat exchanger (condenser) for evaporatively cooled fuel cell system

Objective: Characterise the different possible geometries regarding single phase heat transfer and pressure drop and determine the optimised parameters (pitch and amplitude) for each.

- HyperStudy and Acusolve used for the analysis
- Re = 985 and Pr = 1 for the simulations
- Baseline duct with d = 2mm, A = 0.25 mm and L = 5 mm
- Shape variables control the amplitude (0.1 - 0.4 mm) and the pitch (2.5 - 5 mm)
- Responses: friction factor \( f_F \), Colburn factor \( j \) and area goodness factor \( j/f \)
Results (helical tube)

Friction factor ($f_F$)

Colburn factor ($j$)

Area goodness factor ($j/f$)
Summary

HiETA Technologies design and manufacture high efficiency compact heat exchangers.

Two study cases have been presented, showing the benefits of Hyperworks software solutions to our product development activities.

The optimisation approach for our product development means:

- Finding an optimal solution which increases the efficiency and compactness of our products
- Reducing development time and costs
Thank you for your attention!