Inspiring Great British Manufacturing

ENCOMPASS – ALM Inspection

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Project Overview (1)

- H2020 Project started November 2016

- http://encompass-am.eu/

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Project Overview (2)

- Project dedicated to addressing some of the barriers to the efficient use of Additive Layer Manufacturing
  - Specifically for Laser Powder Bed Fusion (L-PBF)
- Geared towards case studies from aerospace, medical and automotive sectors
- The planned primary output is an “Integrated Design Decision Support (IDDS)” system to span the whole manufacturing chain for a laser powder bed fusion (L-PBF) process to provide a greater chance of “right first time” and hence lower costs.
  - Includes post-build operations such as inspection
  - Tries to reduce need for iterative design refinement by feedback to designer highlighting issues that will affect downstream operations
  - Tries to increase throughput and reduce costs by enabling targeted post-build operations

ENCOMPASS Inspection Activities

Overview

- Early feedback to designer on likely inspection challenges for proposed component design
  - Design for inspection / inspectability via simple model of inspection that can be executed from CAD environment
  - Target audience has very limited appreciation of inspection technologies
- Suggested post-build strategy for a given design
  - Use of inspection simulation model and CAD to create suggested inspection plan and hence reduce inspection effort and improve performance
  - Enabling targeted inspection of critical features from design, to provide time and effort savings
  - Enabling targeted inspection of component regions identified from build monitoring, as efficient route to improved quality
- Work package focuses on 2 inspection modalities highly relevant to L-PBF components
  - Optical inspection (manual visual / machine vision / optical metrology)
    - Also relevant to multiple finishing techniques, such as blasting, as line of sight access similarly important
  - Radiographic inspection (2D X-ray and Computed Tomography)
- Work package also providing inputs tangentially linked to inspection
  - Tool to predict regions of design in which powder is likely to be trapped
  - Study on the use of Product Manufacturing Information (PMI) in digital workflow

