Automating Canister Design for Powder HIP

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03-10-2017
Net Shape Manufacturing at MTC

- HIP, CIP, MIM and SPS equipment for process development, demonstration & validation.
- Process agnostic advise including manufacture feasibility, technical support & close links to the supply chain.
- Advanced Near Net Shape modelling and dedicated design team for fast and accurate component development across a range of powder process.

### Process Development

- Process Selection

### New Product Introduction

- Component Complexity & Material Efficiency
The geometry of the HIP canister defines the shape of the HIPed component.

The canister must be designed to accommodate a 30-40% shrinkage in volume as powder consolidates during HIP.

During HIP the change in shape of the HIP canister is not linear and is closely linked to the local stiffness of the HIP canister and the width of the powder cavity.
Simple HIP Canister Design

- Traditionally HIP canisters are designed using ‘basic principles’
- This means measuring the packing density of the powder to find the volume change then assuming linear shrinkage expand canister cavity dimensions.
- This method does not account for canister stiffness and so is inaccurate, typically a large safety factor is used ‘overstocking’ the part to achieve geometry.
The cost of a HIPed component is impacted by a number of factors.

2 key factors are ‘amount of powder’ and ‘amount of machining’ post HIP.

Using a large overstock significantly increases the amount of powder and machining needed, increasing the cost.

Using physical demonstration parts to refine the design of a HIPed component may take several attempts resulting in very high development timescales and costs.
HIP Canister Design Using Simulation

Desired Geometry → Optimisation for HIP → Design Canister Cavity → Design Tooling → HIP

Iterative Design → Modelling
HP Turbine Case Study

- Poor material efficiency
- Expensive Forgings with long lead times
- Large machining time and cost
Compact Simulation

- Uses the finite element (FE) method
- Based on a thermo-mechanical model where thermal expansion and the external pressure deform the component
- Includes a pressure dependent yield stress, allowing it to not only shear, but permanently collapse too
- Yield strength decreases with temperature, softening it

Overlaid undeformed / deformed geometries in the FE model, the colour scale represents displacements
HP Turbine Case Study

- Increase in material efficiency and less energy consumption due to less machining (overstock reduced by 80%)
- Reduction in costs and lead time
- Enables use of high performance PM materials
Issues with Design Using Simulation

- Requires a **manual design stage** as an input
- Requires back and forth **re-design** and simulation interactions between a modeller and designer.
- Requires **not very user friendly** simulation software with expensive licences and top-end computing power.
- To make the modelling accurate a large amount of temperature related **material property data** is often required. To get this data interrupted HIP cycles are often used (expensive and time consuming)
1. The tool must use the desired component geometry as an input.
2. The tool must be user friendly so a designer can use it.
3. The tool must be reasonably accurate without the need for material calibration with expensive interrupted HIP cycles for each new material.
4. The tool must automatically optimise the HIP canister design without the need for modeller-designer interaction.
Automatically Optimising HIP Canister Design Tool

- Integrated through a Python plug-in for Abaqus
- Geometry is designed with t-splines; a free-form CAD format that allows “organic” shapes
- The initial CAD guess is based on a “reversed uniform compaction”
- The Abaqus FE model takes the canister CAD and for a specific material & process returns the deformed geometry after HIP
- Matlab is used to obtain significant statistics of the average and spread of the miss-match between the deformed FEA and the target CAD
- The CAD is modified to minimise the miss-match iteratively
Valve Case Study
Valve Case Study

- Desired geometry designed in CAD
- Pre-HIP geometry fabricated using automatic modelling
- Canister designed around pre-HIP geometry
Comparison to Target Geometry
Designing Using the New Tool

- Reduced design time by 85%
- 95% accuracy achieved
- 25% better material efficiency
- Development time and cost reduced by 3x.
Current Limitations

- Manual design is still required after geometry is optimised to make the canister manufacturable by conventional sheet metal fabrication.
- Has only been validated for stainless steels and Ni superalloys.
- Requires FEA software licence to run.
Conclusions

- Using the new self optimising canister design tool resulted in:
  - The ability to use a target component as a starting point with no need for manual capsule design.
  - Significant reduction in capsule design time
  - Better capsule design using an optimal geometry rather than a ‘good enough’ geometry with a safety factor reducing both mass of powder required and machining of the post HIP components
  - A design tool that can be used and calibrated by design engineers not just computer modellers.
Next Steps for Development

- Integration of MTC model into commercially exploitable design software
- Use the tool to accelerate and support the development of a wide range of HIPed component into the HIP supply chain
- Qualify the tool for key materials and component types
- Develop a rapid calibration test for new materials
- Streamline the automatic CAD optimisation capabilities
- Combine the use of automated canister design with flexible encapsulation methods to maximise benefits