ENCOMPASS Inspection Activities

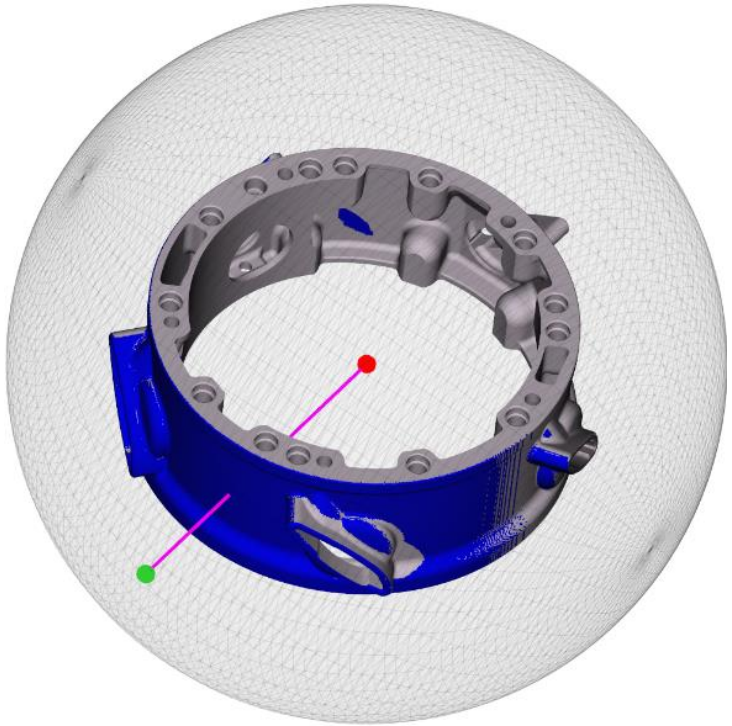
Optical Inspection - Introduction

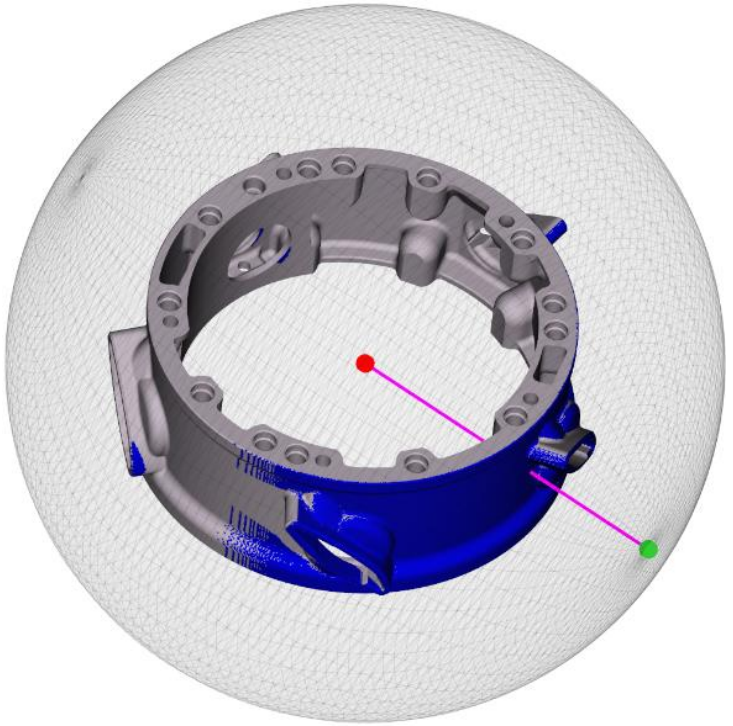
- Simple ray-casting model developed for highlighting regions of CAD design that are likely to be hard to access for line-of-sight post-processing steps:
  - Manual visual inspection
  - Machine vision automated inspection
  - Fringe projection / structured light dimensional metrology
  - Laser line scanning dimensional metrology
  - Laser polishing
  - Blasting
- Intention is for model to be simple and approximate, requiring only limited prior knowledge of the specific inspection hardware to be used, and allowing fast evaluation.

Example output for a complex geometry (design courtesy of GRM Consulting Ltd., K-Tech & MTC), highlighting surface elements visible from above, right.

ENCOMPASS Inspection Activities

Optical Inspection – Sphere Sample Examples





Two views from the viewing sphere being evaluated on a use case geometry provided by ITP. The green circle represents view sample, red circle represents centre of viewing sphere. Blue highlighted regions represent visible regions in each case (using parallel rays).

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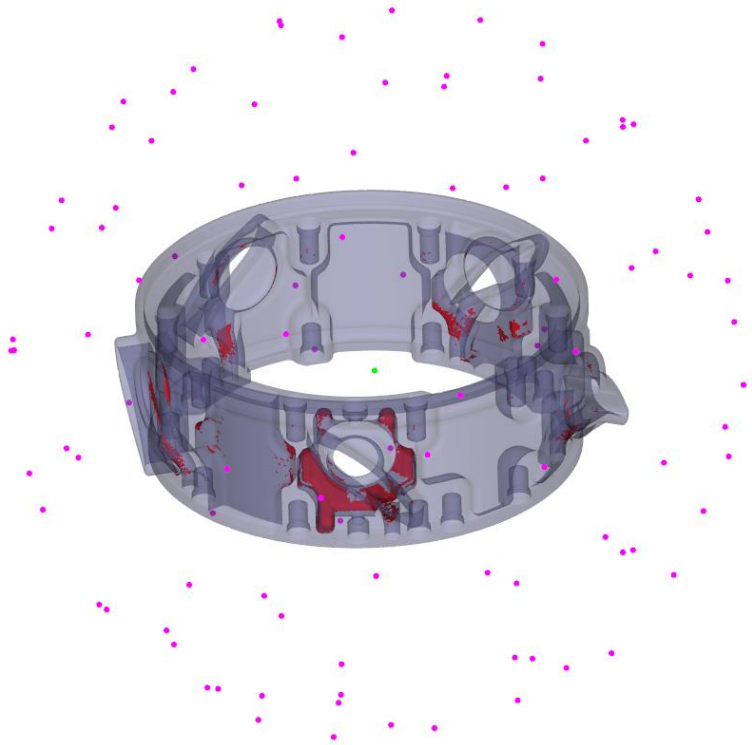
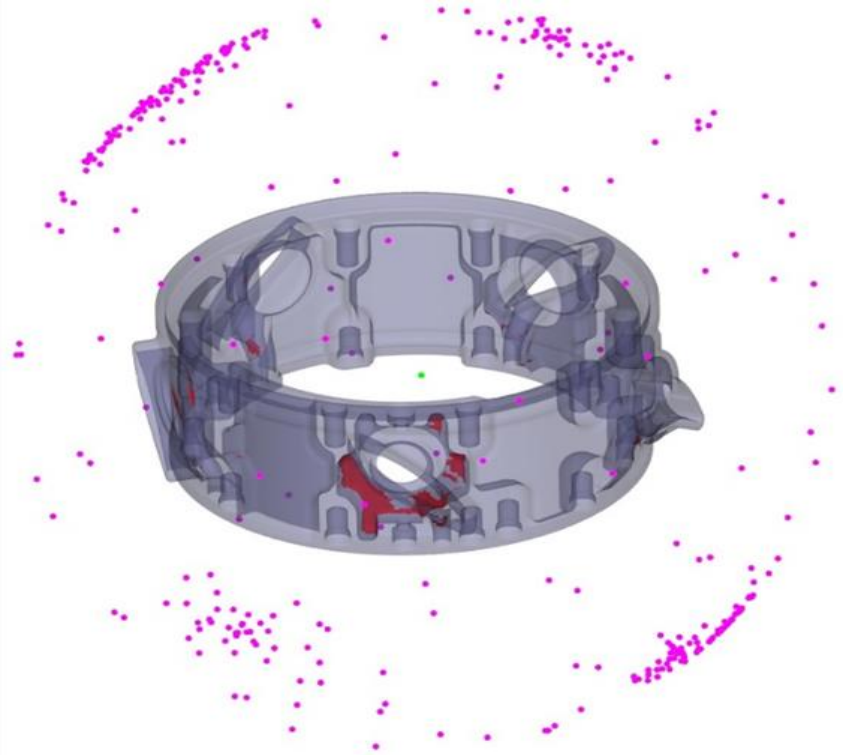
Optical Inspection – Cumulative Results from Sphere Sampling



Results for 100 different views for the use case geometry provided by ITP. Non-visible regions are highlighted in red. Pink points represent points on the viewing sphere, and green point shows centre of viewing sphere.



Results from refinement of the computation on the left by adaptive sampling – note the clustered samples & improved coverage

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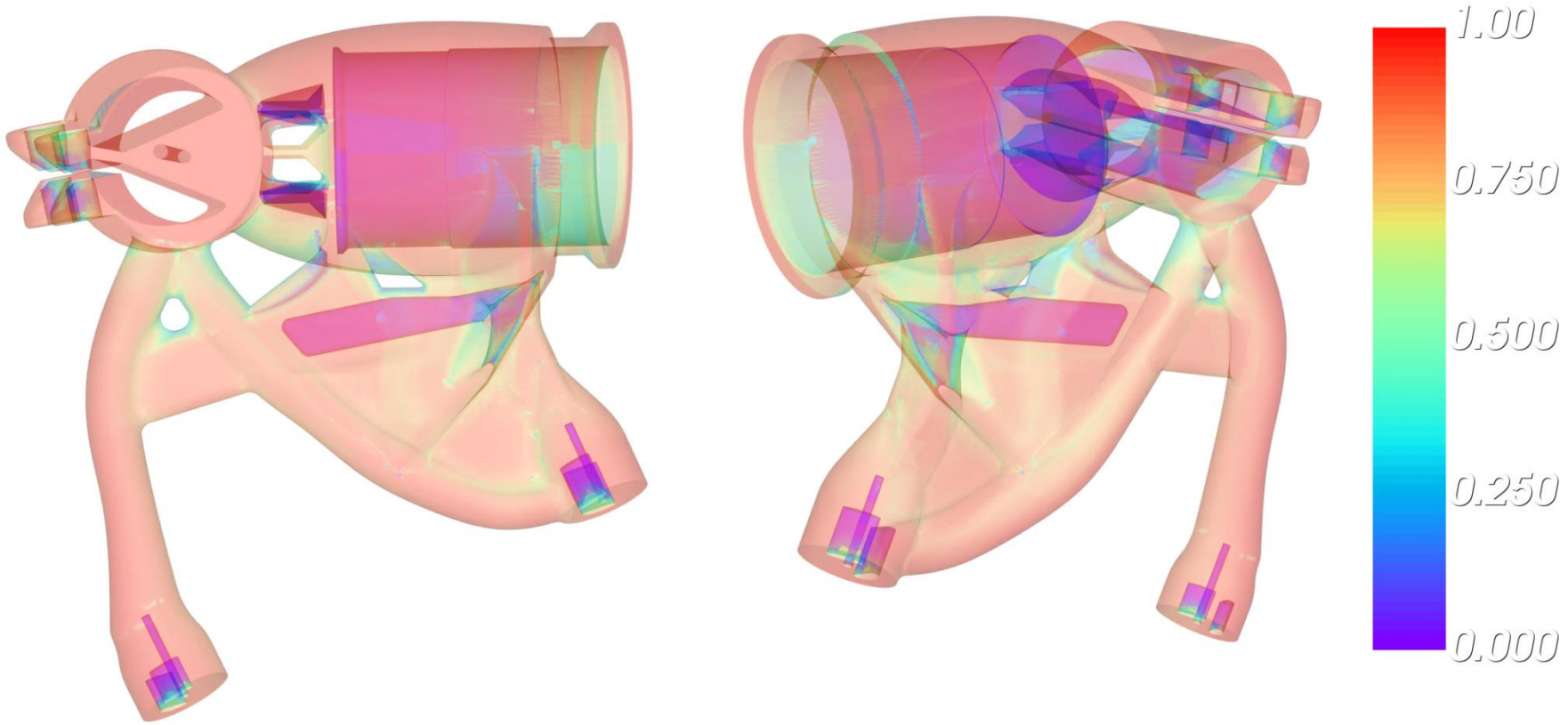
Optical Inspection – Considering Angle to Surface



Example output for a complex geometry (design courtesy of GRM Consulting Ltd., K-Tech & MTC), plotting mean(cos(theta)), where theta is angle to surface normal, for 100 random viewing angles.

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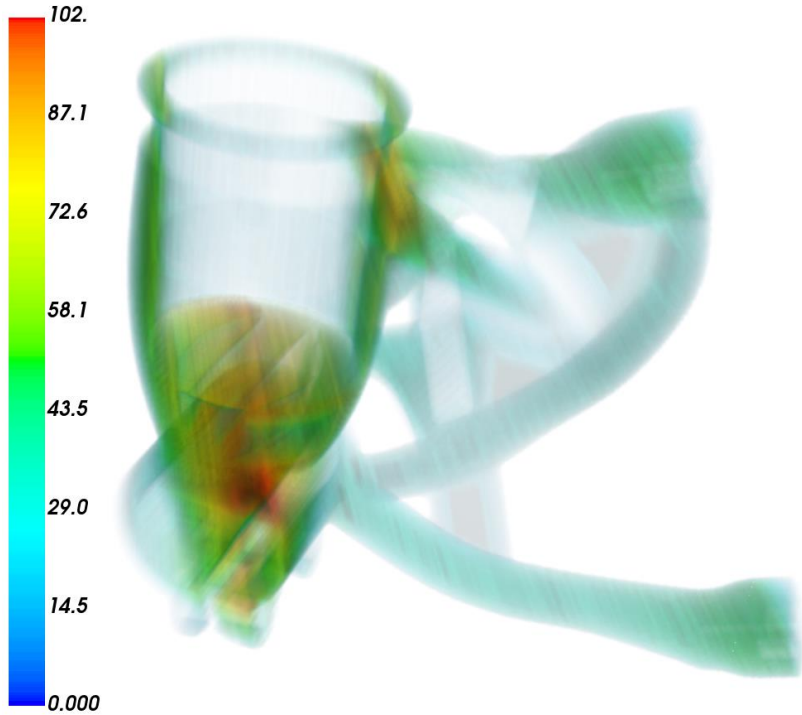
Radiographic Inspection – Introduction

- Ray-casting model developed to assess radiographic detectability of CAD geometry, considering
  - Material path length
  - Effective magnification
- In contrast to optical inspection model, rays here are cast through to a detector plane, not to the component surface, but much of previous functionality remains relevant.
- Intention is for model to be simple and approximate, requiring only limited prior knowledge of the specific inspection hardware to be used, and allowing fast evaluation.



Example output for a complex geometry (design courtesy of GRM Consulting Ltd., K-Tech & MTC), plotting material path (in voxels) for a single viewing direction.

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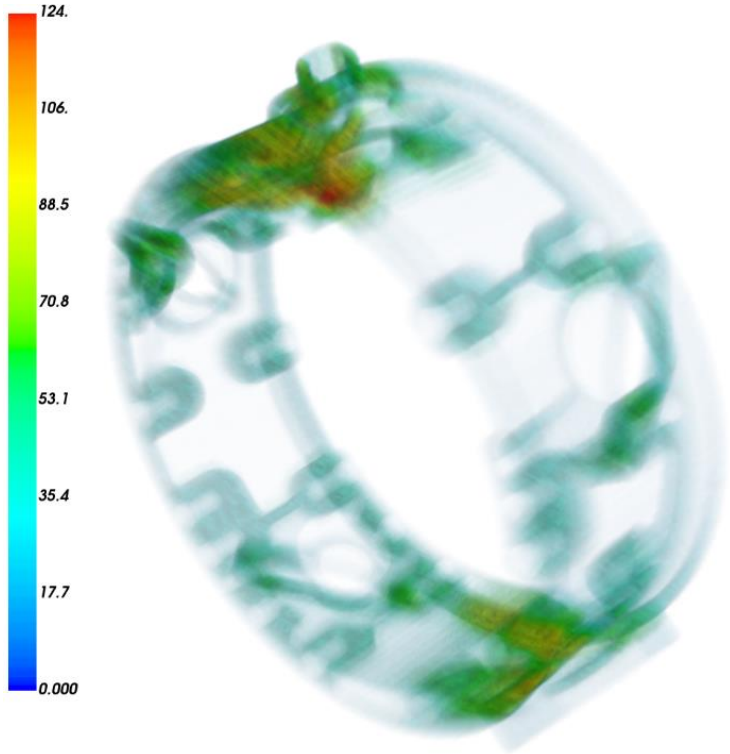
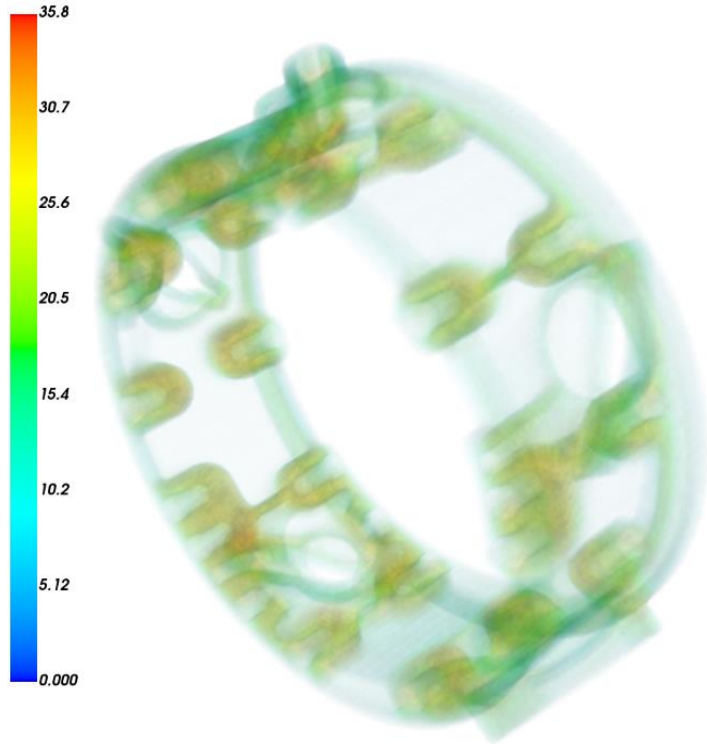
Radiographic Inspection - Material Path



Material path analysis for a single view of the use case geometry provided by ITP. The unit of the colour axis is voxels.



Material path analysis for 100 views of the use case geometry provided by ITP. Mean of the minimum 10 values for each voxel is plotted. The unit of the colour axis is voxels.

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Radiographic Inspection - Magnification

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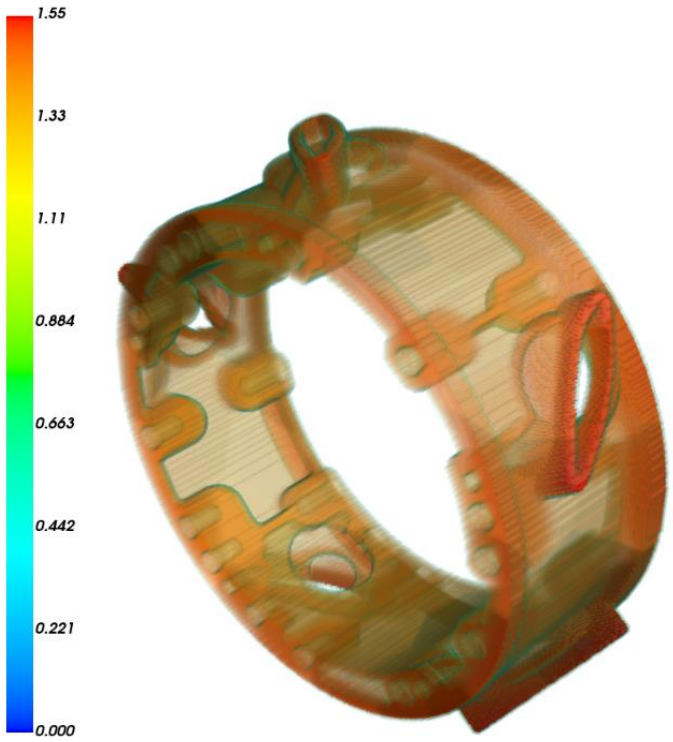
Results for 100 different views for the use case geometry provided by ITP, plotting mean of maximum 10 magnification values at every location.



In practice, likely to want to overlay magnification & material path analyses, as detectability will broadly vary with both quantities.

ENCOMPASS Inspection Activities

Trapper Powder Modelling

- Morphological analysis on the component geometry allows the identification of regions in which unconsolidated powder is likely to be trapped
  - Fully enclosed regions (no means of clearing powder)
  - Regions only accessible via narrow channels (limited access for clearing powder)
  - Regions of tight curvature (where tacky powder is likely to adhere and remain)
- Analysis is completed on a voxel representation of the geometry – the tangential link to the inspection activity.

Example output for a complex geometry (design courtesy of GRM Consulting Ltd., K-Tech & MTC), highlighting narrow channels from which powder is likely to be hard to remove.

ENCOMPASS Inspection Activities

Product Manufacturing Information (PMI)

- Product Manufacturing Information (PMI) is used in the context of Computer-Aided Design (CAD) systems and Model-Based Definition (MBD) in order to communicate component attributes.
- These attributes typically include:
  - Geometric Dimensions and Tolerances (GD&T)
  - Text annotations
  - Material specifications
- But can in principle also include:
  - Surface finish
  - Integrity requirements
- In the context of the project, PMI provides optimal, fully digital, means of specifying design
  - Enabling tools for downstream processes such as inspection to automatically read in requirements for e.g. creation of inspection plan

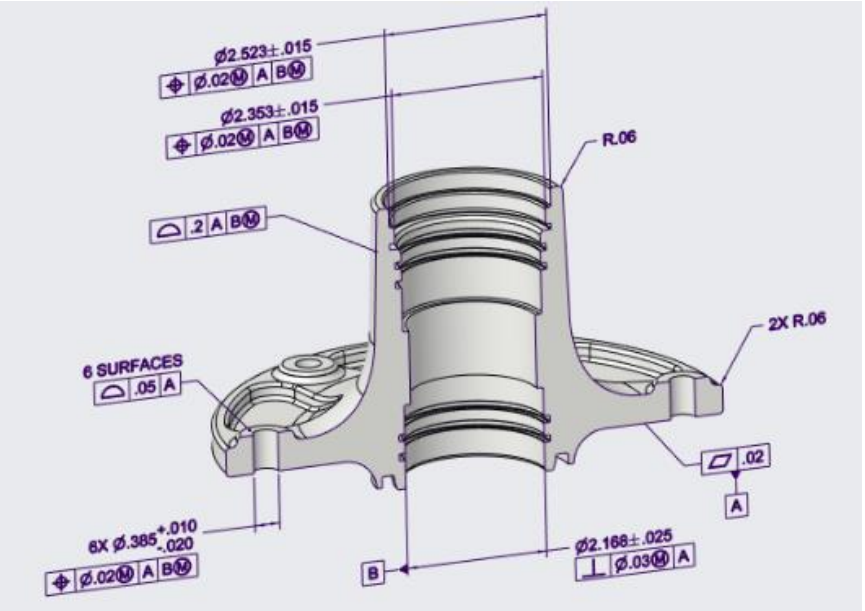


Illustration of CAD model with PMI (from Creo CAD package website www.ptc.com)

ENCOMPASS Inspection Activities

Ongoing & Future Work

- An initial interface of the described tools to the CAD environment provided by Altair Hyperworks has been created
- Generic spherical sampling can readily be adjusted to reflect actual inspection geometry
  - E.g. for X-ray Computed Tomography or a specific optical inspection geometry
- Simple generic models developed are now being used to suggest post-build strategy
  - Linking models to a numerical optimisation *
  - Incorporating specifics (e.g. constraints) of hardware available
  - Facilitating targeted inspection based on possible problem sites identified in build monitoring

* N Brierley et al., “Optimised Multi-Shot Imaging Inspection Design”, Royal Society Proc. A, accepted 2018.

Conclusions

- ENCOMPASS project is developing an “Integrated Design Decision Support (IDDS)” system, spanning the full laser powder bed fusion (L-PBF) process chain, including inspection, to increase the probability of “right first time”.
- Within this, the inspection activity is geared towards
  - Enabling design for inspection (alongside other considerations)
  - Suggesting an initial post-build inspection strategy
  - Facilitating a targeted post-build inspection, incorporating build monitoring data
- Simple generic models have been developed to represent
  - Optical inspection
  - Radiographic inspection
- These models are now being built on to deliver the remaining work package outputs.

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Questions?

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